# Examining the Social Acceptability of Cisterns in Rainwater Harvesting for Residential Use in the Region of Waterloo, Ontario.

by

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**Author's Declaration**

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

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

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**Abstract**

As water infrastructure in urban Ontario strains to meet the demands of a growing population, alternatives to the conventional water supply approach that complement demand management strategies are important to enable more sustainable water use at the household level. The adoption of rainwater harvesting (RWH), for indoor and outdoor uses by single-family households can reduce a households withdrawals on municipal water by 30% if rainwater is used for toilet flushing, laundry and outdoor uses (Despins 2009). The amount of potable water savings because of RWH is influenced by the rate of adoption and the allowed uses of rainwater at the individual household scale. The adoption of RWH systems would lead to reductions in potable water demand, which, in turn would lead to reduced demands on municipal water sources (e.g., groundwater or surface water), and storm water infrastructure resulting in overall reduced ecosystem stress and increased resiliency for climate change adaptation. Greater onsite storm water retention would mimic natural processes and would help reduce excess overland runoff that can result in water contamination.

Presently, RWH systems tend to be more accepted and utilized in rural areas. However, there is a history of cistern use in rural and non-rural Waterloo. This history and capacity seems to be largely forgotten or unknown by urban citizens and local government officials. Century houses' cisterns are often removed or filled in due to: a perceived lack of need, safety concerns and disrepair because of disuse. The increasing popularity of "green" building features and certifications have added some RWH systems for indoor and outdoor use to the urban environment, however, these remain limited instances. Moving RWH forward requires commitment from the Provincial and municipal government. Municipalities' actions must support the sustainability objectives often referenced in their legislation and policy. This study establishes the drivers of RWH and examines the barriers to practice in the urban environment by examining existing examples and academic literature RWH systems within Canada and internationally. Results from a survey conducted in the City of Waterloo are used to reflect the systems user's perspective. Interviews with municipal officials and RWH experts further highlight the drivers and barriers to RWH in urban Ontario. Based on the surveys, participants were generally willing to consider adopting RWH systems and a greater use of rainwater in the house, although a lack of information acts as significant barrier. However, Waterloo municipal officials who participated in the interviews described a much less enthusiastic attitude towards RWH. Although barriers identified in this research, including: legislative barriers, risk tolerance, perceptions of water abundance and economic realities shape the willingness to adopt RWH, this study indicates the barriers are surmountable through education and economic signaling.

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**Dedication**

I would like to dedicate this thesis to my father.

David Bishop Fortier

I could not have done this without you, from the painful hours of learning to count at the beginning of my education, all the way though to your input through numerous thesis revisions.

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**List of abbreviations**

CCME Canadian Council of Ministers of the Environment

CELA Canadian Environmental Law Association

CWWA Canadian Water and Wastewater Association

CMA Census Metropolitan Area

CMHC Canada Mortgage and Housing Corporation

CT Census Tract

ENGO Environmental Non Governmental Organization

FBR *Fachvereinigung Betriebs- und Regenwassernutzung* e.V.

FP Figtree Place

LEED Leadership in Energy and Environmental Design

l Liters

l/p/d Liters per Person per Day

LTWS Long Term Water Strategy

Ml/d Million liters per day

MLS Multiple Listing Service

MPIR Ministry of Public Infrastructure Renewal

MMAH Ministry of Municipal Affairs and Housing

n.d. No date

PAH Polycyclic Aromatic Hydrocarbon

POU Point of Use

RWH Rainwater Water Harvesting

RMoW Regional Municipality of Waterloo

TRCA Toronto Region Conservation Authority

UCSESA The Union of Concerned Scientists and the Ecological Society of America

WSEP Water Strategy Expert Panel

WSUD Water Sensitive Urban Design

## 1.0. Introduction to Study

As urban populations in the Greater Golden Horseshoe continue to grow, increasing the pressure on the surrounding ecosystem, new approaches to accommodate sustainable growth are sought. This research focuses on residential water uses, specifically in single-family houses. To accommodate the scale of conventional residential water uses vast networks of structures have been created to meet demand. Projected future demands cause increasing concern as municipalities approach the limits of their infrastructure. Potable water is required for drinking and cooking, and according to conventional norms, potable water is also used for cleaning, laundry and outdoor uses. The disposal of waste and stormwater are additional engineering concerns of increasing significance as areas grow and the impervious nature of urban construction interrupts the natural hydrologic cycle. The awareness of these realities has renewed interest in older, decentralized practices such as rainwater harvesting (RWH), to prolong the life of current infrastructure capacity, to avoid the expansion water infrastructure.

### 1.1. Description of systems studied

For the purposes of this study, RWH is defined as the practice of collecting precipitation, rainwater or snowmelt, from the roof of single-family houses through the gutters and downspouts system. For simplicity, this study refers to the stored precipitation as rainwater, acknowledging that winter contributions to the cistern would mostly be from snowmelt. The downspouts direct the precipitation into cisterns or holding tanks where the water is stored until needed. These tanks are similar to rain barrels but can be located underground, have greater capacity for rainwater and have many options for treatment and access to rainwater.

In this study, cisterns are the commonly used term and defined as containers that hold the collected rainwater below ground or in a basement. Holding tanks refer to containers that store the rainwater above ground. Holding tanks are cheaper storage systems commonly found in warm climates where the stored precipitation is not at risk of freezing. Below-ground cisterns tend to be more expensive since they require considerable excavation to place in the ground, especially in temperate or cold climates where the contents of the cistern must be below the frost line to avoid freezing and cracking the cistern (Coombes 2005, König 2005).

It is possible to install holding tanks in colder climates, but to ensure their integrity they must be emptied in the colder weather. The use of seasonal holding tanks to store rainwater severely limits their use, making it considerably more difficult to justify the cost of the system. RWH systems range in complexity: the simplest system is a rain barrel, followed by systems with larger cisterns or holding tanks that are exclusively used for outdoor uses, and finally there are RWH systems that can be used for outdoor and some indoor uses. To use rainwater indoors requires systems more sophisticated than a simple rain barrel since it requires the installation of a parallel indoor plumbing system. The additional parallel plumbing for indoor use makes the inclusion of RWH systems more economically feasible in newly constructed residential buildings (or "new builds") than as retrofits (Despins 2009, Henderson 2009, Leidl 2008, 2009, Polley 2009). Some cisterns that supply water for indoor uses have a floating gauge in the cistern, where once the rainwater falls below a certain level municipal water fills the tank to continue regular indoor supply with municipally treated water.

It was also common for century cisterns, i.e. cisterns that were part of water provision systems in houses 100 years and older, to be located in the basement of houses. Although the cisterns were not necessarily being located below the frost line, the heat from the house would reduce the likelihood of freezing.

## 1.2. Research question

This study seeks to answer the question: "What are the current and likely future barriers to and drivers of innovation in urban residential water demand management, specifically in respect to the use of cisterns for RWH in mid-sized urban areas, such as the Region of Waterloo?" To answer the research question appropriately, additional underlying questions are considered. For example, what is the utility of cisterns as a method of water conservation? What is the level of social acceptability of cisterns as a water conservation method? What is the feasibility of cisterns as a method of residential water conservation? These questions require an examination of cisterns' user friendliness and the larger socio-cultural context, i.e. potential drivers and barriers from technical, social, economic and institutional influences.

## 1.3. Context to drivers and barriers to RWH

This study examines possible drivers of and barriers to RWH from technical, social, economic and regulatory perspectives in the Greater Golden Horseshoe in Southern Ontario. A primary barrier or deterrent to the adoption of residential RWH is the current supply oriented attitude towards water. In Southern Ontario, there is a widespread and erroneous perception that there is an abundance of water in the province (Bakker 2007, de Loë and Kreutzwiser 2007, Sprague 2007, Wolfe and Brooks 2003), effectively acting as a barrier to conservation. However, Southern Ontario contains a number of growing urban areas (Ministry of Public Infrastructure and Renewal 2006—now Ministry of Energy and Renewal). Growing urban areas typically result in growing water demands that stress traditional water supplies and structures (De Oliver 1999, Spinks *et al*. 2003). Currently, these growing communities are making important water planning and management decisions to provide for future growth.

Water availability in Canada is challenged by: climate; changing demographics and settlement patterns (De Oliver 1999, Environment Canada 2007, Thomas 1998, Waller *et al*. 1998); pollution of water sources (Morris *et al*. 2007, Waller *et al*. 1998); lifestyles that demand increasing amounts of water (Thomas 1998, Waller *et al*. 1998); and agricultural, commercial and industrial sectors that compete with the residential sector for water allocations (Bakker 2007, Thomas 1998). These challenges to water availability are driving forces for alternative approaches to the current conventional hard strategies.

The incorporation of more "soft" strategies including demand side management, rather than the traditional "hard", supply side approach of pipes, pumps and dams widens the options available to ensure water needs are met (Brandes and Brooks 2007, Brooks 2005, Gleick 2000, Morris *et al*. 2007, United Utilities Canada Ltd. 2006, Wolff and Gleick 2002). RWH is one example of a "soft" strategy that can help meet urban water demand while alleviating households' sole reliance on municipal water, decreasing potable withdrawals. Reduced withdrawals align with conservation efforts that seek to reduce total household potable water withdrawal and use. This study examines the potential for reducing the uses of potable water for activities that do not require it for users' health. Reducing potable water withdrawals also has an energy component to be considered (Geller *et al*. 1983, Leidl 2008). Less potable water withdrawals would result in less energy, chemicals required and greenhouse gases that result from treating source water to a potable state as well as pumping water to its various destinations (Maas 2009).

### 1.4. The Westvale neighbourhood in Waterloo, Ontario

This study focuses on Westvale, a suburban residential neighbourhood in Waterloo, Ontario. Significant development occurred in Westvale in the 1990s; as part of one of the development phases, a small percentage of the new houses built included cisterns, to collect rainwater from the house's rooftop for outdoor uses. This local history suggests that the neighbourhood might provide a stratified sample of cistern and non-cistern experience.

### 1.5. Academic contribution

This study will contribute to the growing Canadian RWH literature, in both historical and contemporary contexts. This study establishes whether or not there is any evidence of RWH systems used in the historical Waterloo non-rural setting. In many places the practice of RWH has long been forgotten, but is beginning to experience a rediscovery to provide water sustainably for increasing populations while managing the uncertainties of climate change. It is important to document government decision makers' and their electorates' understanding and willingness to advance conservation efforts with innovations like RWH. This study contributes to the literature decision makers can consult to inform their decisions and gauge the public's willingness to participate in RWH.

### 1.6. Applied contribution

Decision makers are continually adapting to new situations and realities, requiring them to seek counsel from the past for perspective and ultimately a better future. The re-adoption of abandoned technologies such as RWH is one example of how the past benefits current planning to accommodate a larger population while trying to minimize the negative consequences to the surrounding ecosystem within which we exist. This study begins to investigate the differences and similarities among individuals with respect to their existing attitudes towards water conservation, RWH, willingness to alter current practices, and incentives required to increase this willingness. This study could encourage decision makers to promote RWH in urban areas to supplement residential water supply with rainwater for non-potable uses by demonstrating the potential RWH has to reduce demands on municipal potable water.

In Canada, cisterns are a relatively unexplored and under-utilized option for water conservation (Mitchell *et al*. 2007, Thomas 1998). The results of this study could provide a basis for publicity or awareness campaigns or plans for other water conservation efforts by encouraging individuals to question prevailing water norms and consumption habits. Examining the drivers and barriers to innovation could help inform Waterloo's Regional and City officials' considerations for long term planning. Communities interested in pursuing RWH campaigns for indoor uses could use the results of this research to inform plans and social marketing efforts to improve the likelihood of the plans; successful implementation by understanding the feasibility of the systems and the broader socio-cultural context the program must fit within (McKenzie-Mohr 1999). By identifying the spectra of barriers to and drivers of cistern use, it could aid in the development of education materials aimed at homeowners and policy recommendations targeted at municipal officials (Kirkland *et al*. 2002, Thompson *et al*. 2002). Educational materials are important since one can expect when introducing, or reintroducing in the case of RWH, unconventional technologies or methods, resistance for a host of reasons (Gleick 2000, Rogers 1971, Waller *et al*. 1998, Wolfe and Brooks 2003).

Well-informed stakeholders could help shift focus away from traditional "build" mentalities to values and ethics that embody more "soft", sustainable approaches; also, well-informed stakeholders can help to combat misperceptions, the problem enunciated as, "Facts are facts but perceptions are reality" (variously attributed to Aristotle or Einstein; cf. Falkenmark 2001: 539). Informed users with a more active role in their water supply might lead to a more connected and holistic understanding of urban water services. Urban residents are often far removed from the natural hydrologic cycle and even the artificial urban water systems that serve them. Populations that are more informed and involved may cultivate greater understandings of the systems, encouraging alterations in behaviour, from using less water to more thoughtful consideration of product purchases that end up in the water.

## 2.0. Methods

### 2.1. Introduction

This research examines the feasibility of cisterns as a method of residential water conservation by considering the technological, economic, institutional and social aspects that influence the inclusion of RWH in single-family residential buildings. The methods used to address the research question, involves a comprehensive literature review, surveys and key informant interviews. Please note the appendix section contains the complete survey questionnaire for further detail. Interview participants included consultants, residential builders, government officials at the municipal level, homebuilders, academics and technical experts.

### 2.2. Research methodology

This research was a cross-sectional study. Temporal considerations are limited to the "observations of a sample cross-section of a population of phenomena at one point in time" (Babbie 2002: 87). By examining current perceived barriers held by community members, consciously anticipating future conditions for drivers to and barriers of RWH, and by consulting a broad array of sources, this work will be relevant and avoid focusing on "yesterday's innovativeness" (Rogers 1971: 295).

This study employs case study exploration, which is a type of qualitative methodology, to better understand local urban RWH efforts (Eisenhardt 1989, Yin 2005). Case study research explores variables and their interactions in a specific instance and allows multiple levels of analysis (Eisenhardt 1989, Yin 2005), which is advantageous since many variables can influence the urban adoption of RWH. Eisenhardt (1989) stated that case studies could both examine and create theory. This study does not attempt to generate broadly applicable theories given the limited size of the case studies and samples. The formation of theories, particularly from case studies is an iterative process and thus requires numerous studies to generalize (Eisenhardt 1989). However, it is possible for a single case study to contribute to understandings within social sciences (Flyvbjerg 2006), the broad discipline encompassing this study.

### 2.3. Literature review

A literature review drawing on peer-reviewed academic sources was critical. This study applies the benefits of, barriers to and general perceptions of RWH gained from the surveys and interviews to the characteristics and variables of the diffusion of innovation. Non-academic sources, such as those listed below, provide a more complete understanding of past practices and current status of RWH and the Region's local experiences:

- Historical sources (e.g. Waterloo archives, historical narratives, anecdotal knowledge, books and historic site fieldwork, e.g. Schneider Haus and Doon Heritage Crossroads) to better understand the Region's historical water supply.
- Web-based searches for government case studies and reports (e.g. CMHC has funded and published numerous reports regarding rainwater harvesting, which are important foundations for the Canadian context) (Waller *et al*. 1998, Russell 1999). In addition, provincial and municipal planning documents and water conservation promotional material (e.g. Growth Plan for the Greater Golden Horseshoe 2006, Long Term Water Supply Strategy 2007, Official Plans) were included.
- Government databases are also important to this research to set initial context. For example, Environment Canada's municipal water use database contains the most recent water use data (Environment Canada 2005).
- Municipal bylaws were briefly reviewed since they provide information as to municipal conservation measures, such as restricting outdoor water use.
- Municipal follow up focus groups for rain barrels and general water conservation efforts were also consulted to better gauge local sentiments.
- Local media sources (e.g. *The Kitchener-Waterloo Record*) to derive an idea of local understandings or perceptions of water conservation efforts.

The diversity of sources allowed triangulation of the findings to ensure the best possible representation of the community's unique situation.

## 2.4. Surveys

A general survey approved by the University's Office of Research Ethics, was distributed to 550 households within a portion of the Westvale neighbourhood. All homeowners' opinions, whether or not they have cisterns, provided important insight, either into the residents' without cisterns perceptions, knowledge and concerns regarding RWH or feedback from residents' with cisterns about the cistern systems' use and utility. Initially, the sample was to be much smaller, based on the assumption that the City had a record of which properties had cisterns. The sample would have included an equal number of households with and without cisterns. However, the City had no documentation as to which houses had cisterns. Therefore, the sample size was expanded to encompass the houses built during the cistern pilot project, with the intention to ensure inclusion of those houses that were part of the cistern pilot.

In the absence of municipal documentation as to which houses had cisterns, the sample area within the study area was determined by using aerial photographs of the neighbourhood, taken around the time of

the pilot project (approximately 1989, according to McMahon 2007).
The area was probably larger than necessary (i.e., some of the houses could have been built before or after the pilot project), but it was desirable to include all homes that might have a cistern.

Three additional houses, outside the Westvale neighbourhood, in “Uptown” Waterloo were also surveyed. The houses were identified through snowball sampling as century homes equipped with cisterns either presently or until recently.

In an effort to counter low response rates respondents were offered the option to complete the survey online or via hardcopy. Cook *et al*. (2007) indicated that including an online option for surveys is more convenient for respondents, resulting in greater potential for higher response rates. The survey was delivered in an envelope with the University of Waterloo logo to lend credibility to the package and avoid it being thrown directly into the trash. The package contents consisted of an information letter, a survey and a pre-stamped and addressed envelope.

#### *2.4.1. Survey structure*

Since there was no way to distinguish which Westvale houses had cisterns before distributing the survey, it had to be applicable to all respondents, so it included instructions on which questions to answer based on a respondent's situation. The survey sought to identify two main groups of people. The first group was those houses with cisterns; the other group of interest was those households without cisterns. The survey began with general questions to develop a basic understanding of the households’ characteristics (e.g. the number of residents and their approximate ages) as well as information about the houses themselves (e.g. age of house, type of house, number of floors and presence of RWH systems).

For those with cisterns, the survey sought to gather feedback about the RWH systems. Those respondents who indicated they had cisterns were asked who installed their cistern systems and if they were still in use. Respondents’ cistern use further differentiated what questions they answered. For those respondents who indicated they continued to use their cisterns, the survey gauged their utility depending on season. Questions in the survey also asked about respondents’ initial impressions of the cistern system and its expected benefit, to verify the claim from McMahon (2007) that people were initially uninterested in the systems. Initial expectations for the systems were compared with respondents’ actual experiences, level of satisfaction and willingness to move into another house with a similar system. Later questions sought better understanding of the usability of the systems: i.e. the ease of operation, maintenance, and system capacity.

The following sections of questions examined respondents who indicated they did not or were not sure if they had a cistern and their awareness and perceptions of RWH. One question asked about respondents' willingness to use rainwater for outdoor activities and another asked all respondents about their willingness to use rainwater indoors. Questions for those without cisterns inquired about the perceived benefits of or barriers to the installation of a RWH cistern system to their house, these responses are compared to those discussed in the literature review.

All respondents were to complete the last few sections of the survey regardless of the presence of a household cistern system. These last few sections were more general in nature inquiring about water conservation, willingness and perceptions of expanding the uses of rainwater inside the house and views on future growth planning. These questions of a broader scope were included to gauge respondents' overall attitudes towards rainwater use indoors, water conservation, participation in local water conservation campaigns and how these factors related to their views and expectations for the Region's growth planning. These questions allowed a better understanding of participants' views on the "bigger picture". These questions also helped to examine if those people with cisterns were more or less likely to be willing to expand their uses of rainwater to indoors, since cistern experiences could influenced their willingness.

Anecdotal evidence and some of the literature (Exall 2004, Waller *et al*. 1998) indicated there is considerable concern about the human health implications of using rainwater indoors. Practical feedback at water practitioner events attended—a "Waterlution" workshop in May 2008, Canadian Institute Conference on Drinking Water Quality Management in 2008 and the CWWA National Water Efficiency Conference in October 2009—emphasized that these health concerns are particularly evident in households with young children; the fear being that young children might accidentally consume the non-potable water. When one considers parents' health fears and possible time shortages, it was reasonable to assume households with children might be less willing to invest the time and effort required to maintain RWH systems.

2.5. Interviews

Interviews with upper- and lower-tier municipal officials, RWH experts and practitioners were undertaken to gauge organizational willingness to promote RWH on a residential scale and to elaborate on perceived benefits and barriers from a regulatory and practical perspective. Input from experts with significant experience in implementing innovative demand management and conservation strategies and innovative builders with RWH installation experience were critical sources. They helped confirm or dispel some of the concerns regarding RWH mentioned in the surveys or other general barriers mentioned in the literature. Participants with insight into the Westvale cistern pilot project were valuable to further illuminate the project itself and its outcomes.

Semi-structured interviews were conducted in person when possible. A set number of identified important open-ended questions were asked uniformly of all participants for meaningful comparisons. This format ensured regularity while also allowing for unexpected themes, considerations and opportunities that might come up by chance to be examined. Most interviewees were identified through snowball sampling. Snowball sampling method is defined as "starting with one or two people and then using their connections, and their connections to generalize a larger sample" (Palys 1997:139). Palys (1997) warns that this method of sampling can result in less than representative samples since there is a good chance that respondents will connect you with individuals with similar characteristics or views. This is advantageous from this study's perspective since finding urban RWH innovators can be difficult. Others participants were chosen based on the researcher's networking at practitioner events, conferences or previous research.

Interview participants were presented with an information letter and a consent form at the time of interview. The information letter was similar to the recruitment email delivered before the interview. The consent form allowed participants to indicate whether they agreed to the use of attributed quotations or not. Interviews done in person were conducted with an audio recorder, again something to which the participant had to consent. The presence of the audio recorder was beneficial so appropriate focus could be paid to the participant and to allow detailed and accurate transcripts to be performed post-interview.

Interview analysis illuminated how participants' perspectives fit within the given social, regulatory, political and risk tolerance context. Also examined were other influencing forces on these perceived drivers and barriers. Examples of influencing forces included: information sharing from general practical applications of RWH both within Canada and internationally; and; their specific types of systems, their use, users' experiences and outcomes.

### *2.5.1. Interview Participants*

In total, 11 interviews were conducted. The professional composition was four municipal officials, three builders, two academics, and two water consultants. When possible, the researcher conducted interviews in person, but two interviews were conducted by telephone. There was a range in participants' understanding and practical experience or involvement with RWH.

Three residential homebuilders with RWH experience were consulted for their unique practical experiences. The next few paragraphs focus on these builders given their valuable applied experience with RWH and municipal regulations. Two of the builders also own dwellings dependent on rainwater to meet their domestic needs, something not well reflected in the literature and will help cultivate a more informed understanding of urban RWH and its potential in Ontario. The specific builders consulted for this research are more open or tolerant to "green innovations" than the average builder or municipal official.

Ben Polley, herein referred to as Polley, is a Guelph area builder and has been involved in the alternative home building industry for nine years. Polley first encountered and explored water-related alternative systems because of his growing customer base, who would request a technology that required a specialized skill set. Polley would educate himself on the technology or process in order to provide the service. Polley's experiences and acquired knowledge later became "an extension of the original business" (Polley 2009). Polley was sufficiently committed to alternative options and change that in 2007 he ran as an MPP candidate for the Green Party of Ontario in the Guelph riding.

Rolf Paloheimo, herein referred to as Paloheimo, is a builder who resides in and has built in the Toronto area. His experiences and presence in the national spotlight have expanded his builder role beyond the norm. Paloheimo was initially a commercial builder who wanted to enter the residential building industry. "I was inspired by the notion of building off-grid, for water in particular" (Paloheimo 2009). Paloheimo built the "Toronto Healthy House", a CMHC sponsored project in the 1990s. He has since embarked on considerable information sharing, with the national and international community, promotion and patenting alternative residential systems (Paloheimo 2009).

Tom Krizsan, herein referred to as Krizsan, is a developer and builder who has been in the industry for over 31 years and is considered a local (Guelph/Wellington/Waterloo) innovator (Henderson 2009, Krizsan 2009). Krizsan's company (Thomasfield Homes) participated in the Westvale cistern pilot project. Most of his company's "green" works since Westvale have been energy related, with some xeriscaping and stormwater management (Krizsan 2009). Polley and Paloheimo are two examples of successful RWH projects, meaning the systems are still in operation and meeting household needs.

Krizsan of Thomasfield Homes did not have the same positive experience with RWH.

## 2.6. General research limitations

A major challenge to this research was data availability. The roughly twenty-year time lapse since the Westvale cistern pilot project was completed hampered information-finding efforts, particularly when trying to identify individuals who worked on the project. Applying this study's findings to an area as large as Ontario is difficult, given the comparatively small sample studies here. There were also limited sources that discussed the prevalence of RWH in non-rural Ontario.

The use of surveys to assess individuals' water use and reactions to efficiency and conservation campaigns is a common data collection instrument (Corral-Verdugo & Pinheiro 2006, De Oliver 1999). However, a potential limitation is that participants may be inclined to give responses that they considered the "right" ones. This type of response reaction can result in biased responses. Participants may perceive pressures or have a desire to please the researchers or to act in a socially acceptable way (Babbie 2002, Corral-Verdugo & Frías-Armenta 2006, Corral-Verdugo & Pinheiro 2006, De Oliver 1999). These sentiments on the part of the participants could influence their responses "and may overstate their conservationist intents" (De Oliver 1999: 373).

This study's findings are also limited by respondents' awareness of RWH. It is possible that some residents in Westvale were unaware of the presence of a cistern; there was certainly no indication from the roadside which houses had cisterns. If a cistern was buried in the back yard and was only used for outdoor use, there would have been a visible pump to bring the water up. However, if someone bought a house with a cistern, but did not intend to use it, they could have removed the pump and thus taken away evidence of the existence of the cistern for subsequent owners, influencing participants' cistern awareness. The willingness of participants to participate in surveys or interviews is also contingent on a variety of personal or logistical situations.

The limited geographic scope of this study confines the ability to generalize from the findings to other location with similar characteristics. The variability in provincial regimes results in different legislation and policy frameworks among provinces, so results are most relevant to the Ontario socio-political environment. However, results may be useful in further studies in Canadian and international contexts, as long as there is awareness of site differences.

## 2.7. Summary

The literature review greatly influenced the survey and interview questions by informing the drivers of and barriers to RWH. The three research methods utilized in this study (literature review, surveys, and expert interviews) help triangulate the sources for greater accuracy when presenting the potential for the application RWH in Southern Ontario and best practices.

## 3.0. Literature Review

This chapter explores the concepts and literature that frame and influence the adoption of RWH systems in the urban residential setting. The three main sections of this chapter reflect the main research question and underlying research questions. The first section examines the possible drivers to RWH. The following section examines the barriers to RWH. The third main section examines the feasibility of RWH. This chapter's final main section examines the feasibility of urban RWH from technical, economic and social perspectives, to better understand the systems themselves and the broader socio-political context surrounding the innovation. Canadian and international experiences with urban RWH are also considered throughout this chapter to provide a practical perspective to RWH.

### 3.1. Drivers to RWH

This study considers two different kinds of driving forces that support RWH. The first category of driving forces is those benefits resulting from RWH that decision makers should consider when making decisions that affect the environment (Thompson *et al*. 2002). In many cases, the managers who make decisions that affect the environment are not managers whose prime responsibilities are directly related to the environment, but whose decisions nonetheless affect the environment. The second category of driving forces is the tools that decision makers utilize to encourage desirable environmental responses from the public who are the resource users. Some examples of these tools are water pricing, incentives such as rebates, regulations such as the Building Code and by-laws such as those restricting outdoor watering (Coombes 2005, Krishna 2005, Waller *et al. 1998,* Water Strategy Expert Panel (WSEP) 2005). While voluntary compliance is preferable, the fact remains that the toolbox has to include certain "coercive" measures such as by-laws and regulations.

#### *3.1.1. Sustainability and sustainable water infrastructure in the Regional of Waterloo*

The World Commission on Environment and Development, commonly referred to as the Brundtland Commission (1987), was key to popularizing sustainability efforts. Sustainability is a complex concept that this study will not discuss in detail. In general, sustainability aims to conserve nature, plan with the needs of future generations in mind, involve the collaboration of nations, it requires a certain level of universal wellbeing, all of which imply a level of equality and involve meaningful participation from residents (Corral-Verdugo and Pinheiro 2006, Gibson *et al*. 2005). The Regional Municipality of Waterloo (RMoW) has pledged to develop a sustainable community (Region of Waterloo 2010). Sustainability has considerable normative and ethical underpinnings to achieve greater equality among humans and secure a healthy and "productive" ecosystem for the long term that will help reduce conflict over scarce resources and inequity (Corral-Verdugo *et al*. 2008, Corral-Verdugo and Pinheiro

2006, Gibson *et al*. 2005).

RWH can help Waterloo achieve greater sustainability and is consistent with the general concept. The adoption of residential RWH fulfills some of the “essentials” of sustainability mentioned by Gibson *et al*. 2005: 116-118. RWH challenges conventional thinking and practice. Sustainability calls for substantial change from stakeholders in their approaches and actions. “Sustainability stands as a critique; it is a challenge to prevailing assumptions, institutions and practices … [it is an] admission of broad failure and the need for substantial change” (Gibson *et al*. 2005: 38). The drivers to RWH meet the sustainability goal that advocates long term and short term planning. RWH helps to reaffirm the recognition of links and interdependencies, especially between humans and the biophysical foundations for life. The drivers and barriers to RWH also emphasize the intertwined means and ends – culture and governance as well as ecology, society and economy to the large-scale adoption and benefit of the practice.

Gibson *et al*. (2005) provided a foundation with which to consider the Region of Waterloo and the sustainability of its water infrastructure. Considering the increasing pressure on centralized urban infrastructure makes one question the systems’ current and future sustainability (Spinks *et al*. 2003). For the purposes of this study, it is considered a desirable goal to advance sustainability in the Region. One way of doing this is by maintaining the current scale of water infrastructure and delaying if not eliminating the need for the acquisition of new sources and infrastructure, despite a growth in population.

Green building programs like, Leadership in Energy and Environmental Design (LEED) that promote low impact building, have helped advance instances of RWH. LEED includes RWH as an option that results in the allocation of the programs’ points system, contributing to a dwelling's level of certification or rating e.g. bronze, silver, gold or platinum (Canadian Green Building Council 2009, Leidl 2008). A number of other similar green building rating programs exist within Canada and internationally, with the programs continued popularity, expansion, observed savings and the ongoing development of standards it reinforces the importance of these stakeholders in promoting green building efforts like RWH and regulation.

### *3.1.2. Legislation and policy*

The importance of the sustainability concept is evident in some provincial legislation, which ultimately influences municipalities’ actions. The *Planning Act* states that it is in the Province’s interest to promote sustainable development, the conservation of natural resources including water efficiency and conservation, the preservation of human health, and the maintenance of ecosystem wellbeing and functions. The *Planning Act* also makes effective Provincial Policy Statements (2005), which outline general provincial policy planning guides, one of which is "the wise use and management of resources" (Municipal Affairs and Housing (MMAH) 2009) thus supporting water conservation efforts (Leidl 2008). Another important aspect of the Act is that it provides direction for Official Plans' contents, processes and authorizing hierarchy. An Official Plan conforms to or reflects provincial interests while indicating a municipality's future planning efforts, policies and objectives for regional growth. The *Planning Act* also gives municipalities the power to create zoning by-laws to guide development.

Through the *Municipal Act*, the Province creates and gives authority to municipalities, to govern, make decisions and create by-laws that protect the "environmental well-being of the municipality" (MMAH 2009a: 11(2)). This includes "waste management, public utilities, … drainage and flood control" (11(3)). According to the Act, the provision of public utilities, including water provision and sewage treatment, is within municipal jurisdiction.

The *Building Code Act*, which includes plumbing, fire safety and accessibility considerations, gives Building Code inspectors the authority to enforce compliance with the Building Code and its standards for new home designs, buildings and renovations. The Ontario Building Code, herein referred to as "the Code", has taken the National Building Code, a nation-wide recommendation, as a model for the Provincial document. However, the Ontario government has made considerable alterations to the national model (National Research Council of Canada 2009). The Code is under the direction of the MMAH. However, municipalities actually implement and enforce the standard through their building inspectors (MMAH 2006). Leidl (2008) indicated that "equivalents clauses" give inspectors some flexibility to allow some features not covered by the Code; "approval for 'equivalents' can be given based on past experience or thorough testing, if the municipal inspector is convinced that the performance of the proposed technology matches or exceeds that of those prescribed in the Code" (Leidl 2008: 21). This flexibility offers opportunities for building code enforcers to allow innovative options, should they deem them acceptable.

In 2006, the new Ontario Building Code was introduced. This updated Code is objective- rather than prescriptive-based to make it more flexible and open to innovation by stating objectives that must be achieved rather than exactly how a given part of construction must happen for a particular objective (Canadian Home Builders' Association *et al*. n.d). The Code promotes energy efficiency and some green technologies including green roofs, storm and greywater reuse and begins to recognize the need for greater water conservation (MMAH 2006, 2009). In 1997, the Code first allowed the use of non-potable water indoors for toilet flushing in cases where it was clear that potable water alone could not meet household demand. The 2006 Code, allowed the use of non-potable water for toilet flushing regardless of the quantity of potable water supply available, effectively allowing the use of rainwater indoors in the urban setting. The Code also considers safety precautions related to RWH, for example, back-flow prevention to ensure the use of rainwater in a house does not endanger the large-scale infrastructure (Leidl 2008).

The *Places to Grow Act* (2005) and resulting policy framework, *Growth Plan for the Greater Golden Horseshoe* (2006), are important documents governing future urban growth and development. The documents guide growth in Southern Ontario's existing urban areas and influences municipal governments plans for growth and how to meet residents' needs. This Act supports conservation including the application of RWH and greywater recycling (Leidl 2008, Ministry of Public Infrastructure and Renewal (now Ministry of Energy and Renewal) 2006, 2009).

Despite the significant direction municipalities receive from higher levels of government municipalities remain important influences since they actually implement plans and can fine-tune their decisions to best fit their local needs. Municipalities may differ in their planning and approvals procedures depending on whether the area has a single or multi-tiered municipal government or because of any special provisions or allowances made between a Region and the Province. Official Plans for municipalities guide the creation of by-laws, strategies and implementation of plans, which affect homeowners' and builders' decisions. According to the *Planning Act* 17(1), once the Minister issues approval of a municipal plan making it the Official Plan, the freedom of the municipality is limited by its new Plan.

#### *3.1.3. Canadian Standards Association (CSA)*

The CSA is a non-government, not-for-profit organization that creates standards to ensure safety in a number of industries (CSA 2009). Its standards represent best practices that tend to be incorporated into government documents or legislation (Leidl 2008). The standards B128.1-06 "Design and installation of non-potable water systems" and B128.2-06 "Maintenance and field testing of non-potable water systems" are important to RWH since they provide guidelines for the installation and long-term maintenance of non-potable water systems for residential and commercial places. These guidelines are important since these non-potable systems are currently relatively uncommon (CSA 2006). The scope of B128.1-06 stated that non-potable water could be used for “flushing toilets, irrigating lawns and gardens, washing automobiles, showering, bathing, washing clothes, or heating or cooling” (CSA 2006: 4). The accepted uses of non-potable water by these standards could act as a driver to the expansion of uses of rainwater in the Ontario Building Code in the future, which currently limits the use of non-potable water, to toilet flushing and outdoor irrigation.

However, water quality standards or treatment requirements of non-potable water are not specifically covered in the standards; instead, the standard refers to local requirements (CSA 2006). The standard’s reference to local guidelines or requirements is not useful considering, currently; there are no water quality guidelines for rainwater (Leidl 2008). Despite the value of these non-potable water CSA standards’ they are not required since they are not yet included in the Building Code or well publicized. The majority of Leidl’s (2008) sample of water practitioners was unaware of the B128.1-06 or B128.2-06 standards’ existence, likely since they are relatively new and not included in the Code.

#### *3.1.4. Alternative water management concepts*

##### *3.1.4.1. Water Soft Path*

The water soft path concept was modeled on the soft energy path, which was first articulated by Lovins in 1977 for more efficient management of energy resources (Brandes and Brooks 2009). The water soft path approach stands in contrast to the conventional “hard path” approach, which typically involves supply-oriented management exclusively serviced by centralized, large-scale expensive engineered systems (Brooks 2005; Wolfe and Brooks 2003, Wolff and Gleick 2002). The water soft path aims to achieve more sustainable water use by:

- Identifying services desired and questioning whether they require water, and if so, how much water is needed to provide the service.
- Matching the quality of water according to the activity. Limiting high quality (potable) water to activities that require it (e.g. drinking), which would ultimately decrease the amount of potable water used and related costs.
- Incorporating decentralized options, which can be “just as cost effective” as traditional centralized infrastructure, particularly when combined with informed and educated users (Gleick and Wolff 2002: 5). A decentralized system also offers greater resilience in case of conventional system failures.
- Planning for water flows for ecosystems.
- Using backcasting in planning. Backcasting involves envisioning a desirable future

(including growth scenarios with some set level of water use) and planning back from the future to achieve that goal.

"Soft" methods are the best "new" source of water for growing urban populations and, at this point, are less expensive than tapping "new" sources (Brandes and Brooks 2007, Brooks 2006, Dolan *et al*. 2000, Gleick and Wolff 2002, Morris *et al*. 2007). Greater adoption of "soft" methods requires a shift from the prevailing conventional mentality that relies exclusively on building large-scale infrastructure to more diversified systems that "complements [centralized infrastructure] with extensive investment in decentralized facilities, efficient technologies, and human capital" (Gleick and Wolff 2002: 1). RWH is one example of a "soft" method that could help populations meet their water needs without tapping new water sources or constructing more large scale infrastructure. The adoption of household RWH systems would encourage more small-scale supply options or decentralization as the water soft path advocates. Using rainwater for activities that do not require potable water to ensure user safety e.g. toilet flushing is also consistent with the water soft path approach.

#### *3.1.4.2. Other alternative water management concepts*

Additional water management or planning concepts that are alternatives to the conventional approach are Water Sensitive Urban Design (WSUD) or Low Impact Design (LID). RWH is one of many possible decentralized "tools" of WSUD or LID that offers a local water supply solution other than relying on centralized systems (Coombes *et al*. 1999). A watershed approach is implicit in WSUD and LID. These alternative concepts encourage greater reintegration of the natural hydrologic system in urban areas, encouraging local measures (Coombes *et al*. 1999, Coombes *et al*. 2002). The use of harvested rainwater is advantageous since it "provides for urban development while maintaining hydrologic and water quality characteristics closer to those existing prior to urbanization" (Zimmer *et al*. 2007: 193). WSUD and LID can be part of new developments or retrofitted into existing urban areas. LID encourages decentralized stormwater management that is "lot level" efforts, amongst other traits such as increased permeable surfaces (Coombes *et al*. 1999, Coombes *et al*. 2002, Zimmer *et al*. 2007).

Considerable potential exists for WSUD, with significant potable water and economic savings possibilities for participating communities (Coombes *et al*. 1999, 2002). The potential savings are evident when one considers Figtree Place (FP), a redevelopment in Australia constructed with WSUD elements. FP achieved an estimated 60% in water savings at a cost less than conventional water-related infrastructure and design (Coombes *et al*. 1999).

*3.1.5. Existing Canadian RWH context*

Storing rainwater in cisterns was once common practice before widespread municipal water infrastructure (Brandes *et al*. 2006, Farahbakhsh 2007, Gleick 2000, Juuti *et al*. 2007, Mitchell *et al*. 2007, Thomas 1998). Thomas (1998: 101) wrote that RWH "has more of a past and a future than a significant 'present' ". Water related infrastructure has become common and widespread in urban Canada. Significant investment, billions of dollars annually, must be spent to maintain and replace existing infrastructure let alone add to capacity. It was estimated that across Ontario, $34 billion would have to be spent on water infrastructure between 2005 and 2030, $25 billion for infrastructure renewal and the remaining $9 billion for new infrastructure to accommodate growth. This $34 billion investment results in an $18 billion shortfall between what is required for water infrastructure and total financing (WSEP 2005: 7).

Canada Mortgage and Housing Corporation (CMHC) and other researchers have responded to the need for alternative water sources through research initiatives. Research studies sponsored by CMHC (Russell 1999, Waller *et al*. 1998) have examined rainwater collection as a potable water conservation method in Canada involving Toronto's Healthy House, which is not connected to municipal services. Russell (1999) found in a Nova Scotia urban case study, that the technologies used in the Toronto Healthy House could be competitive in cost as long as fire hydrants were supplied with non-municipal water.

Both Ontario and Nova Scotia have a history of RWH. Anecdotal evidence of urban and non-urban cistern use exists in Ontario. However, Nova Scotia seems to have a better-documented history of RWH use. Perhaps the prevalence of RWH in Nova Scotia is a result of its long-standing and continued necessity due to the rocky geology in many areas. For example, lighthouses in Nova Scotia were often on rock so their residents would often be unable to access potable water except from cisterns. In contemporary terms, RWH has become vital in areas in Nova Scotia where wells have been contaminated by road salt (Waller *et al*. 1998). Historical evidence shows that cisterns were once commonplace in Ontario prior municipal water supply (Despins 2008), despite access to surface or groundwater, as was evident at the Doon Heritage Site. Rainwater was valued as a "soft water" which was used for bathing and laundering (Doon Heritage Site 2009).

Literature supports the anecdotal evidence that RWH continues to be practiced in rural Canada (southwestern Ontario, at least) and is more prevalent than RWH in urban areas (Dolan *et al*. 2000, Exall 2004, Thomas 1998). Of the sample studied by Dolan *et al*. (2000: 165), 50% of agricultural and 63% of non-farm respondents indicated they engaged in RWH. The collection of rainwater was the second most common outdoor water saving effort for non-agricultural participants. RWH tied with "never water lawn" as the most common outdoor water saving effort for non-agricultural respondents (165).

A common driver for water conservation Dolan *et al*. 2000 identified was the "immediate consequences of water storage" (166), experienced by respondents personally or by those in their social network. For respondents, water shortages meant negative financial repercussions by either having to ship water in or the cost of drilling new and deeper wells. Respondents also indicated that water saving efforts stemmed from "water conservation as a lifestyle or learned behaviour, primarily reflecting their upbringing" (167). These findings make one wonder how the same incentives can be applied in the urban setting, without the same lifestyles, emphasis, influencing factors (cost of new well) and thus lack of drivers.

#### *3.1.5.1. Guelph, Ontario*

The University of Guelph has become an important hub of RWH research in Ontario. This research is complementary to the Westvale case study because it provides further research into social barriers when trying to initiate sustainable water use. The research efforts of Despins (2008), Despins *et al*. (2009) and Leidl (2008) provide important contemporary examples of urban RWH for indoor uses in Ontario involving four urban RWH sites around the Guelph area. These sites were tested for rainwater quality and discuss variables that influenced harvested rainwater. In these four sites, rainwater was used for toilet flushing and irrigation and for laundry in two.

These studies are of great importance to this urban Ontario RWH research since they provide tangible and quantifiable examples of urban RWH water quality. They serve as "hard" evidence regarding urban RWH in Ontario to contrast with perceptions identified in this study. The Guelph studies provide technical performance information that is necessary to provide to decision makers and consumers. The Guelph research and collaboration has influenced the City's aggressive approach to water conservation efforts and ultimately its long-term water strategy. Guelph's long-term water strategy offers incentives in the form of rebates for greywater recycling and RWH systems over the next ten years (RMSi 2009) and is further discussed in section 5.3.4 and in the appendix.

#### *3.1.5.2. Toronto, Ontario*

CMHC's Healthy House in Toronto is a duplex and is another important example of innovative residential design and application. The design for the Toronto house won CMHC's Healthy House Design Competition in 1992. The duplex is an example of urban infill and is not reliant on municipal water services. The house has a RWH system to supply potable water, low flow fixtures to reduce water consumption and a water recycling system that treats water for non-potable uses (CMHC 2010). The house was involved in regular water quality testing for a period to determine water quality and the efficacy of the systems. The builder of the house lives on one side of the Healthy House duplex house with his family. The other house was sold after CMHC had finished renting it as a demonstration house (CMHC 2010, Paloheimo n.d.).

The Toronto Healthy House was a pioneering example of green building in Canada. Townshend *et al.* (1997) credited the relative ease of the project's acceptance by regulating authorities through the "[c]ooperation by the CMHC, Toronto Public Health, and Ontario Ministry of Environment and Energy" (p. 177). The entire cost of the water related systems was $15,000 per house. It is thought that future installations would not be as expensive as the original Healthy House given the systems relative infancy, future systems would benefit from economies of scale and greater familiarity (Townshend *et al*. 1997, CMHC 2010).

Other informative studies regarding RWH exist, particularly in the international context and will be examined in section 3.1.6. Other Canadian examples of RWH have been published by the Toronto Region Conservation Authority (TRCA) that demonstrate RWH is technically feasible in structures other than single-family houses, by monitoring the use of RWH systems in a commercial setting, a high rise structure and school environment (TRCA 2008). The findings from Canadian and international examples of RWH serve as important learning opportunities, particularly regarding factors influencing harvested rainwater quality (see section 3.3.2.).

#### *3.1.6. International Examples of RWH*

Numerous international examples of RWH exist. The investigation of the systems could improve Canadian decision-making and planning regarding RWH by establishing the systems acceptance (Thomas 1998). Bermuda is considered a long-term successful example of RWH since it has been the nation's primary residential water supply for over 300 years. In Bermuda, treatment of rainwater is not considered necessary because of regulations and well-maintained roofs (Thomas 1998, Waller *et al.* 1998). Anguilla, a small island state in the Caribbean, relies heavily on rainwater harvesting (Weger 2008). Bermuda and Anguilla do not have the same level of urbanization as Southern Ontario, but they are two examples of long-practiced and modern RWH. Case studies of more recent successful urban

RWH include Australia and Germany (Ellison 2008, König 2005, Thompson *et al*. 2000, Waller *et al*. 1998).

### *3.1.6.1. RWH in Australia*

RWH is extensively practiced in Australia (Coombes 2005, Despins *et al*. 2009); although there are different drivers for the acceptance of RWH within the country. Some places within Australia adopted RWH because they had no municipal water option, while other places within the country were driven to adopt RWH because of drought conditions. RWH encountered some initial resistance but now “is the only source of water for 3.2 million Australians” (Coombes 2005: 2). The Government of Australia strongly supports the expansion of sustainable water use in their long-term water planning efforts and acknowledges the potential for water savings through "unconventional sources", such as RWH (Australian Government 2009).

### *3.1.6.2. RWH in Germany*

Germany has developed a market and culture that has allowed RWH to flourish, with RWH professional associations, guiding regulations and legislation promoting RWH (Despins *et al*. 2009, Köing 2005). In Germany, acceptable uses of rainwater are flushing toilets, laundry and outdoor irrigation (Herrmann and Schmida 1999, Köing 2005). A key driver to RWH in Germany has been that in some states RWH systems are required for new developments. Schwarz and Ernst (2008: 497) estimated that between 3 and 5 percent of German households have a RWH system installed.

The "Water Resources Act" and the German constitution emphasize the importance of water efficiency and wise water use for the benefit of future generations (König 2001). The installation of RWH systems in the house is governed by DIN 1989, the standard that sets the necessary aspects in order to achieve the safe installation, operation and maintenance of RWH systems for the household and to avoid any cross-contamination with potable water infrastructure (König 2001, *Fachvereinigung Betriebs- und Regenwassernutzung* e. V. (FBR), 2001). The FBR also supports the RWH industry in Germany, as a professional non-profit association that involves many stakeholders involved in RWH. FBR also participates in research and working groups to advance the local RWH industry (FBR 2007).

### *3.1.7. Practical benefits of RWH*

There are numerous benefits for communities if RWH were widely adopted. First, it is “a freely available and relatively high quality water source” (Spinks *et al*., 2006: 1), thus greater reliance on RWH would reduce demands on municipal water infrastructure and alter supply paradigms. Thomas

(1998: 95) stated that RWH is being reexamined to achieve greater "domestic water autonomy". Thomas' (1998) observations are apt given the growing municipalities within Southern Ontario that seek to secure reliable means to meet the water demands of a growing population (Ministry of Public Infrastructure and Renewal (now Ministry of Energy and Renewal) 2006, Spinks 2003, Waller *et al.* 1998, XCG 2007).

Reductions in potable water demand would in turn lead to reduced demands on municipal water sources (e.g., groundwater or surface water), and storm water infrastructure resulting in overall reduced ecosystem stress. Greater onsite storm water retention would mimic natural processes and would help reduce excess overland runoff that can result in water contamination. Harvested rainwater used for outdoor activities would also infiltrate and recharge groundwater (Coombes 2005, Coombes and Kuczera 2003, Mitchell *et al.*, 2007, Spinks *et al.*, 2003, 2006, Thomas, 1998, Waller *et al.*, 1998, Zimmer *et al.* 2007).

It is advantageous to delay the taking of water from the Great Lakes considering their low renewability (Dolan *et al.* 2000) relative to their volume. WSEP (2005) encouraged alternatives to simply building pipelines to the Great Lakes to supply growing water needs once limits to local ground and surface water sources were met. The low renewability of the Great Lakes may not be easily observed since they have a long retention time, if one compares the volume of water in the Great Lakes to the inflows of water from drainage areas. As a result, hydrologic changes resulting from climate change or other anthropogenic changes (e.g. water diversions) can strongly influence the Lakes' water levels and the amount of water municipalities have to allocate (McBean and Motiee, 2008). It has been suggested that "because the underlying decline [of lake levels] has been ongoing for approximately 33 years, it may be prudent to include lower lake levels in future management planning" (Sellinger *et al.* 2008: 367).

#### *3.1.8. Adaptation to climate change*

Human societies have endured climate change and its implications in the past (Pandey *et al.* 2003); therefore, it would be wise to examine past adaptation strategies to inform urban planning. RWH could act as a means of adaptation to climate change resulting in greater resilience by diversifying water supply sources (AbdelKhaleq & Ahmed 2007, Pandey *et al.* 2003).

It is important to build communities' resilience considering the uncertainty that climate change creates. One possible implication of climate change and other anthropogenic impacts in Southern Ontario is the hydrological changes for the Great Lakes Basin (McBean & Motiee 2008). Climate models and predictions of the future consequences of climate change are imperfect (McBean & Motiee 2008). Despite imperfect knowledge, solely relying on large-scale infrastructure limits future possibilities and potential resilience (Vourinen *et al*. 2007). Possible changes associated with climate change include increased average precipitation and number of severe events in most of the basin areas, resulting in increased stream flows, flooding and erosion, but not necessarily increased lake levels given the possibility of increased evaporation (McBean & Motiee 2008, Sellinger *et al*. 2008, The Union of Concerned Scientists and the Ecological Society of America (UCSESA) 2005). Increased precipitation is particularly problematic for urban areas with combined sewer and stormwater infrastructure since heavy precipitation could result in overflow. Overflow could contaminate surface water, decreasing beach use for recreational purposes and increased instances of waterborne diseases in the Great Lakes given that the lakes supply drinking water for over 50 million North Americans (McBean & Motiee 2008: 239, Mitchell 2007, Patz *et al*. 2008, UCSESA 2005).

Urban areas have experienced unprecedented growth, which significantly alters the hydrologic cycle and watershed patterns (Juuti *et al*. 2007c, Morgan *et al*. 2004, Vourinen *et al*. 2007, Zimmer *et al*. 2007). The combination of urbanization, increased impervious surfaces, and increased frequency of severe precipitation events will overtax sewer systems, decrease groundwater infiltration, increase erosion and runoff and increase the potential for increased surface water contamination (McBean & Motiee 2008, Morgan *et al*. 2004, Patz *et al*. 2008, Sellinger *et al*. 2008, UCSESA 2005, Zimmer *et al*. 2007). Greater onsite retention capacity resulting from RWH could alleviate some of the resulting impacts of severe precipitation events and reduce reliance on conventional water sources. Whether there will be more or less rain in the future, both scenarios would benefit from the application of RWH in the residential context.

#### *3.1.9. Potential savings for Waterloo*

This section provides an estimate for the potential of RWH in Waterloo. Assume every millimeter of precipitation that falls on a square meter of catchment area results in one liter of precipitation collected. Also, allow for a loss of 20% of the total rainwater landing on the catchment area before it is collected in the cistern. Rainwater losses are attributed to evaporation and any leaks within the system (Despins 2008). The average annual precipitation (AAP) for the Regional Municipality of Waterloo (RMoW) between 1971 and 2000 was 940.3 mm (Environment Canada 2010). Despins (2008) assumed the average roof size of a single detached house (AR) was 140 $m^2$.

Given:

AAP x AR –loss= Total possible precipitation harvested per single family house

940.3mm x 140 $m^2$ = 131,642 l

131,642 l x .20 = 26,328.4 l (loss)

131,642 l – 26,328.4 l = 105,314 l harvested rainwater

Based on the above numbers and assumptions, if an average a single-family house in the RMoW participated in RWH they could reduce their reliance on municipal potable water by 105,314 l per year. Despins (2008) estimate of 30% municipal water savings resulting from the use of rainwater for toilet flushing, laundry and outdoor irrigation assumed a five-person household. According to the 2006 census the Census Metropolitan Area (CMA) of Kitchener, which includes the City of Waterloo, has an average household size of 2.6 persons (Statistics Canada 2009). Assuming daily per capita residential water use of 260 l/day, the average household uses 676 l/day, resulting in yearly household use of 246,749 l/year. Therefore, RWH has the potential to meet 42.7% of yearly household water demand. Table 4.1 illustrates that toilet flushing accounts for approximately 29% of total household use. The larger geographic scale of the CMA of Kitchener is used for data collection rather than only the City of Waterloo, since it demonstrates the potential for RWH on a larger regional scale and includes three potential urban centers that could benefit from adopting RWH.

3.2. Barriers to the adoption of RWH

Despite the significant benefits the adoption of RWH would bring to Ontario communities, one must consider the barriers. Barriers are defined as a broad range of conditions that may hinder the adoption of RWH by reducing the effectiveness or making implementation of the systems more difficult. Potential barriers must be identified and evaluated as early as possible in order to be overcome, in this case, to encourage the adoption of RWH (Kirkland *et al*. 2002).

Some of the possible general barriers to greater efforts to improve environmental performance are:

- Avoidance of the unknown;
- Denial of a problem;
- No [specifically] delegated responsibility;
- Lack of resources;
- Negative attitudes;
- Unfavorable political climate (Kirkland *et al*. 2002: 62-63).

Barriers to "green" building, including RWH, identified in the literature are:

- Conservation methods are seen as short-term fixes rather than long-term solutions (Waller *et al*. 1998);
- Poorly informed populations and decision makers (Leidl 2008, Wood 2007);
- Liability concerns (Vickers 2001);
- Water quality health concerns (Despins 2008);
- Institutional inertia (Leidl 2008, Wolfe 2009);
- Resistance to change and fragmented water management (Rogers 1971, Waller *et al*. 1998, Wolfe and Brooks 2003, Wolfe 2008);
- Legislation (or lack thereof) through its regulatory framework or through the values and/or perceptions of its administrators (Despins 2008, Leidl 2008, Waller *et al*. 1998, Wood 2007);
- Limited uses of rainwater (Leidl 2008);
- Building Code confusion on the differences among rainwater, greywater and non- potable water (Leidl 2008);
- The cost of RWH systems (Despins 2008, Leidl 2008, Vickers 2001, Wood 2007);
- Public education (Leidl 2008, Wood 2007);
- User involvement in operations and level of knowledge required (Leidl 2008, Wood 2007) and
- Servicing requirements and level of training (Ellison 2008, Waller *et al*. 1998, Wood 2007).

#### *3.2.1. Complacency with the status quo*

The literature notes three conditions that create complacency and a lack of urgency to conserve water: a lack of concern for water conservation unless presented with a water crisis; the realities of urban growth; and, the perception of water abundance (Bakker 2007, de Loë and Kreutzwiser 2007, Geller *et al*. 1983, Kay *et al*. 2007). An attitude of complacency results in excessive water withdrawals as is evident in Southern Ontario and stand in contrast to regions that face severe water scarcity and, out of necessity, have altered consumption patterns, such as Australia and Israel (Corral-Verdugo and Pinheiro 2006, Geller *et al*. 1983, Kay and Mitchell 1998, Mitchell *et al*. 2007, Thomas 1998, Wolfe and Brooks 2003). On average, Ontario water users withdrew 260 liters per person per day (l/p/d) (Environment Canada 2007a). Water withdrawals could be lower while maintaining a high quality of life when one considers that other OECD countries have considerably lower water withdrawal rates, for example, 200 l/p/d for Sweden and 150 l/p/d for France in 2007 (Morris *et al*. 2007: 39).

### *3.2.2. Legislation*

#### *3.2.2.1. Federal*

The Canadian constitution gives both federal and provincial governments water management powers; these provide the basic framework by which Ontario governs and directs municipalities (Bakker 2007, Canadian Environmental Law Association (CELA) 2004, de Loë and Kreutzwiser 2007, Hill *et al*. 2007, Muldoon and McClenaghan 2007, Saunders and Weing 2007). Provinces are considered owners and primary managers of the resources within their borders; this assertion is supported by legislation pursuant to the powers allocated in the Constitutional Act (de Loë and Kreutzwiser 2007, Hill *et al*. 2007, Muldoon and McClenaghan 2007, Saunders and Weing 2007). Provinces are in control of allocating water among users when there are no transboundary considerations or agreements.

This fragmentation leads to considerable differences among provinces and their approaches to water management (Bakker 2007, Furlong and Bakker 2007, Morris *et al*. 2007, Muldoon and McClenaghan 2007, Saunders and Weing 2007, WSEP 2005). Often, the federal government leaves water management to its provincial counterparts (Muldoon and McClenaghan 2007, Saunders and Weing 2007, WSEP 2005). "In general, in balancing federal and provincial interests in water management, the tendency of Canadian courts has been to read the federal interest narrowly and to restrict it to the particular power being invoked" (Sprague 2007: 22). A limit to federal power over water management demonstrates the important role of the provinces in water management. However, transnational issues become federal jurisdiction; even in these cases, a large role often exists for the province. Given the fragmentation in water management mentioned above, it has resulted in frequent gaps in policy, regulation and management of Canada's water supplies (Muldoon and McClenaghan 2007, Saunders and Weing 2007, WSEP 200).

#### *3.2.2.2. Provincial legislation*

In Ontario, residential RWH regulation is limited to the Building Code and a standard developed by the Canadian Standards Association (CSA). The Building Code, although it is progressive and encourages RWH for some indoors uses, still poses some barriers to the widespread adoption of RWH. For example, the current Code does not permit the use of rainwater for activities other than toilet flushing and outdoor irrigation, so other low risk activities that do not require the use of potable water, like laundry, continue to be unallowed.

In addition, "grey areas" exist in the Code that gives inspectors the ability to approve some technologies or applications not explicitly allowed by Code. This represents an opportunity for inspectors to encourage innovation like RWH. However, the possibility to encourage innovation is dampened by the risk it poses for inspectors, who have to assume personal liability for any approvals for things that deviate from Code. Therefore, allowances are less likely to be made for those systems perceived to be of higher risk (Despins 2008, Leidl 2008).

Finally, the *Municipal Act*, although it charges municipalities with ensuring the environmental well being of their jurisdiction, also restricts RWH innovation. Section 86(1) requires mandatory water and sewer supply to all buildings along existing municipal water lines (MMAH 2009a), which acts as a barrier to residential RWH.

*3.2.3. The role of developers and builders*

Developers and builders are major influences in the types of housing produced, particularly for houses built on speculation (Koebel 2008). "The builder, more than any other firm, decides how to balance the characteristics of supply against market demand" (Koebel 2008: 46). Mohamed (2006) indicated that residential developers have a reputation for "*satisficing* [original emphasize]]—the setting of suboptimal targets to which people aspire" (28) ultimately resulting in less than desirable subdivisions and individual lots. Mohamed believed satisficing encouraged developers to duplicate projects for their consistency, precluding innovations such as RWH. Mohamed (2006) argued that reducing risk for developers through policy does not end satisficing. Literature suggests that developers and builders are risk averse and are slow to change (Koebel 2008, Mohamed 2006, Toole, 1998). Developers and builders look for:

- Predictability, in the approvals process;
- Predictability in the building process;
- Standardized systems; and
- Predictability of post-building upkeep to reduce costs (Mohamed 2006).

A difficulty for developers and builders to adopt RWH systems is a lack of standardized RWH systems. If they were to install a RWH system they would likely want to purchase an off-the-shelf package from a major manufacturer to eliminate the risk involved with installation, troubleshooting and warranty. Koebel (2008) believed that "builders rely on larger manufacturers and suppliers who stand behind their products" (47). RWH systems that are an off-the-shelf package supported by one supplier is advantageous compared to having the individual components of a RWH system supported by numerous different supplies.

## 3.3. Feasibility of RWH

### *3.3.1. Diffusion of innovation*

Despite RWH having a substantial past in human civilizations, (Juuti *et al*. 2007, Pandey *et al*. 2003, Vourinen *et al*. 2007) its practice is "new" by modern urban standards. Thus, for the purposes of this research, urban RWH is considered an innovation. Roger's studies of the diffusion and characteristics of innovation helped illustrate some drivers of and barriers to the acceptance of RWH (Carter *et al*. 2007, Rogers 1971, 1976, Winch and Courtney 2007).

Rogers' *Diffusion of Innovations* (1983) identified the following characteristics that suggest the adoption of an innovation will occur:

- "Relative advantage", the perception that an innovation is better than pre-existing condition;
- Its positive "compatibility" with existing norms and values;
- The "complexity" of the innovation i.e. those innovations less complex are more likely to be adopted;
- "Triability", the users' ability to test the innovation for only a period of time, i.e. it is desirable when potential users are not "married" to the innovation and can cease use without significant negative ramifications; and,
- "Observability", refers to the idea that innovations more visible to individuals are more likely to be adopted, since visible innovations will likely receive more attention and could be referred to in discussions.

At this point in the study, given the characteristics of innovation identified above, some barriers to the adoption of RWH are apparent. The first characteristic, regarding the perception of "relative advantage" to RWH, will be explored later in this study. One can surmise the practice of RWH might encounter some resistance given the second characteristic of innovation (positive compatibility with existing norms). However, compatibility will be explored later in the study. The final three characteristics of innovation (complexity, triability and observability), illustrate barriers to RWH systems given their nature. Some might consider RWH systems complex, thus posing a possible barrier; this idea is explored in chapter six once the results of this research have been presented. The parallel plumbing required for the indoor use of non-potable water requires commitment to the systems and does not positively influence the systems ease of "triability". Finally, unless there is a considerable effort to "market" or raise awareness of the RWH systems, they are likely not easily visible, again representing a possible barrier, if the application of systems is not well marketed.

According to Rogers, most technological innovations are composed of two parts: the "*hardware* [original emphasis]", the actual physical system and the "s*oftware* [original emphasis*]*, consisting of the knowledge base for the tool" (Rogers, 1983: 35). According to Rogers, both of these components carry uncertainty, thus a barrier, for potential users

Rogers' (1983) indicated the adoption of "preventative innovations" (Rogers, 1983: 171), is more challenging since the motivation for their adoption is to prevent some future event. A deterrent to preventative innovations is that the unwelcome consequences that one seeks to avoid in the first place might still happen whether or not a preventative option is chosen. Therefore, preventative innovations tend to have fewer incentives and less widespread adoption (Rogers 1983). This research considers RWH as a preventative innovation and, as such, according to Rogers is less likely chosen.

### *3.3.2. Technical feasibility of RWH*

#### *3.3.2.1. System Performance*

The amount of rainwater a house can collect is dependent on the size of the roof or the 'catchment area', the amount of precipitation a location receives, and the size of the cistern. In theory, for every millimeter of rainfall, one liter of water can be collected per square meter of the catchment area (Despins 2008). Thus, larger catchment areas mean greater surface areas from which to collect precipitation. However, losses do occur. Despins (2008) and Leidl (2008) assume rainwater losses of 20% in their models measuring RWH systems performance. Cistern size is another important aspect of a RWH system. A large cistern can hold more water, which decreases the likelihood of runoff or surplus water, beyond the cisterns' capacity, to be released.

The demand a household places on its RWH system influences the size of a cistern. If a household demands too little rainwater, meaning the system is not used very much, and the cistern is "oversized" it is likely that cisterns will remain near full capacity. An oversized cistern decreases the amount of rainwater the system will collect and for use, thus nullifying some of the benefits of RWH discussed in section 3.1. It is ideal for a cistern's rainwater to be drawn down frequently, in order to collect as much precipitation as possible. However, if demand is too great then the cistern could run dry, and in most cases, if this were to happen there is a "back-up supply", of municipal or well water, that is used to refill the tank; again, decreasing the benefits of RWH by relying on municipal water. Generally, households that depend more on RWH to meet household demands, especially potable demands, will have larger cisterns (Despins 2008).

#### *3.3.2.2. Water quality*

This section briefly examines some of the possible influences on harvested rainwater quality, compiled from the Canadian and international RWH literature. It is beneficial to understand what variables affect rainwater quality in order to make informed decisions about the actual risks associated with its use and to compare perceptions of rainwater quality to actual quantified and documented testing.

A number of environmental conditions can affect rainwater quality, such as the frequency of precipitation events, drought, and seasonal change (Despins *et al*. 2009, Spinks *et al*. 2003). Despins *et al*. (2009) found significant differences in rainwater quality between seasons with the highest quality water observed in winter months, with low total and fecal coliform counts. The poorest rainwater quality was observed during the summer months. The authors surmised reduced “microbiological activity” because of the cold temperatures “inhibit[es] the growth of bacteria in the cistern” (Despins *et al*. 2009: 127). Also, colder temperatures might meant lighter loads of animal-related contaminants (feces) because of fewer animals passing on or over the rainwater catchment area (the roof), since some species migrate or hibernate in the winter. Additional influences on rainwater quality as a result of location are: pollution from surrounding land uses (Coombes *et al*. 2002, Despins *et al. 2009*); trees that overhang the catchment area; and, the accumulation of different deposits on roof tops between precipitation events (Despins *et al*. 2009).

Coombes is a well-published authority on RWH and has been able to study the application of the principles of WSUD through “Figtree Place” (FP). Houses in FP use rainwater for indoors (toilet flushing and indoor hot water uses) and outdoors (irrigation) (Coombes *et al*. 1999, 2002). Mistakes made during the construction phase of FP, some of which such as the construction of "first flush" pits could not be fixed, resulted in FP being labeled a "worst-case" scenario by the researchers (Coombes *et al*. 1999: 339, 2002). Nevertheless, FP demonstrated the RWH systems had built-in safeties that improved the quality of rainwater between the roof, tanks and point of use (POU).

Rainwater quality differed between the roof and tank level, with improved rainwater quality at the tank. "Concentrations of bacteria in roof water entering rain tanks were typically two orders of magnitude greater than the concentrations found in tank water" (Coombes *et al*. 1999: 339, 2002). A built-in feature of RWH systems that improve water quality is pre-cistern treatment such as the "first flush" system (Coombes *et al*. 1999, Despins *et al*. 2009). At FP the first flush pits diverts the first 2 mm of a rainfall event from the cistern, since it carries the most dust, debris, animal or bird feces from the roof collection area (Coombes *et al*. 1999).

Differences in rainwater quality exist between the cisterns themselves and at the POU. Generally, water at POU had improved quality, particularly in turbidity, total and fecal coliform measures, compared to within the cistern (Despins *et al*. 2009). Coombes (2005), Coombes *et al*. (1999, 2002) and Despins *et al*. (2009) observed that typical treatment methods for conventional large-scale water systems are at work within the individual cisterns, as is evident with the rainwater quality improving between the surface of tanks and the POU. Coombes (2005), Coombes *et al*. (1999), Despins *et al*. (2009), Köing (2005) and Spinks *et al*. (2006) support the importance of contaminants and debris settling to the bottom of the cisterns improving the quality rainwater drawn from the tank and the role of biofilms in "extracting contamination from the tank water" (Coombes *et al*. 1999: 339).

The quality of harvested rainwater can also be influenced by the material and components of the RWH systems themselves. For example, rooftop material that leeches or degrades would influence quality (Despins *et al*. (2009). Cistern material also influenced water quality; concrete tanks, for example, are considered beneficial to a system since concrete is known to increase the pH level of the more acidic rainwater.

Post-cistern treatment or disinfection, e.g., UV or ozone purification or running rainwater through a hot water heater, also influenced rainwater quality (Despins *et al*. 2009, Köing 2005, Spinks *et al*. 2003). Conventional hot water heaters as a means of treatment are of particular interest in the literature given their ubiquity and effectiveness when consistently kept between 50-70 degrees Celsius (Coombes 2005, Coombes *et al*. 1999, 2000, Despins *et al*. 2009 and Spinks *et al*. 2003). Rainwater contaminated with fecal and total coliform levels above the Australian Drinking Water Guidelines met the Guidelines standards once it went through hot water systems kept between 52 and 65 degrees Celsius (Coombes *et al*. 1999: 340, Coombes *et al*. 2002: 309).

A lengthy exposure to high heat is important for the "pasteurization" of rainwater (Coombes *et al*. 1999: 340, Coombes *et al*. 2002, Exall 2004). The ability of hot water systems to pasteurize depends on temperature and length of contact with the harvested rainwater. These two variables are influenced by the size of hot water tanks and household's hot water demand, particularly at "peak" times when operating temperatures can fluctuate enough that the water produced does not meet drinking water guidelines (Coombes *et al*. 1999). The ideal hot water heater requirements to ensure consistent pasteurization of rainwater may result in negative implications for energy demand, particularly during peak energy usage.

On average most rural Guelph sites had better rainwater quality than urban locations. However, this does not preclude RWH from the urban environment since rainwater would be used for non-potable activities and can undergo treatment before use. Despins *et al*. (2009) concluded that RWH was a safe practice. "The absence of heavy metals, CCME PAHs, *Legionella,* or *Campylobacter* in any of the cistern-stored rainwater samples indicates that there is minimal risk associated with the non-potable use of harvested rainwater" (133). Despite variations depending on sites and systems, RWH systems can produce water that is "of consistently high quality" (133) particularly after some level of treatment.

#### *3.3.3. Economic feasibility of RWH*

Resource pricing, in this case, the price of municipal water is an important variable influencing water conservation, the adoption of RWH and other innovations for greater conservation (Geller *et al*. 1983, Renzetti 1999, Reynaud *et al*. 2005, Vuorinen *et al*. 2007, Waller *et al*. 1998, WSEP 2005). The province guides the pricing of municipal water, so price varies among provinces. Renzetti (1999) insisted that the substantial funding from higher-level governments has helped relieve water users from paying the full cost of water, acting as a disincentive to conservation and innovation. Shrubsole and Draper (2007), Waller *et al*. (1998), WSEP (2005) agree that often water prices do not reflect their true value and does not cover all costs is supported. In 1999, Renzetti estimated that residential water users pay approximately a third of the marginal cost for water supplied (688). WSEP estimated that Ontario's water revenue did not cover all costs "in 2003 Ontario municipalities took in as water-related revenues only 64 per cent of the full costs of providing water and wastewater services" (WSEP 2005: 53). In fact, Canada has been criticized for the lack of information or data to create a realistic idea of "water valuation" to inform decision makers and encourage conservation (Dupont & Renzetti 2008).

Water rates that do not reflect water's true value will not encourage conservation, stifling innovations and individuals will be less willing to invest in conservation efforts, given their perceived cost compared to under valued potable water (Renzetti 1999, Reynaud *et al*. 2005). Full and true pricing of water in the existing system is difficult to achieve given existing attitudes towards water and current pricing schemes. People do not want to pay more for the resource ultimately leading to lack of political will on the part of politicians (Geller *et al*. 1983, Reynaud *et al*. 2005).

Post-Walkerton efforts have focused on full cost recovery of water infrastructure. The *Sustainable Water and Sewage Systems Act* (SWSSA) (2002) was the legislation to ensure municipalities publish, "full-cost recovery plans" that are reflected in water rates. Justice O'Connor suggested that these full cost financial plans should be mandatory before jurisdictions can receive their Drinking Water License. However, as of April 2010, SWSSA (2002) has yet to be proclaimed so it is not yet enforceable; some concepts that SWSSA addressed are now incorporated into other Acts. For example, the "Financial Plans Regulation" under the *Safe Drinking Water Act (SDWA)* (2002) was included in 2007, the Regulation seeks to have municipalities submit "financial plans" to be approved by the Minister to ensure "long-term financial sustainability" of water related infrastructure (Gerretsen 2009). However, the Environmental Commissioner of Ontario, Gord Miller, criticized the "Financial Plans Regulations" under the *SDWA (*2002) as being less stringent and effective than those the under *SWSSA*. "[I]t is clear that the province is taking a more flexible and gradual approach to phasing-in the requirements for sustainable financial planning, than had originally been intended under *SWSSA*" (Environmental Commissioner of Ontario 2008). Under the Financial Plans Regulation in SDWA, "full-cost recovery" is not explicitly required like in SWSSA but rather implied (Environmental Commissioner of Ontario 2008: 92). In addition, the Financial Plans Regulations do not require the Province to approve financial plans, reducing oversight (Environmental Commissioner of Ontario 2008). The slow movement towards meaningful water rates hinders economic driving forces for RWH.

Substantial literature exists that supports the idea that the expansion of water withdrawals accompanied by more infrastructure can result in negative economic and ecological impacts (Brandes and Brooks 2007, Brandes *et al*. 2006, Brooks 2005, Coombes *et al*. 2002, Gleick 2000, WSEP 2005, Wolfe and Brooks 2003, United Utilities Canada Ltd. 2006, Wolff and Gleick 2002). The Greater Toronto Area (GTA) serves as an example of the cost of new infrastructure compared to conservation. The "extra water" made available through conservation can be delivered more cheaply than water made available through the tapping of new sources and expanded infrastructure. It was estimated in the GTA, the water resulting from efficiency efforts cost approximately $ 0.57 per liter, while water supplied through new infrastructure can cost $1.20 to $4.40 per liter when including wastewater costs (United Utilities 2006: 2).

Coombes *et al*. (2002) debunked the perception that WSUD design is costly to implement with relatively little pay back. Coombes *et al*. (2002) compared two contrasting regions, the Central Costal Region (CCR) and Lower Hunter Region (LHR) in terms of water pricing and wealth in New South

Wales, Australia and simulated their potential for municipal water savings based on the adoption of RWH for toilet flushing, hot water and outdoor uses. The CCR had a population of 289,110 and was expected to experience annual population growth. The LHR had a population of 455,000 people and was expected to experience annual population growth. Potential annual municipal water savings ranged from 14,500 ML or a 48% reduction in water main reliance for the CCR to 24,700 ML or a 48.3% reduction in water main reliance for the LHR. These savings indicated it was possible to delay the need for new supply and infrastructure in some cases by 28 to 34 years and in other cases, the need for new supply was eliminated.

However, the cistern pilot project in Westvale demonstrated that at the time in Waterloo and given the outdoor only uses of rainwater, the cistern was not economically feasible. At the time, the cistern added approximately $4,000 to the total cost of the houses and only resulted in annual savings of $16, resulting in an unreasonable payback period (McMahon 2007). However, the payback period will likely be shortened with the City's increasing municipal water fees (Clemens 2010), again demonstrating the importance of proper potable water pricing.

The final factor considered regarding the economic feasibility of the adoption of RWH systems, is the role of the individuals. One might expect that individuals with higher incomes and that are more education are less constrained by economic forces, more aware of environmental issues, might live in newer and more efficient houses and are thus more likely to engage in water conservation (De Oliver 1999). However, it is the less wealthy that is more likely to produce water savings under voluntary conservation efforts (De Oliver 1999, Harlan *et al*. 2009). Mandatory conservation efforts were needed to encourage the more affluent to engage in conservation efforts, producing water savings similar to those found in less wealthy tracts (De Oliver 1999, Kenney *et al*. 2008). Harlan *et al*. (2009) surmised that the wealthy are less likely to participate in water savings since the cost of water is relatively insubstantial and because of the high value of outdoor water-intensive aesthetics and applications. The trend that the wealthier tend to consume more water is supported in the literature (Corral-Verdugo *et al*. 2003, De Oliver 1999, Harlan *et al*. 2009, Vickers 2001). Awareness of the relationship between wealth and water use is important to keep in mind when considering whom the innovators or leaders in adopting a conservation strategy might be.

#### *3.3.4. Social feasibility of RWH*

The need for water quality to reflect end use, that is "fit for purpose", can be difficult for officials to grapple with (Coombes 2005, Mitchell *et al*. 2007) because it suggests a multitude of standards rather than “one-size-fits-all” approach. However, only a relatively small proportion (approximately 10%) of a household’s total water use is actually “consumed” and needs to be potable to ensure users health (Brandes and Brooks 2007, Environment Canada 2005, Hamlin 2000, Mitchell *et al*. 2007, Thomas 1998). It is also easier to enforce that only potable water is used within the house since it is “less risky”. “If the water issuing from any public pipe is equally and maximally safe, we need not worry about people consuming waters that are not intended for drinking” (Hamlin 2000: 322). In fact, the provision of municipally treated potable water to all households no matter their socio-economic status, was championed by social movements in the nineteenth century, and was described Hamlin (2000) as a great equalizer in modern societies.

By only allowing potable water into the house it reduces the risk and any possible liability that might result from improper system use or accidental rainwater ingestion. A possible argument against RWH to supplement municipal water for low risk activities is the perception that municipal water systems are risk free. However, this is short sighted, since contamination of municipal water supplies is possible and would affect numerous users, possibly resulting in widespread negative results (Coombes 2005, Leidl 2008, Spinks 2006).

Literature exists that examines the role of socio-economic variables and individual psychologies in the acceptance of water conservation, which contributes to a more informed understanding of this study’s greater context, particularly when the role of cost is discussed in future sections. “Personal normative beliefs about water conservation” (Corral-Verdugo and Frías-Armenta 2006: 416), or values and perceptions also influence individuals likelihood to participate in conservation efforts (Corral-Verdugo *et al*. 2003, Corral-Verdugo and Frías-Armenta 2006, Corral-Verdugo and Pinheiro 2006, De Oliver 1999). This study investigates participants’ personal beliefs about water conservation and how it influences their willingness to participate in RWH.

One’s “future orientation”, defined as an individual’s ability to engage in the creation and achievement of long-term goals, plans and actions (Corral-Verdugo and Pinheiro 2006: 191) is considered in the surveys and interviews conducted with participants. Corral-Verdugo and Pinheiro (2006) indicated those with greater “future orientation” (often older individuals) are more likely to adopt sustainability oriented tendencies or technologies. Corral-Verdugo and Pinheiro (2006) established that younger individuals, particularly those under 18 years of age, are less likely to exhibit future orientations but that these future orientations likely increase with adulthood. Based on the above, one can assume that those more willing to adopt RWH are likely to have a greater future orientation, thus able to consider the well-being of future generations in relation to the present use of resources.

Another variable that likely shapes the social acceptance of RWH is the Walkerton tragedy, an important event that has shaped perspectives towards water in Ontario and has not been forgotten by public officials or citizens. Since the Walkerton tragedy, there is heightened awareness of water quality issues and encourages cautious behaviour from decision makers and citizens regarding water liability and general health concerns (de Loë & Kreutzwiser 2007, Leidl 2008). Despite the potential for cautious behaviour towards innovations because of the Walkerton tragedy, interest towards RWH within the RMoW exists. A survey unrelated to this research, conducted on behalf of the RMoW, indicated 21% of its participants would be willing to use cisterns. Of the participants who indicated they would not be willing to install a cistern 9% of the sample indicated they would consider it if they were part of a subsidized program (Metroline Research Group 2005).

#### *3.3.4.1. Education and outreach*

Communication channels within a social system also influence the diffusion of an innovation. To overcome resistance to unfamiliar innovations, widespread and comprehensive education programs and awareness campaigns are advocated to allow a greater understanding (McKenzie-Mohr 1999, Kirkland *et al*. 2002: 69). Since innovations are relatively new to the majority, individuals tend to seek out "innovation-evaluation information" (Rogers 1983: 35) to become better informed and reduce the uncertainty of an innovation to the potential user. Public education can foster voluntary compliance and acceptance of environmental initiatives, which is preferable to top-down approaches (McKenzie-Mohr 1999, Thompson *et al*. 2002).

Not all education efforts need to be "formal", some could be informal awareness campaigns conducted through individual communication channels, which exist within a social system. Mass media is an important outreach option as it can be used to reach a larger number of people; however, Rogers' (1983) considered interpersonal communications more effective although more limited in the number of people reached. Koebel (2008) and Wolfe and Hendriks (*under review)* emphasized the importance of information sharing among builders to make them more comfortable with innovation and reduce their risk aversion.

### 3.4. Summary of literature review

This literature review has set the foundations for this study by identifying: the likely drivers of and barriers to urban RWH; and the feasibility of adoption the practice given the current technical, economic and social realities. The historic and current examples of RWH and its benefits indicate that RWH and generally the adoption of fitting the quality of water for purpose are important to reduce demands on municipal water. Urban RWH is technically feasible and using harvested rainwater for activities that do not involve the consumption of rainwater, appears to be safe. This statement is supported by the many successful examples of modern RWH explored above, although it is important to have informed consumers, legislators and decision makers for responsible decisions and actions.

## 4.0. Context for Study

4.1. A brief introduction to the Regional Municipality of Waterloo (RMoW)

The RMoW has a two-tiered governmental structure, with different responsibilities allocated to the two levels. The RMoW (the upper tier) is responsible for conservation programs and research; the City of Waterloo government (one of the lower tiers) is responsible for building approvals in the City of Waterloo (Henderson 2009, Rapp 2009). A possible driver to RWH within the RMoW is that they have previously been receptive to some innovative initiatives for water conservation, possibly because of significant population and urban growth and its implications for groundwater supplies. The City of Waterloo has had a population growth of 1000% between 1948 and 2001 (Morgan *et al*. 2004: 175). The sharp increase in population was aided by the influx of students, or seasonal residents, into the community beginning in 1948. Regardless of the source of the population increase, to meet the increased demand for water, Waterloo had to secure additional supply sources beyond its reliance on groundwater. In 1992, the RMoW began to draw water from the Grand River, rather than relying solely on groundwater, as it had done historically. Currently, the RMoW relies on groundwater for 80% of supply and the Grand River supplies the remaining 20% (Region of Waterloo n.d.).

The break down of indoor water uses for the average Waterloo household is as follows in

Table 4.1: Average indoor water uses in Waterloo, Ontario

| Activity | Percent (%) |
|---|---|
| Toilets | 29 |
| Washing Machine | 20 |
| Faucets | 16 |
| Shower | 13 |
| Leaks | 10 |
| Water softener | 9 |
| Bath | 2 |
| Dishwasher | 1 |

Adapted from: Region of Waterloo 2009

If a household were to use rainwater for toilet flushing alone, this could theoretically reduce a household's municipal water use by 29%. The amount of rainwater that could replace municipal water could increase if the RWH system were of an appropriate capacity, and if the Building Code allowed the use of rainwater for clothes washing.

The possible potable water savings that would result from using rainwater for outdoor irrigation is variable given the season and system capacity. Considerably less water is used in cold months, than in the spring and summer months, when individuals use more water for their lawns, gardens and pools. In the summer months, the increased uses of water outdoors can double water consumption (Region of Waterloo 2009). Vickers (2001) estimated that approximately 31% of water withdrawals is used for outdoor purposes by the average single-family household in the United States (Vickers 2001: 12). Leidl (2008) assumed that per capita outdoor water use is 14 l/p/d from May to September in Guelph.

Demand for fresh water will increase with the growing population (XCG Consultants Ltd. 2007 Morgan *et al*. 2004), but it is possible to delay the expansion of infrastructure capacity by reducing per capita demand. XCG Consultants Ltd (2007:15) project population growth of 201,528 people between 2006 and 2031 for the Region; the consultants expect water efficiency and conservation methods will make only a small contribution in reducing future demand.  XCG estimated that even with 100% participation in current water efficiency methods, average demand could rise from 164.6 Ml/d (million liters per day) in 2006 to 216.5 Ml/d by 2031 (XCG 2007: 17).

The RMoW's water supply strategy does not attribute significant water savings to "soft" methods, such as conservation and demand management strategies. Soft strategies are the best "new" source of water for growing urban populations and, at this point, less expensive than tapping "new" sources (Brandes and Brooks 2007, Brooks 2006, Gleick and Wolff 2002, Morris *et al*. 2007, Vickers 2001). One of the soft strategies encouraged by the RMoW is the use of rain barrels for outdoor irrigation however these savings are only seasonal (Region of Waterloo 2008, XCG 2007, Waller *et al*. 1998).

To meet increased water demand the RMoW has taken two approaches. The first has been to investigate the exploitation of new water sources. This approach, articulated by Clarke (2000) in the RMoW's Long-Term Water Strategy (LTWS), outlined the need for:

- An aquifer storage and recovery facility with a capacity of 45.4 ML/d;
- The identification and exploitation of up to 23 ML/d of new groundwater sources;
- As necessary, the construction of a water supply pipeline from Lake Erie with a capacity of 432 ML/d.

Implicit in this approach is the assumption that conservation methods will not allow the Region to meet future anticipated demand. The second approach to meeting increased demand has been the adoption of greater efficiency programs to achieve conservation goals by supplying rain barrels and low flow toilet rebates, and strengthening outdoor water use bylaws (Clarke 2000, Waller *et al*. 1998, XCG 2007). Encouraging a decreased reliance on municipal water by means of conservation efforts, such as the use of cisterns, could delay the need for this pipeline to Lake Erie. Table 4.2 shows examples of municipal water savings given the allowed uses of rainwater.

Table 4.2: Examples of municipal water savings because of RWH

| Example | Uses of Rainwater | Savings |
|---|---|---|
| Figtree Place, New South Wales, Australia | Hot water, toilet flushing, irrigation. | Initial savings (RWH systems not in full operation): A 30% reduction in internal water withdrawals from the municipal system, compared to demand pre-RWH systems operation.<br><br>It was expected once the RWH systems were in full operation there would be a 45% reduction in municipal water withdrawals (Coombes *et al*. 1999: 341).<br><br>Total expected savings compared to a similar conventional community was 60%. (Coombes *et al*. 1999: 342). |
| Maryville, New South Wales, Australia | Hot water, toilet flushing, irrigation. | This example identified a reduction in municipal water withdrawals of 70% with the use of a RWH system (Coombes et al. 2003: 3). |
| Guelph, Ontario | Toilet flushing, laundry and outdoor uses | This local example experienced an average of a 30% reduction in municipal withdrawals across its test sites, because of the application of a RWH cistern system (Despins 2008: 120). |

One could assume that given the close proximity between Guelph and Waterloo, that given similar site characteristics (e.g. climate, geology, water use, roof and cistern size) that RWH efforts in Waterloo would produce similar per capita municipal water savings. Again, the CMA of Kitchener is used for data collection, rather than the City of Waterloo, to reflect the entire Region of Waterloo and demonstrate the larger possible savings. If RWH systems were installed in 4% of the CMA of Kitchener's non-apartment private dwellings the water savings realized would be larger than those achieved through the RMoW's current rain barrel program. The 2006 census indicated the CMA of

Kitchener has approximately 123,498 private dwellings that are not apartments (Statistics Canada 2010); if 4% of these, approximately 4940 non-apartment dwellings, were outfitted with RWH systems for indoor and outdoor use savings would be approximately 520,251,160 l assuming household savings of 105,314 l/year as calculated in section 3.1.9. The 4% adoption rate of RWH in the CMA of Kitchener was used given that Germany, a similar case study to this research, has a 3 to 5% RWH adoption rate (Schwarz and Ernst 2008: 497).

The RMoW has recently renewed the rain barrel program, which was originally a five-year program. The program consists of one distribution day a year when the RMoW sells rain barrels at subsidized prices. As of 2008, the program had distributed 340,000 rain barrels. The barrels have a capacity of 200 l each. By 2006 estimates, the rain barrel distribution program would achieve yearly potable savings of approximately 30,000,000 l assuming the use of 25,000 rain barrels that were drawn down 6 times a season (United Utilities 2006: Appendix 4). The popularity of the rain barrel program has resulted in the distribution of 340,000 rain barrels, one can estimate based on United Utilities (2006) numbers rain barrels have achieved potable water savings of approximately 408,000,000 l. Using RWH systems for indoor and outdoor uses year round would result in greater savings than the rain barrel program, by 112,251,160 l/year. The year round nature of RWH systems for indoor and outdoor uses is also advantageous for its continued stormwater management, further savings could be realized by expanding the uses of rainwater and complementing RWH with other conservation efforts.

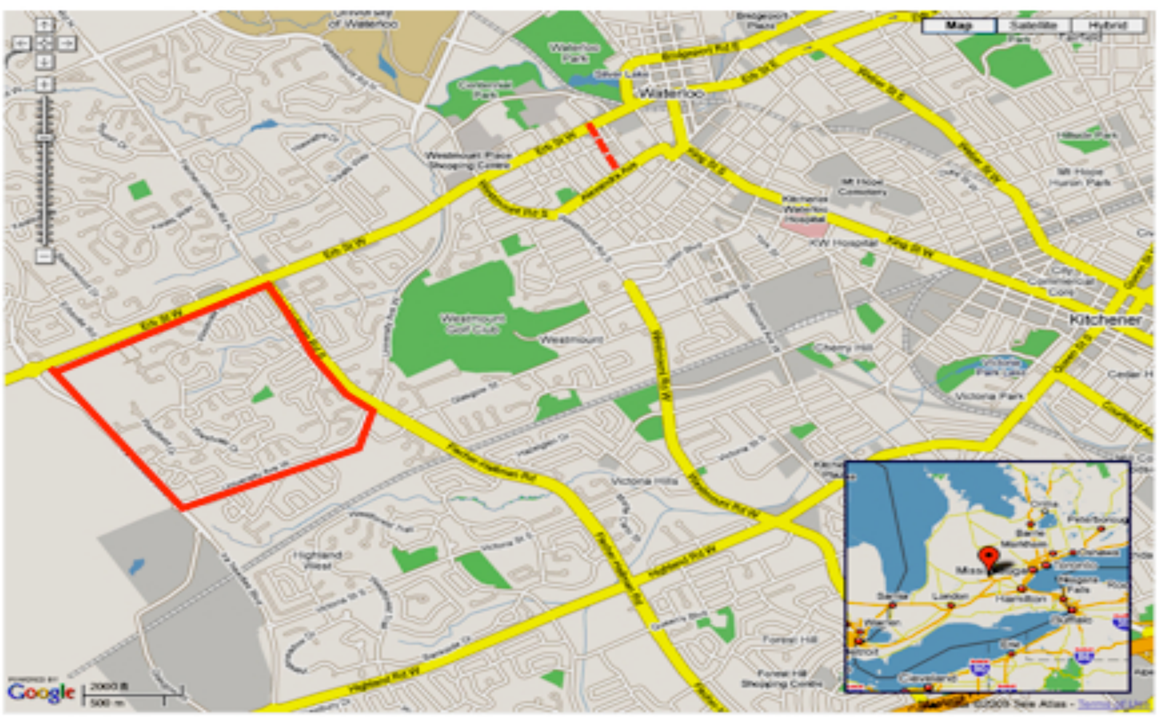
#### *4.1.2. Areas of study*

This study looks at two specific areas in the City of Waterloo. The first is a section of the suburban neighbourhood of Westvale bounded by Erb Street West, Fischer-Hallman Road South, University Avenue West, and Ira Needles Boulevard (Figure 4.1). Westvale, a residential suburb in the City of Waterloo, contains 30 houses that were part of a cistern pilot project (McMahon 2007). Westvale is comprised of mostly single-family houses, with a few townhouses and semi-detached dwellings. The houses listed on Multiple Listing Service (MLS) for the area range in age from the early 1980s to the early 2000s.

The census tract (CT) that encompasses the Westvale neighbourhood is highlighted in red in Figure 4.1 and consists of 2,085 private dwellings, the majority of which are owned by the occupant. The 2006 census revealed that 85.9% of all private dwellings in the CT are single detached houses. The census indicated that 515 dwellings were constructed before 1985 and 1,535 dwellings were constructed between 1986 and 2006. The average value of the dwellings was $255,988, slightly below the average value of dwellings ($261,025) in all of the Kitchener CMA. The average household size in the Westvale CT is 3.1 persons. The median income in 2005 for all private households in the CT was $88,731, significantly above the Kitchener CMA median income of $63,984 (Statistics Canada 2009a).

The broken red line in Figure 4.1 highlights the second area of interest to this study in Uptown Waterloo, which is a more mature neighbourhood, with a number of century structures. A faculty member of the Department of Environment and Resource Studies indicated he lived on Menno Street and at one point, his house had a cistern. The faculty member also indicated that two of his or her neighbours who also lived in century houses had cisterns on their property. Despite the small samples from Uptown Waterloo, these few households help establish the presence of residential RWH systems in non-rural locations. This evidence is important due to the limited Waterloo-specific historical RWH information that exists. It is very likely that other houses of a similar age in the area also have cisterns, but to extend the sample is beyond this study, although further exploration of this matter would be interesting further future research.

Figure 4.1: Waterloo map: Areas of interest




Map source: Google Maps (2009).

The cistern pilot project conducted in Westvale is an example of Waterloo's potable water conservation history. In 1989, the City of Waterloo initiated a pilot project that required twenty percent of new homes in Westvale to have cisterns. If the pilot were successful, similar cistern requirements would be introduced to future residential developments (McMahon 2007). However, very little is recorded or known about the project and its outcomes.

According to an article in the local paper (*The Kitchener Waterloo Record*) by McMahon (2007) the cistern pilot project, and any similar future requirements requiring new homes to include cisterns, was dismantled in 1992 by Council in response to a committee's suggestion (McMahon 2007). This committee had been formed to give developers more of a voice in City politics. Given the elusive nature of any municipal documentation of the Westvale cistern pilot project few additional details about the committee are available. The committee suggested the cistern systems in the pilot project had poor payback potential and the additional cost dissuaded potential buyers (McMahon 2007).

Houses with cisterns in the pilot project were the last purchased and the builder had to reduce the price of those homes with cisterns to sell them. A City survey emphasized buyer disinterest in the cisterns, which found that less than a quarter of the homeowners purchased their home for its water saving possibilities (McMahon 2007). Rapp (2009), the general manager of development services for the City of Waterloo, estimated the Westvale neighbourhood, particularly in the early 1990s was dominated by first-time house buyers and that at the time houses cost between $130,000 and $180,000 to purchase. While the economic factor in consumers' resistance to cisterns seems clear, there has been no evaluation of socio-historical resistance to cisterns. This neglect represents a significant opportunity to learn from a municipal experience and inform a movement towards water efficient and more sustainable communities.

## 5.0. Results

### 5.1. Introduction

This chapter consists of two main sections; the first section examines the compiled results of the surveys and some of the unique perspectives that respondents wrote in themselves. The second section of this chapter examines the common themes and understandings gained from the interviews.

### 5.2. Survey results

Of the 553 surveys distributed in the Westvale neighbourhood and to the Uptown Waterloo residences (herein referred to as Uptown), 144 were returned, a response rate of 26%. Of the 144 surveys returned, eight were completed by respondents online. The literature presents a considerable range for adequate response rate, and there is no agreed normative expectation (Baruch 1999: 422).

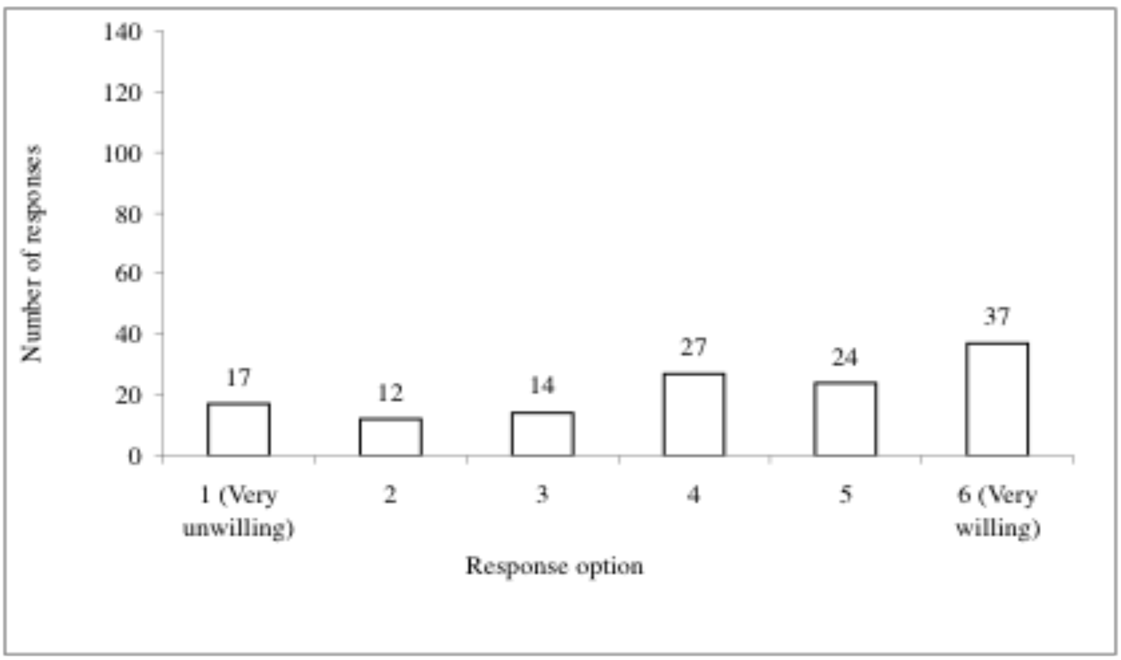
There are indications of general declines in response rates to mail-out surveys in the United States, which is problematic for survey based research (Baruch 1999, Dey 1997). The literature on survey research responses indicates response rates between 20 to 56% (Cook *et al*. 2007, Dey 1997). This study's response rate of 25.6% is considered acceptable based on the literature and since this study does not attempt to make broad generalizations about other urban areas and RWH. It is important to note that the number of responses per question varies; some respondents may have purposely skipped questions because they were not comfortable answering them or felt they lacked the knowledge to answer or were simply uninterested.

The first ten questions in the survey asked respondents basic questions about their household and house. The average household size for the sample was 2.87 people. Of the respondents 68 of the 142 respondents to this question indicated they had at least one child, an individual age 18 and under, living in the house. Two of the total respondents declined to answer this question. From the surveys, 85.3% of respondents indicated that they lived in single detached houses and 96.5% of respondents identified themselves as the homeowners. Eleven respondents, all single-family house owners, identified themselves as having a cistern on their property. Six respondents with cisterns indicated that they were the first owners of their house. The average age of the houses in the Westvale sample was 14.8 years, while the average age of houses with cisterns was 15.2 years. The majority of the Westvale sample homeowners were not the original owner; only 52 respondents (37%) identified themselves as being the first owner of the house. The estimated average age of the participating houses in Uptown was 102 years old. All respondents' form Uptown identified themselves as owners of the house, although not the original owners.

*5.2.1. Respondents' without cisterns perspectives on RWH*

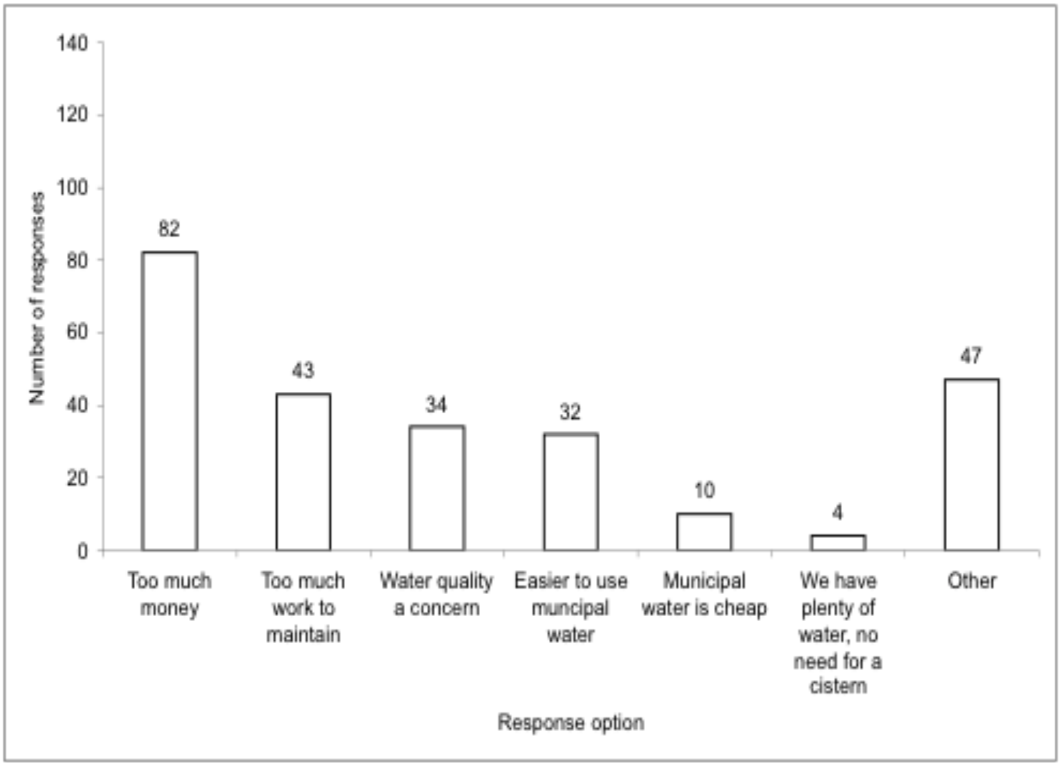
The 132 respondents, who indicated they did not have a cistern or were not sure if they had a cistern, resumed answering questions specific to their situation at question 29. The majority of respondents (65%) acknowledged that they had heard of RWH before participating in the survey. Three survey questions directly examined respondents' perceptions of RWH. One question asked respondents' willingness to install a cistern for outdoor uses. This question had 131 responses. The complete tallies for the six possible responses according to the scale are in Figure 5.1. Almost half of the respondents (46.6%) expressed a willingness to use a cistern for outdoor uses, compared to only one-quarter (22.3%) of respondents who expressed unwillingness.

Figure 5.1: Responses to question 29: Willingness to install a cistern




The question regarding perceived deterrents to cistern installation received 133 responses (Figure 5.2). Respondents were able to identify as many deterrents as they considered applicable from a given list. The most commonly identified deterrent or barrier was the perceived cost: over half (61.7%) of respondents identified cost as a barrier.  Another perceived barrier for 32.3% of respondents was that a rainwater harvesting system would be too much work to maintain.

Figure 5.2: Responses to question 30: Deterrents to installing a cistern



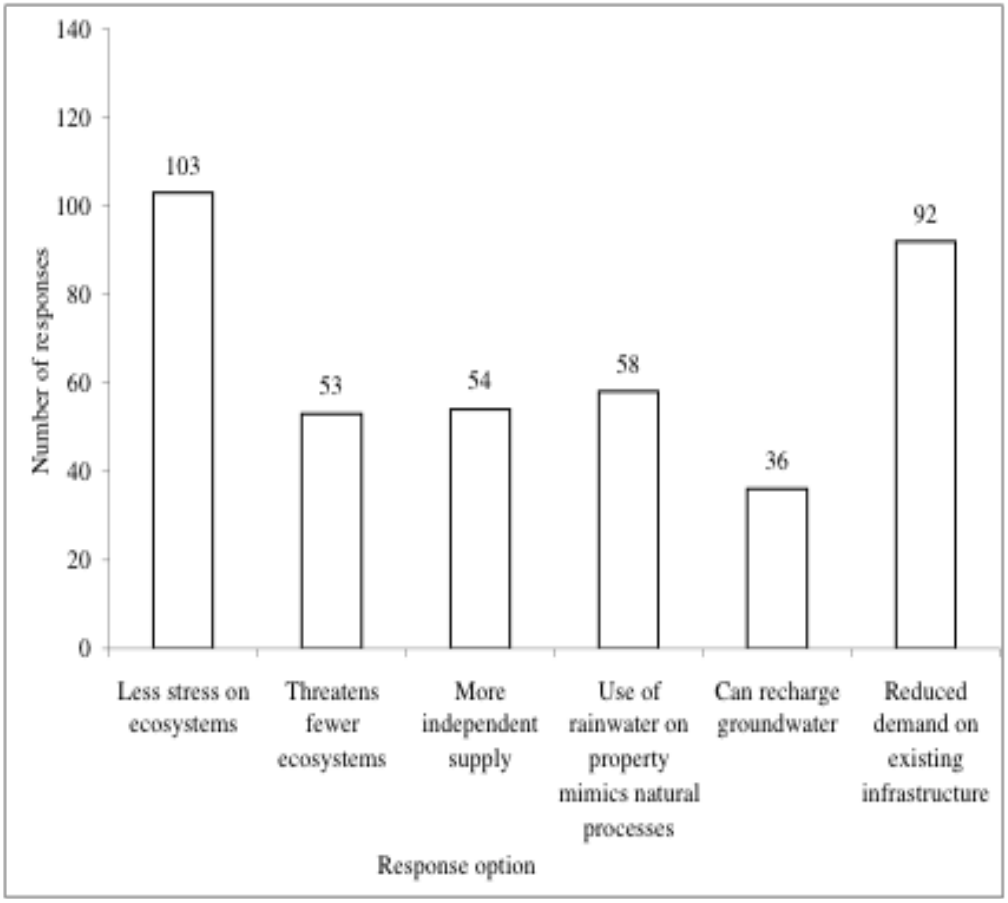

The "other" category provided respondents an opportunity to write in self-identified barriers (see Table 5.1 for a complete list). The most commonly identified deterrent was the large number of unknowns—among those cited were a lack of fundamental knowledge about the system, how it works, maintenance and cost—so it was difficult to judge specific deterrents.

Table 5.1: Question 30: “Other” deterrents to RWH mentioned by respondents

| Deterrent | Number of respondents |
|---|---|
| Not enough information about system “how it works, cost, or maintenance involved, this is hard to answer” (Respondent 6). | 22 |
| “Easier to use a rain barrel” (Respondent 15). Respondents already use one or a few rain barrels to meet their needs. | 8 |
| Not enough room (for additional plumbing, cisterns in the small lots). | 7 |
| Not easily available. | 3 |
| Aesthetics (considered an “eyesore” (Respondent 17)). Worried about destroying a portion of the lawn to insert cistern (Respondent 37). | 3 |
| “I don’t water my grass or garden (drought resistant) and I don’t wash my car. So, no need” (Respondent 87). | 3 |
| Age of potential users (some felt they were to old) | 2 |
| Concern about winter (“No rainfall in winter for refilling Frost problems!” [sic] (Respondent 76)). | 2 |
| “[L]ack of consideration for the environment” (Respondent 18). | 1 |
| Regulations (Respondent 20) | 1 |
| “We only water plants- not the lawn” (Respondent 21). | 1 |
| “If everyone installed a cistern… how much groundwater is removed from the system (sitting in storage) and what impact would that have” (Respondent 96). | 1 |
| If investing the money in system want to be able to use water indoors | 1 |
| Inconvenience | 1 |
| Concern about mosquitoes and children’s allergies | 1 |
| “Lifestyle too busy” (Respondent 101) | 1 |

Another question presented to respondents was whether they could identify any benefits of cistern use. Of the 131 respondents, the majority (78.6%) identified reduced water source stress as a key incentive to RWH, followed by 70.8% of responses that acknowledged the potential of RWH to decrease stress on water-related infrastructure (water supply and stormwater). The other incentives listed in the survey (see Figure 5.3) were also identified by respondents but in comparatively fewer instances.

Figure 5.3: Responses to question 31: Incentives to RWH




*5.2.2. Respondents with cisterns perspective*

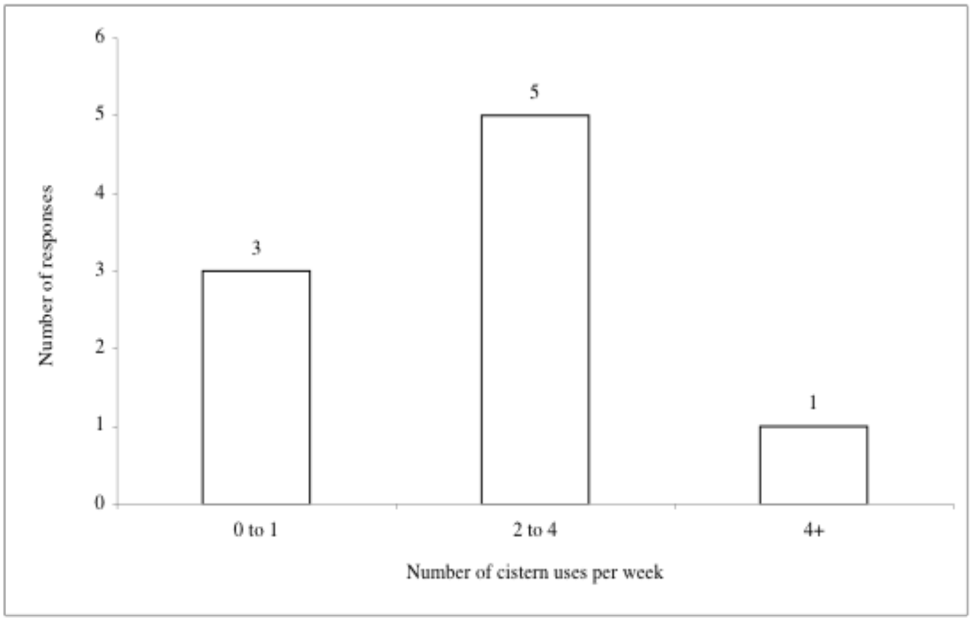
Of the eleven respondents who identified their houses as having a cistern, ten of the respondents consistently answered the questions. Despite the small sample of individuals with cisterns, it is worthwhile to consider any feedback about the systems. Of the eight Westvale respondents with cisterns, all but one indicated that they continued to use their cisterns. The respondent who no longer used her/his RWH system indicated that there were too few uses for the collected rainwater to justify the expense. "If my system worked, I would probably use it, but not enough to justify cost to repair and maintain" (Respondent 139). One of the respondents with a cisterns indicated that the builder did not install their cisterns as part of the City's pilot project; rather they installed it by directly accessing the dwelling's sump system. "Sump around pool collects runoff/rain- we use as a cistern" (Participant 140). Sump systems drain water from in and around a house's (or pool's) foundation to a central collection area that has a pump. When a float reaches a certain level, the water is pumped out, often to storm water systems, or one can access the sump water on demand.

Of the century houses, two continue to have a cistern, while the third resident removed her/his cistern approximately nine years ago. Two of the respondents indicated the builders of the houses had included the cistern while the third respondent was unsure who originally installed the cistern. None of the residents had installed the cistern system themselves. Of the three century homes included in this study, only one household had children.

The respondents who had their cistern removed admitted that, before its removal, they had never actually used it. It was interesting to note Respondent 144's comment: "For the previous owners, the cistern was connected to the hot water tank via the filter, that supplied the house's bathrooms and kitchen. We have attached a pump outside and used the cistern water on the garden". The comment was interesting when one considers the effort and cost a previous homeowner had gone through to install a RWH system for indoor and outdoor use, thus overcoming two considerable barriers to RWH particularly in retrofitting examples. In addition, this presence of rainwater in the kitchen goes beyond current allowances in the building code. The third respondent had the cistern removed in 2000 when it was found during a renovation: "did not know it [the cistern] was there until it collapsed. It had been buried by extra fill by a previous owner" (Respondent 142).

Only two of the ten responses indicated the presence of a cistern as a positive influence on the decision to purchase the house. Most respondents indicated they used their cistern for outdoor irrigation. This restricted usage would limit their use of the cisterns to the warmer months (i.e. late spring, summer and early fall). Responses indicated a range in the number of times the cisterns are used in the summer time (Figure 5.5).

Figure 5.4: Responses to question 14: Cisterns' average weekly summer use




Some households seemed to use the collected rainwater for more activities. Respondent 140 mentioned that in addition to outdoor watering, they use their cistern to fill their hot tub. Respondent 99 wrote that their household uses the collected rainwater for "Drinking water, cooking water, dishwasher, all the sinks receive rainwater". This respondent likely engaged in some plumbing alterations that allowed them to have rainwater meeting their potable needs. All but one cistern user reported winter cistern use to be 0-1 a week. Respondent 99 indicated that they continue to use their cistern more than four times a week in the winter, likely since rainwater supplies so many indoor activities.

One century house respondent stated, "I'm not convinced the water is "clean" enough for washing. When we first moved in, the water coming through the hot water pipes was brown—but maybe the cistern simply needed to be cleaned or the filter replaced—we did neither" (Respondent 144). The other respondent indicated deterrents to greater use as the cost of renovating the house in order to use the water indoors, a lack of information promoting the practice, concern about contamination and the amount of work required to install the systems. The respondent who had removed the cistern in a renovation indicated that he/she would be very willing to install a cistern for outdoor uses, however the respondent also indicated that installing a RWH system was not an immediate need and was further complicated by deterrents. "Not a high priority—expense plus I'm no good with construction projects" (Respondent 142). All three respondents indicated that they viewed water conservation as important.

The survey asked respondents to reflect on their initial expectations regarding the usefulness of the cistern. On average, respondents' recollections of their initial cistern perceptions did not seem to be overwhelmingly positive. Perhaps this lack of enthusiasm speaks to respondents' lack of awareness about the system, or a lack of need for the cisterns. Of the ten respondents who consistently answered questions, three expected the cisterns would be useful and three respondents expected that the cisterns would not be useful at all, while the rest of respondents did not indicate such strong negative or positive perceptions.

Opinions after cistern experience were also canvassed. The three respondents who initially expected the cisterns to be very useful maintained that opinion. One respondent's initial view that the cistern would not be at all useful changed to finding it very useful once she or he had some experience. Of the three respondents who did not indicate particularly strong expectations for their cistern's usefulness in question 17, one remained ambivalent about their use in question 18; the other two found the cisterns less useful than they had initially expected. The respondent who expected that the cistern would not be at all useful maintained that opinion. This sample is too small to draw any robust inferences but is worthwhile to note.

Cistern users' overall satisfaction with their RWH systems varied. Four respondents indicated that they were "very satisfied". Two respondents indicated that overall, they were not particularly satisfied with their cisterns. Considering their level of satisfaction, question 20 inquired about cistern user's likelihood to reside in another house with a cistern. Despite users sometimes less than strong support for RWH systems, six respondents indicated they would move into another house with a cistern. The two respondents who were most unhappy with their cisterns indicated that they would not move into a house with a cistern.

Once the overall usefulness and satisfaction of the cistern systems was examined, it was valuable to inquire about other cistern variables (e.g. ease of operation, maintenance and cistern capacity) that might influence users' overall satisfaction. Responses regarding the operation and maintenance of cisterns varied among the small sample. Three respondents found it easy to operate their cisterns, while two respondents found it difficult to operate their cisterns. Responses generally indicated the maintenance of the cisterns to be relatively easy, with three respondents indicating "easy" and one indicating "difficult". No respondent indicated that his or her cistern's capacity was too big, but two respondents indicated that their capacity was too small.

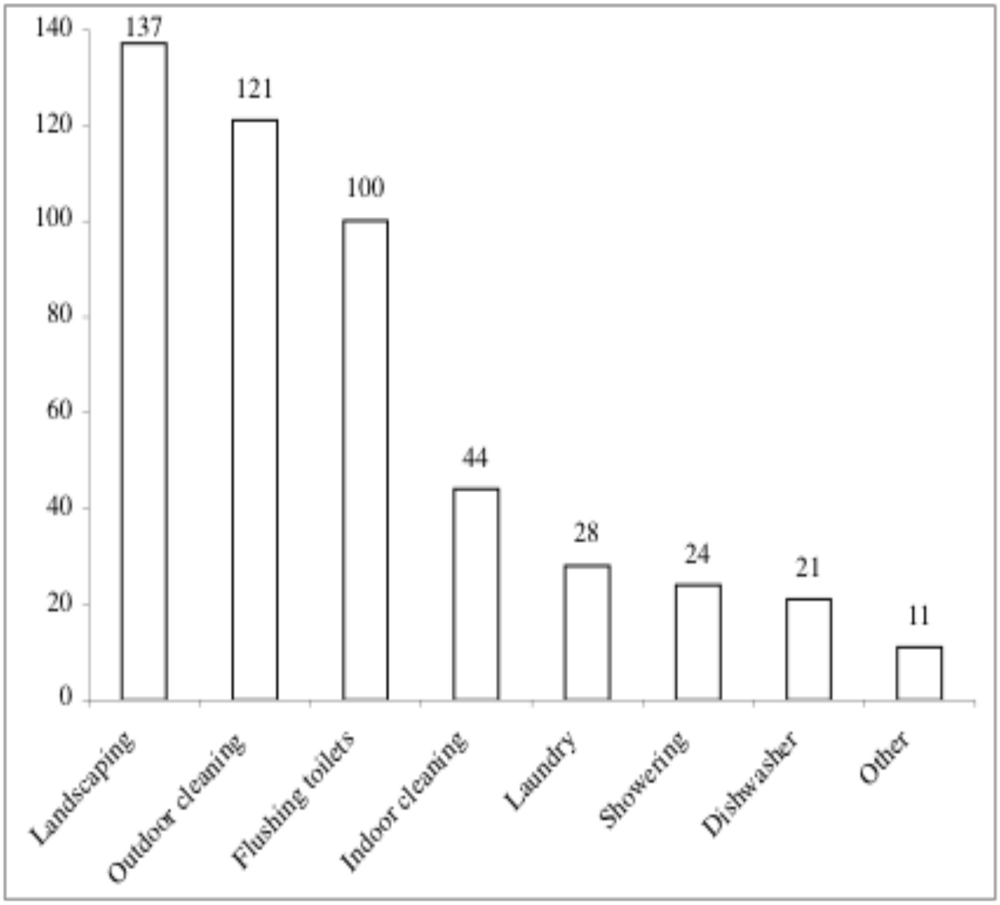
Questions regarding cistern capacity and potential uses helped further gauge users' attitudes or inclinations toward rainwater use, the logic being that if respondents indicated there were too few uses for rainwater and the capacity of their cisterns was too small, potential exists to expand uses. If uses of rainwater were to be expanded beyond outdoor irrigation — for example, to toilet flushing—the additional use(s) would encourage increased cistern capacity in system design, making the systems more practical and valuable. In addition, regular use of cisterns is advantageous, in that frequent drawdown allows the cistern to collect rainfall from later precipitation events and further contribute to reduced reliance on municipal water (Spinks *et al*. 2003). Increased rainwater use also helps justify the RWH systems and any associated costs to users and can lead to fewer instances of municipal water being required to top up the systems.

Respondents were canvassed as to how they would improve their current cistern systems. Suggestions included: improving water pressure for the system; increased capacity; a gauge that lets users know how full the cistern is; a better pumping system and more taps to access stored water. One respondent indicated she or he would be unwilling to use rainwater in the house. "The water presently collected has a very odd smell; I wouldn't trust it in the interior of the house" (Respondent 118). Another respondent indicated another improvement to the system would be an electric pump. "An electric outdoor pump would improve it as the manual pump would dry out + [sic] need to be moistened inside before it would work" (Respondent 144).

### *5.2.3. Combined responses from respondents with and without cisterns*

Subsequent questions sought to articulate what respondents felt were acceptable uses of residential rainwater applications and what perceptions or concerns might prevent an expansion of rainwater uses. Figure 5.4 presents the responses. The three most common activities of the 142 respondents indicated were: landscaping (96.5% of respondents), outdoors cleaning (85.2% of respondents), and toilet flushing (70.4% of respondents). Two respondents declined to answer this question.

Figure 5.5: Responses to question 35: Acceptable uses of rainwater




Respondents had the opportunity to write in any additional uses of rainwater with which they would be comfortable (see Table 5.2). Many respondents expressed that more information about contaminants in rainwater would be needed to make informed decisions. Some other respondents mentioned that some sort of purification process would be required to make them more comfortable with using rainwater.

Table 5.2: Question 35: "Other" activities respondents would use rainwater for

| "Other" possible uses of rainwater | Number of respondents |
|---|---|
| Watering indoor plants | 2 |
| Filling a hot tub | 2 |
| Filling to topping up pond | 1 |
| Fill the kids' water guns | 1 |
| Filling pools | 1 |
| Drinking | 1 |
| Hair washing | 1 |

Once an understanding of respondents' willingness to use rainwater for activities was established, it was important to inquire about what would make potential users of rainwater uncomfortable about expanding uses. The question as to why respondents would not feel comfortable expanding the use of rainwater resulted in 139 responses. The top four factors that made respondents uncomfortable with expanding their uses of rainwater were:

- Contamination concerns, identified by 80 respondents (57.6%).
- Health concerns, indicated by 70 respondents (50.4%).
- The perceived high costs of a renovation required to accommodate a cistern system were a concern to 63 respondents (45.3%).
- Lack of information was identified by 42.3% of respondents as a barrier to expanding their use of rainwater. The concern regarding lack of information was particularly evident through the numerous respondents' comments that indicated they thought cisterns could not be used in the winter due to a lack of rain. In addition to this response option in the survey, a lack of information was an extremely common statement that respondents repeatedly wrote into the surveys. Many felt this lack of knowledge influenced their ability to properly answer some of the survey's hypothetical questions regarding cisterns.

The "other" reasons that made respondents uncomfortable to expand their uses of rainwater are in Table 5.3.

Table 5.3: Question 36: “Other” reasons respondents would not expand uses of rainwater

| Reasons for not being comfortable expanding uses of rainwater | Number of respondents |
|---|---|
| Poor filters in the system so sediments or other contaminants could result in damage or discolouration of clothing or car paint or machines | 4 |
| “I don’t know enough about cistern use” | 3 |
| Cistern water is not clean given the long periods it is left standing stagnant | 3 |
| “Too much pollution and junk in our rainwater to use for dishwashing and showering” (Respondent 135) | 2 |
| “The water presently collected has a very odd smell; I wouldn’t trust it in the interior of the house” (Respondent 118) | 1 |
| “Replumbing of public supply” (Respondent 23) | 1 |
| “Having used cisterns in other homes there is not enough water to use for flushing toilets” (Respondent 14) | 1 |
| “Living close to the dump concerns me, if it would leak into a cistern” (Respondent 54) | 1 |
| “Old lady” (Respondent 71) | 1 |
| “Concerns about allergies- have a family that is highly sensitive to environmental allergens- don’t know if these would be a factor” (Respondent 100) | 1 |
| “Mosquitoes” (Respondent 104) | 1 |
| “The cisterns would need to be promoted with public info sessions and retrofit project promotions” (Respondent 34) | 1 |
| Concern how to access to water e.g. pipes or carry buckets | 1 |

#### *5.2.4. Respondents’ perspectives on factors influencing RWH*

This section focuses on questions regarding current water saving efforts and future planning. Other influencing factors, such as views on water conservation, household water saving efforts and views on population growth in the Region allow for a more complete understanding of respondents’ propensity to consider RWH. Respondents with and without cisterns answered these more general questions.

Over 80% of respondents, both with and without cisterns, indicated that water conservation was important, while only 1.4% of respondents identified water conservation as unimportant. The open-ended question regarding water conservation allowed for a more detailed investigation, as respondents were able to write in their own motivating influences for water conservation. Respondents who felt water conservation was unimportant reasoned that our water supplies are "all polluted so who cares" (Respondent 114). Some survey responses demonstrated the perception of water abundance, such as, "can't possibly run out" (Respondent 133). Numerous respondents referred to fresh and clean water as a limited resource. Some respondents indicated some specific factors threatening water, e.g. climate change, demand, pollution and overconsumption.

The surveys identified a number of common themes that supported water conservation (see Table 5.4 for a complete list). Some respondents emphasized the importance of water for ecosystem and water source's well being or health; others identified water as humanity's "life source" or concern for future need. A number of people expressed concern that Americans would use force in Canada to ensure their water supply. Respondents also mentioned a moral responsibility for water stewardship. A number of respondents indicated the importance of being "responsible custodians" (e.g. Respondent 1). Some respondents acknowledged the economic savings associated with water conservation. There are indications that respondents' felt current water use is unsustainable and can be reduced, such as, "Even spoiled children need to grow up" (Respondent 1).

Table 5.4: Question 33: Common responses on why water conservation is important

| Why water conservation is important | Number of respondents |
|---|---|
| Fresh and clean water as a limited resource | 41 |
| Ecosystem or water source well being | 24 |
| Water as a "life source" | 19 |
| Future need | 17 |
| Water security threatened by climate change, development, overconsumption, Americans as a military threat | 16 |
| Economic advantage | 8 |
| Moral responsibility/ stewardship | 3 |

Respondents were able to select as many options as were applicable from a list of possible household conservation features. The list also included an open-ended section where respondents could write in any additional features not listed. Low-flow toilets were listed by 83 of the 140 respondents (59.3%) to this question. A greater portion, 94 respondents (67.1%) claimed to have low-flow showerheads while just 50 (35.7%) claimed to have low-flow faucets. Approximately 45 respondents (32.1%) reported that they use rain barrels.

Additional water-saving features that respondents included in the surveys were: efficient dishwashers; "smart" water softeners that "regenerates based on capacity (need)" (Respondent 116); forgoing water softeners and dishwashers; and, choosing the "quick" cycles on laundry and dishwashing. One respondent indicated they have some sort of a water reclamation system.

### *5.2.5. Water conservation and future growth*

Having explored individual households in previous sections, the following section takes a more macro-scale perspective. How to manage and plan for population growth can be a divisive topic. The survey responses displayed a variety of perspectives and "solutions" for future growth. The majority of respondents seemed, at some level, concerned about how to meet the water needs of the future population. Over half of respondents (60%) indicated they were concerned about how future growing water demand will be met, while only 7% of respondents indicated they were not concerned.

It was interesting to examine how respondents felt future water needs should be met if one assumes population growth is inevitable. Most respondents (86.5%) supported the encouragement of greater conservation and efficiency measures when asked to identify how the RMoW should try to meet the water needs of a larger population. Figure 5.6 and Table 5.5 displays the breakdown of responses. At first glance, one might perceive the possible answers respondents could choose for this question as conservation focused, forcing responses to indicate support for conservation. The responses indicate there is strong support for conservation. However, respondents were supplied with reasonable options to choose from, including those other than conservation e.g. the pipeline. Response options for respondents can be broken down into two categories either "I am willing to explicitly conserve water by making changes" (e.g. conservation, public awareness campaigns, making water more expensive). Or "I am not willing to conserve by making obvious changes in my life" (e.g. pipeline, building practices, fix leaky infrastructure). The latter two options have conservation implications but do not require the individual to change.

Figure 5.6: Responses to question 38: Opinions on how to meet future water needs

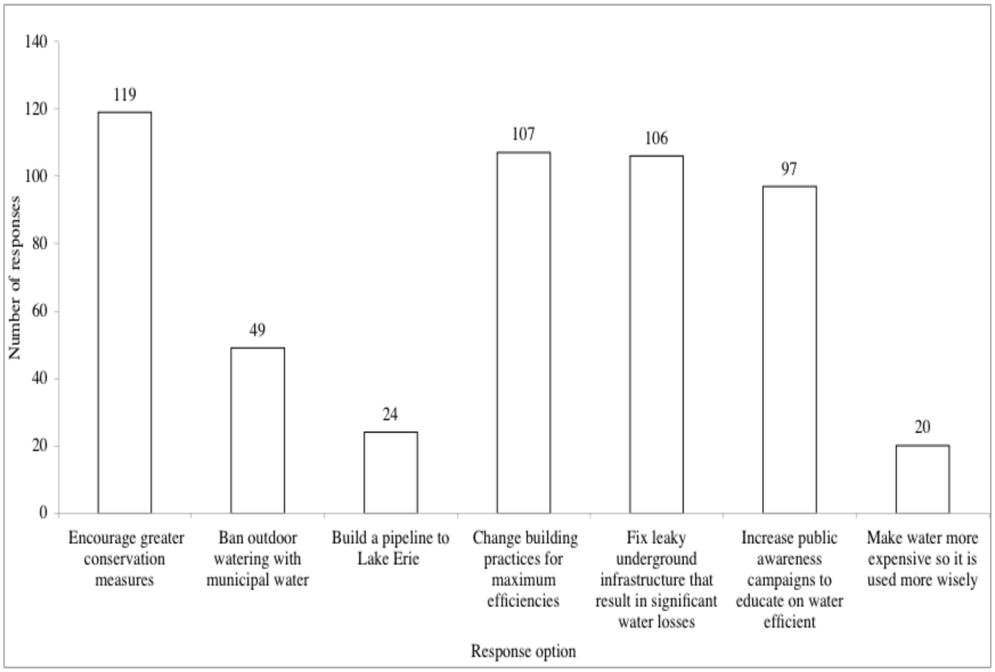



Table 5.5: "Other" Responses to question 38: On how to meet future water needs

| "Other" suggestions for how to meet future water needs | Number of responses |
|---|---|
| Incentives to make efficiency affordable | 7 |
| "Reinstate the practice of installing cisterns in new housing" (Respondent 94). | 5 |
| "Housing should be limited by the water supply instead of endless building of houses" (Respondent 95). | 4 |
| "Cap the population of the Region, allow no more people here. It can be done!" (Respondent 133). | 4 |
| "Organized campaigns" | 3 |
| "Limit use by large companies and establishments using auto sprinklers" (Respondent 78). | 3 |
| "Bill homes that overuse based on number of occupants" (Respondent 118). | 2 |
| "No" to making water more expensive. | 2 |
| "Design grey water systems in new builds and encourage old homes to be renovated so as to accommodate grey water re-use" (Respondent 144). | 2 |
| "Don't know not enough information" (Respondent 116). | 2 |
| "Pipeline to Lake Huron" (Respondent 53). | 1 |
| "Encourage getting rid of front lawns" (Respondent 52). | 1 |
| "Region does not listen I tried to communicate" (Respondent 112). | 1 |
| "Increase penalties for wrong use of water" (Respondent 5). | 1 |
| "Take [water] from the Georgian Bay this is the lowest cost. See reports back 50 years ago" (Respondent 64). | 1 |
| Visible metering to raise awareness about water use | 1 |

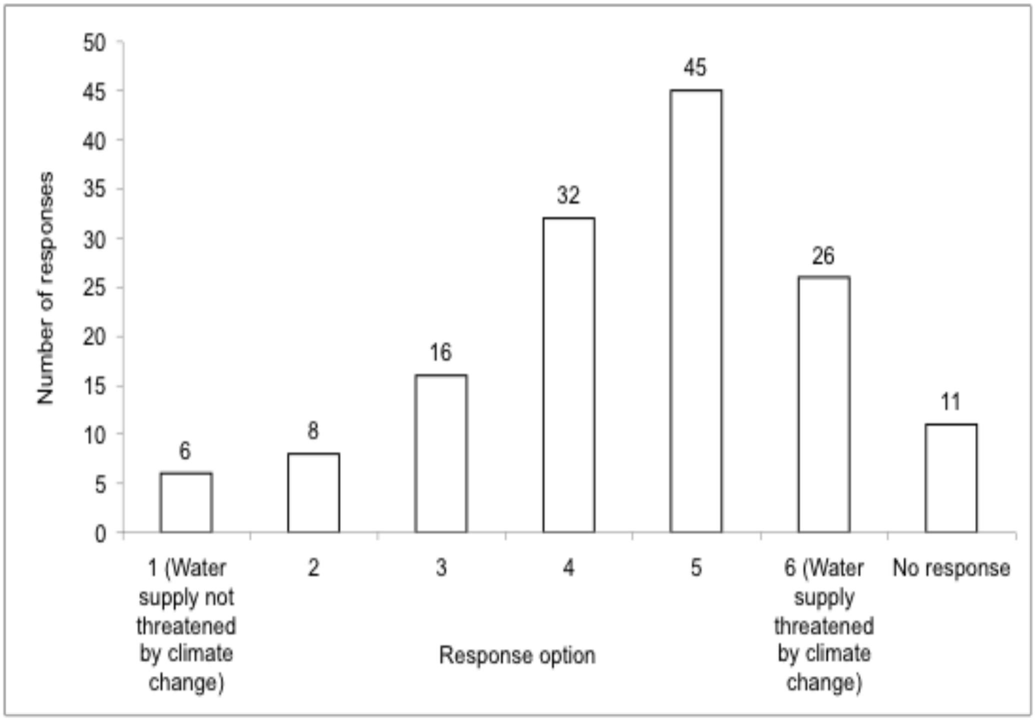
Due to the substantial investment a pipeline to Lake Erie would require, approximately $700 million in 2007 dollars (XCG 2007), and its potential impact on conservation efforts, it was of interest to further investigate respondents' perspectives on the pipeline idea. Question 40 asked respondents if they thought building the Lake Erie pipeline was a good idea. Respondents' tolerance towards the Lake Erie pipeline to supplement municipal water supply varied. Some respondents left the question blank, or wrote in a question mark or included comments indicating their uncertainty. Others indicated a lack of information prevented them from making an informed decision. Of those 126 respondents, 46.8% of responses indicated that relying on a pipeline was not a good idea, whereas 18.3% of respondents thought the pipeline was a good idea. This question did not ask respondents to write in any comments, yet it generated some comments:

- Pipeline idea "is nuts" (bad idea) (Respondent 18).
- "I don't think we need to resort to that [a pipeline]…yet" (Respondent 52).
- "I'm not concerned too much, but I'm sure that it will have to happen" (Respondent 144).
- "Definitely not" supportive of the pipeline (Respondent 56).
- "I don't know" (Respondent 50).

It is interesting that only 18.3% of respondents indicated support for a pipeline to Lake Erie to supply water, despite the strong support for the pipeline by municipal authorities. The lack of support for the pipeline in this survey indicates that municipal officials are planning for the pipeline despite a lack of strong public support. The municipal authorities stress water conservation efforts, but quickly acknowledge the need for a pipeline to supply water in their long-term water supply strategy (XCG 2007) rather than intensifying conservation efforts or exploring other non-conventional options. However, as stated earlier, this study's sample is a relatively small portion of the total population and thus not necessarily representative.

Also of interest were respondents' views on climate change and its implications for local water security. A number of respondents indicated that they "did not know" or were unsure of the answer to this question and did not respond. Just over half of respondents strongly believed water security is threatened by climate change. Comparatively few (about 10%) of respondents indicated they felt climate change did not threaten water security. Overall, there seemed to be a consensus that climate change could threaten the Region's water supply.

Figure 5.7: Responses to question 39: Opinions on climate change and water supply security




It seemed that individuals' tolerance of future planning options was in some ways influenced by their views on climate change (see table 5.6), thus making the relationship between climate change and water security factors for consideration. More than half of respondents who felt climate change threatened local water security did not support the pipeline to Lake Erie. Current supply side management in Ontario relies on finding new sources of water; however, it appears that most respondents who were concerned about climate change's threat to water security reacted by indicating, "we have to make do with less".

Table 5.6: Question 39 and 40: How responses about climate change and water security relate to tolerance for a pipeline to Lake Erie

| Support for pipeline | Climate change's threat to water security | | |
|---|---|---|---|
| | Yes | No | Do not know |
| Yes | 7 | 5 | 0 |
| No | 33 | 6 | 3 |
| Do not know | 4 | 2 | 5 |

Finally, the survey asked respondents if they were concerned that their taxes would increase in order to build new water-related infrastructure. It was thought that any respondents who supported the pipeline would connect the financial reality with these expectations, thus accepting an increase in taxes. However, survey responses did not reflect this perception (see Table 5.7). The majority (57%) of respondents were very concerned about potential tax increases. Those in opposition to the pipeline tended to be concerned about taxes increasing, but the majority of respondents who indicated they supported the pipeline were also concerned about the potential for tax increases. Perhaps this general concern about paying taxes reinforces the idea that no one wants to pay taxes, but also, that there is not necessarily a strong enough connection in the public's mind between new infrastructure and its substantial costs.

Table 5.7: Questions 39 and 40: A comparison of respondents support for the pipeline and concern taxes will increase

| Support for pipeline | Concerned taxes will increase | | |
|---|---|---|---|
| | Yes | No | Do not know |
| Yes | 11 | 2 | 0 |
| No | 31 | 5 | 0 |
| Do not know | 7 | 0 | 3 |

The initial assumption was that those less willing to install a RWH cistern system for outdoor use would be more likely to support the pipeline, but support for the pipeline was about evenly divided for these respondents (Table 5.8). This support indicated that some may understand the need for conservation but do not wish to adopt RWH. Respondents who indicated that they were willing to install a RWH system were less likely to support the construction of the pipeline.

Table 5.8: Question 29 and 39: A comparison of respondents support for the pipeline and willingness to install a RWH system

| Support for pipeline | Willingness to install RWH system | | |
|---|---|---|---|
| | Yes | No | Do not know |
| Yes | 11 | 8 | 2 |
| No | 28 | 10 | 3 |
| Do not know | 5 | 1 | 3 |

The end of the survey included some space for respondents to write in any additional thoughts or comments they wished to express. Respondent 96 inquired about the effect on the hydrologic cycle if there was a mass uptake of RWH and how it would influence the ability of precipitation events to recharge ground and surface water.

Two respondents indicated their opposition to water use regulations referring to them as “draconian” (Respondent 25). Some respondents seemed resigned to the pipeline and appeared to implicitly trust in government projections. As one respondent wrote, “the pipeline to Lake Erie will have to be built anyway, sooner or later; sound planning seems to dictate that it be sooner” (Respondent 25). This type of language indicated a lack of power behind individual action for change or willingness to change behaviour.

### *5.2.6. Additional comparisons*

It was initially thought that households with children, defined here as individuals aged 18 and under, would be less willing to install a cistern, due to time constraints or child-related health concerns. To explore this relationship, half of the surveyed households without cisterns, 65 of the 131 eligible returned surveys, had children. The majority of both groups, meaning respondents with and those without children, indicated they would be willing to install a cistern for outdoor use. Generally, households with children were more likely to identify themselves as willing to install a cistern; three-quarters of respondents with children in the household (51 of 65 or 78.5%) indicated they would be willing to install a cistern, compared to 57.6% (38 of 66) of responding households without children.

Another factor, which might influence the adoption of RWH systems with greater cistern capacity, is the acceptance of rain barrels. Some of the households indicated they already used rain barrels, which met their perceived needs. This indicated that respondents thought that rain barrels were a significant contributor to water conservation. Perceptions’ that reflected a lack of need for non-potable water supply for the house indicated that these homeowners were not planning beyond the current water servicing and quality structures, that is, they accepted the norm that only potable water should be used within the house to meet water demand. Some respondents indicated they would rather move into a house that is already equipped with a cistern to avoid the lawn damage that a retrofit installation would entail.

### *5.2.7. Summary of survey results*

The results of the residential surveys provide considerable insight into respondents’ concerns and perceptions of RWH and future planning for water demands. It was apparent from the survey responses that those households with RWH systems were in the minority. Not much information about the City of Waterloo's cistern pilot project was uncovered but is understandable given the significant time lapse. Despite the small sample sizes, some important themes from the surveys were apparent. Many respondents felt they were not informed enough about RWH to formulate strong opinions about the practice, let alone consider the investment needed for the system. However, respondents overall seemed willing to accept greater RWH efforts. Trust in the rainwater quality was another important perception reflected in by a number of respondents concerns about the health implications of expanding the uses for rainwater to the house. Perceived cost of the systems and potential for interior renovations proved to be consistent barriers identified by potential users.

## 5.3. Analysis of interviews conducted with municipal officials and builders

### *5.3.1. Drivers for RWH*

Discussions with participants emphasized that there are comparatively few tangible drivers to RWH in urban Ontario. Many of the current RWH "motivators" are based on altruistic or philosophical concepts rather than tangible benefits such as monetary savings. Given the current lack of perceived need to conserve water, the current water pricing structure, policy and regulatory guides, there is little motivation or significant benefit to push the adoption of RWH. The current pricing of water, socio-political climate and regulatory structure results in the following few drivers:

1. Environmental altruism: This "green" sentiment or "feel good factor" could be associated with individuals with offspring or concern for the greater future good and was mentioned by a number of participants (Despins 2009, Henderson 2009, Leidl 2009, Paloheimo 2009, Polley 2009). The survey results alluded to environmental altruism, in that those survey respondents who indicated they did not support the pipeline project were more likely to exhibit willingness to install a RWH system than those who supported the pipeline. RWH represents one way in which urban living can start to reintegrate itself into the hydrologic cycle. "It [RWH] reconnects you from the artificial city environment" (Paloheimo 2009). This perspective could is fueled by a belief that it is our (individual and societal) role as stewards of the environment to engage in a more sustainable water relationship.

   Krizsan offered some interesting perspective to this driver of environmental altruism, particularly from a business perspective, which is often aligned with profit maximization. One would think the market's response, the discontinuation of the project, and lack of follow-up would make a builder less inclined to engage in future innovative efforts. However, Krizsan seemed to have an optimistic and positive outlook; "we are going to have some good and bad ideas, we are going to have some false starts, but these are all natural when you innovate and try to come up with better ideas and systems" (Krizsan 2009). Despite the "failure" of the Westvale project, his company has continued to introduce innovative "green" features to their communities (albeit no more residential cisterns). "We have responsibilities in our society, we are stewards of the environment; there are always better ways to do things and unless you have experimented by doing different things, things don't improve. We are stagnating at a certain level" (Krizsan 2009). He cited the industry's large footprint on the environment as an incentive.

2. A more sustainable approach to urban water systems: "[T]he city has become an artificial bubble. We have cut ourselves off from the water cycle [...] we arranged at great expense to be exempt from it, but I think to our detriment. It makes sense to collect rainwater and use that" (Paloheimo 2009). Water systems that mimic the hydrologic cycle and seek to minimize the expansion of large-scale infrastructure reflect a more holistic and integrated relationship between the ecosystem and its dependent users.

3. Public praise: To assist the shift in perceptions and appreciation for alternative decentralized water supply options, public demonstrations and rewards (e.g. a plaque, or community or media exposure) are believed to be important incentives (Henderson 2009, Paloheimo 2009, Polley 2009). "It has to be an incremental step: have peers talking about 'I have this plaque, I am number one builder'; everyone likes to be patted on the back" (Henderson 2009).

4. House certification: Developers or builders who are part of "green" housing certification programs (e.g. LEED, Built Green) would improve their rating with a RWH system installed (Despins 2009).

5. Past experiences: RWH is not considered as foreign, and thus intimidating, to potential users as other more recent innovations such as a greywater reuse systems (Henderson 2009, Leidl 2009). Leidl considered RWH "a good bridge, transition technology of them all, since it already has a higher level of social acceptance (people have rain barrels, all Mennonites have cisterns in their yard, those who grew up on a farm had it)" (Leidl 2009).

There are fewer drivers to RWH in absolute numbers and in tangible benefits compared to the barriers to RWH adoption. Additional drivers to RWH are not abundant due to some of the overarching problems with the current water supply system in Ontario. Despite the sentiment that ideas like RWH is "the right thing to do", the economics do not support it in such a way as to provide motivation (Henderson 2009, Paloheimo 2009, Participant A 2009, Polley 2009).

*5.3.2. Barriers to RWH*

The interviews helped identify and explain a number of the barriers to residential adoption of RWH. Participants from differing backgrounds identified a number of common barriers. Common barriers to RWH were:

- Trust
- Regulations
- Liability
- Cost
- Lack of information or uninformed perceptions
- Building officials
- Location
- Lack of support (standards, also technical and physical assistance for servicing, maintenance and troubleshooting)
- Lack of standardized systems

1. Trust: Many participants cited a lack of trust or a fear of the non-conventional as a significant barrier to RWH (Henderson 2009, Meagher 2009, Paloheimo 2009, Participant A 2009, Polley 2009). For systems to be accepted, users must trust the quality of water captured and stored and ultimately the RWH systems themselves. Multiple participants indicated the Walkerton tragedy increased sensitivity to water quality issues and might negatively influence users' trust in sources, particularly those perceived as non-conventional.

   Questions of trust are present for a number of stakeholders involved in urban water supply. Trust concerns arise from:

   a. The users' perspective (i.e. "do I trust the rainwater enough to use it in my house?") and

b. The regulators’ perspective, since they are the ones who must consider whether or not to permit the adoption or promotion of a product, potentially risking their professional or personal credibility or even legal liability. This subsection brings questions of trust and municipal legal liability together in the following senses: “do I trust that these systems are safe and will not harm the general public?” In addition to, “do I trust that potential users will consistently follow the maintenance and operational guidelines to safely use the RWH systems?”

Two municipal officials interviewed obviously lacked a sense of trust in expanding the uses of rainwater in the house. This lack of trust is understandable considering their role in urban water supply and liability issues if they endorse something that later has negative results.

Within the barrier of trust, some participants identified municipalities as entities with low risk tolerance with unattainable expectations (Ellison 2009, Henderson 2009, Paloheimo 2009). “Government officials have an abundance of caution. Society, as officials interpret it, insists on zero risk, but that is impossible to guarantee” (Ellison 2009). Polley (2009) claimed that builders have low risk tolerance and are very leery of uncertainty. The literature (Mohamed 2006, Toole 1998) supported Polley’s claim, that developers or builders are less inclined to include RWH systems due to liability concerns and for houses built on speculation, concern that not all of the lots with the feature would be sold, i.e. a real risk that the builder will not make his money back (Polley 2009).

2. Regulations: Participants repeatedly mentioned that the Ontario Building Code (2006) was a barrier to the greater application of RWH (Meagher 2009, Paloheimo 2009, Polley 2009, Rapp 2009). The Code is the housing standard that building inspectors work with; “as long as they show they meet regulations, we are not going to get in anyone’s way” (Rapp 2009). Participants explained the Code’s most recent publication severely limited the potential for rainwater indoor use as it stipulates that rainwater can only be used for outdoor irrigation and toilet flushing (Despins 2009, Leidl 2009, Polley 2009, Rapp 2009). One of the builders interviewed indicated he thought the restrictions were inadvertently drafted and will be changed: “the changes in the Code that completely precluded various rainwater uses were completely ‘accidental’ by MMAH; so it wasn’t motivation, it was a lack of understanding of what they were doing” (Polley 2009). Although change is possible, it will not occur until the Code’s next scheduled review, anticipated to be in 2011 (Despins 2009, Henderson 2009, Leidl 2009, Polley 2009).

"To change the Code is like pulling teeth, it can take years to change" (Henderson 2009). Henderson also indicated surprise at the idea that the Code is progressive within Canada: "isn't that frightening? We are progressive?"

The regulations that act as a barrier to the adoption of RWH were instituted to ensure the safety of citizens. A number of participants indentified public health authorities and health-related concerns as particularly strong barriers to RWH as they can influence regulatory openness to innovation (Ellison 2009, Henderson 2009, Paloheimo 2009).

3. Liability: If municipalities participate in an educational or incentive campaign promoting the practice of RWH, the risk of municipal government liability surfaces (Despins 2009, Galliher 2009, Henderson 2009, Leidl 2009, Meagher 2009, Paloheimo 2009, Participant A 2009, Rapp 2009). Despite the fact that a small-scale RWH system would be on the homeowner's property and thus not the responsibility of the municipality, as a broken water main would be, the municipalities still have concerns. If a municipality has promoted or offered incentives for RWH, it could be liable for the consequences of any potential back-flow or cross-contamination of the larger potable water supply due to system failures, a lack of proper maintenance, or user negligence (Henderson 2009, Leidl 2009, Participant A 2009, Rapp 2009).

4. Cost: Participants identified the high cost of the systems relative to cheap municipal water as a significant barrier to the adoption of RWH applications.

5. Lack of knowledge or uninformed perceptions: As Henderson (2009) explained, "people don't know what cisterns are". The lack of understanding about RWH has led to misguided perceptions. "Perception is a problem with RWH rather than scientific issues" (Ellison 2009). This study's survey demonstrated the sample population was generally unfamiliar with RWH and its utility. The possibility of children and pets consuming rainwater from the toilet was a concern raised. It should be recognized that a toilet and anything that has been in it, including potable water, must be considered contaminated from the start, no matter how recently cleaned, therefore the problem is not "potable vs. non-potable" water, but drinking out of the toilet (Ellison 2009).

   A lack of clear understanding of RWH and its value is further complicated by concern for the system's aesthetics, homeowners do not want an "eyesore", which is often considered a deterrent to the adoption of rain barrels given their colour and potential mismatch with the larger house structure (Henderson 2009, Meagher 2009). A number of participants cited international examples of RWH or greywater reuse (Australia, Germany, Britain and some southern United States) as places demonstrating a tolerance for these “non-conventional” water supplies. Ellison (2009) believed that perhaps Canadians do not realize it is a “luxury” to use potable water for non-potable activities.

This lack of understanding is not limited to non-conventional technologies, but includes conventional large-scale water infrastructure as well, perhaps as a result of minimal user interaction with water services since municipal water is monitored and maintained by a few professionals compared to myriad users. Rarely do urban water users have the water-related responsibilities required for a RWH system, particularly an indoor one (Leidl 2009). However, it does not matter whether the system is large scale or small; if water supplies are not properly maintained and monitored, users could get sick (Henderson 2009).

6. Building officials: Many participants identified building code enforcers as potential barriers to the uptake of RWH and expansion of allowed uses of rainwater within the house (Despins 2009, Ellison 2009, Galliher 2009, Henderson 2009, Leidl 2009, Paloheimo 2009). “Building officials are often limiting points in lots of communities regarding the acceptance of innovative projects and practice” (Galliher 2009). Perhaps this stance is further complicated by a lack of knowledge or certified personnel in the installation and up-keep of RWH systems (Despins 2009). One might conclude that if building officials are simply following the building code, then they are not barriers, the code is. However, the building code officials do have some flexibility in making code allowances and should they choose not to allow the use of rainwater beyond code they too are barriers.

7. Location: Some participants believed that rural areas were more likely to accept RWH and a greater use of rainwater in and around the house. Perhaps rural acceptance is because: the housing lots are likely to have more space; greater need; fewer alternatives or less access to potable water; a firmer grasp of the quality level required for specific applications resulting in the ability to justify the cost; or more accommodating building officials (Henderson 2009, Leidl 2009, Polley 2009).

8. Lack of support (standards; also technical and physical assistance for servicing, maintenance and troubleshooting): This lack of support is evident in the lack of comprehensive, objectively based RWH standards or guidance in Canada that users or technical providers can use as benchmarks (Galliher 2009, Leidl 2009). "There is much needed research and standards that are lacking in the Canadian context" (Galliher 2009). Even if clear technical standards within which to work existed, there is a lack of service providers to help users maintain their systems.

   A lack of support extends to municipal bodies as well, since regulatory measures and other municipal efforts to ensure safe use, registration and recording of RWH systems might be beyond municipalities' existing roles, responsibilities and current resources (Meagher 2009). "Indoor use for RWH gets complex enough that it is something to stay away from; with all the rules, codes and inspection schedules you have to follow, that is not an administrative process we are comfortable with right now" (Meagher 2009).

9. Lack of standardized systems: The presence of complete systems on the RWH market would be advantageous for ease of servicing and troubleshooting, particularly while the industry is young in a given area (Leidl 2009). Currently, Waterloo has a business that supplies RWH systems to Southern Ontario. It imports and supplies German systems (Despins 2009, Leidl 2009). Perhaps, if there were local producers, it might help lower the cost of RWH systems, although the German systems are said to be rather refined due to their prevalence and development in Germany (Despins 2009, König 2001).

#### *5.3.2.1. Means to overcome barriers to RWH*

Some participants offered some practical ways to overcome barriers that are expressed below and are arranged according the barriers identified.

1. Trust: One government official interviewed differed from his peers and opined that this fear is misplaced. Legitimate precautions regarding cross-contamination and back-flow must be observed and these efforts should alleviate the fear of municipal water contamination. "Based on what we have seen from the data from the University of Guelph test houses that we have been privy to … it proved what we had already known, that the water quality issues aren't huge. People are scared and it partly has to do with Walkerton" (Meagher 2009).

The builders' experiences offered some important perspective into this trust consideration. Two of the three builders (Paloheimo and Polley) and their families live in houses with a RWH system, amongst other "green" features. The builders constructed their dwellings and rely on rainwater as their potable water supply, implying a significant level of trust in their RWH system. One house (Polley's) is located in a rural location, while the other is in downtown Toronto. Both households had engaged in regular water quality testing in the past, but have since stopped, indicating a level of trust in the water provided by the RWH systems. Because of previous testing that indicated acceptable water quality, they were confident in their ability to monitor and maintain the RWH systems. At the time of the interviews, both houses were at least 10 years old and previous testing of their respective water supplies indicated that they met drinking water quality standards (Paloheimo 2009, Polley 2009).

For two years, the University of Guelph tested the water quality at Polley's house on a bi-weekly basis with excellent results, representing a way to overcome concerns about water quality and the efficacy of treatment. "[O]n every condition of quality for which they were measuring, we had near immeasurable readings, so the water was approaching distilled water quality once passing through our filtration systems" (Polley 2009). Polley's system used slow sand filtration, an active carbon filter ("for taste"), followed by UV disinfection. The residents "purposely ignored" the component manufacturers' instructions for maintenance, "to see what would induce a failure and we still have not managed to get there" (Polley 2009). Polley used this approach so he, as the builder, would know what his clients should experience. Polley's company also does any servicing of the RWH systems that users might not feel comfortable doing themselves, this "expert" servicing might help improve users trust in their systems, given the knowledge that the systems are being properly maintained.

In Paloheimo's case, at the beginning of his involvement with the Healthy House project, he felt he needed to live in the house in case any of the relatively new and untested systems that replaced the need for municipal services encountered problems. The RWH system relied on ozone for treatment. The system initially used UV, but found ozone reduced maintenance demands. Initially there was regular testing of the rainwater, but testing eventually stopped due to cost and the residents' feeling that the system was behaving safely. "You test till you feel safe, then it is a hassle. I will probably do it again when I start marketing systems" (Paloheimo 2009).

2. Regulations: There are some innovative “green” houses plumbed in such a way to allow for a greater use of rainwater in the house than the Code allows, but these systems are “grandfathered in” since the dwellings were built under a prior version of the Code. Paloheimo and Polley’s houses had their potable water supplied by rainwater as permitted by the previous Code. To sell the innovative structure, it would have to be renovated to meet current Code so potable water would no longer be supplied by rainwater (Paloheimo 2009, Polley 2009). Polley and Paloheimo indicated that they had not encountered regulatory barriers or resistance regarding rainwater use in the house before the new Code. “I didn’t find any resistance so I assumed it [RWH system] was fairly typical” (Polley 2009). Also, the building official involved in Polley’s house identified his systems as comparable to the Mennonites’ RWH systems, “and had been employed for centuries without fail, so why not?” (Polley 2009).

   If one desired to build a green house that went beyond Code, the vendor could apply for a permit to expand the uses of rainwater in the house beyond current Code, which might or might not be approved by the municipality (Polley 2009). Some successful, although limited, applications occurred as part of the University of Guelph’s rainwater research test houses. Rapp (2009), the general manager of development services, the department that oversees building permits at the City of Waterloo, did not immediately rule out the possibility of going “beyond what the regulations say is appropriate” (Rapp 2009). He seemed far more hesitant about issues that the Code does not specifically address. However, he did indicate a willingness to engage in discussion and exploration to determine the viability of such a permit. When asked if that was something he would be willing to do despite it requiring extra time and people, he responded with “Yeah, but that is what we do” (Rapp 2009).

   Leidl (2009) indicated that, since the Code approved the use of rainwater for toilet flushing, there should be no difficulty including it, however back-flow protection regulations could be tricky to navigate since there is concern if the property were resold. Municipalities are concerned what future owners might do, since they might not understand the risks of back-flow and unintentionally circumvent the protective devices in place, this results in costly measures and thus greater deterrents for the household.

   > It is a concern, if you sell your house that the purchaser might connect the pipes resulting in a back-flow event. Even if there is an air gap, they want you to put this device on [a supersonic check valve], that will not allow any flow in the other direction, ok for a commercial setting maybe, but for homeowners, it is ridiculous. It is expensive to install and every year you have to get it inspected, so you pay $150 for a plumber to come in, test it and submit the results to the city. [These are] a set of

> regulations established more for the commercial or industrial sector, but due to an absence of anything else, they have applied it to the residential sector. We never had to deal with auxiliary water supply before in the residential sector, always had a pipe (Leidl 2009).

4. Cost: Interview participants indicated that the cost of a RWH system is difficult to justify given current water pricing. The under-pricing of municipal water is a particularly significant barrier if one is already paying, through municipal taxes, for large-scale municipal infrastructure. One could reason that the infrastructure being paid for through taxes would not be utilized if one reduces one's consumption of potable water (Galliher 2009, Henderson 2009, Meagher 2009, Paloheimo 2009, Participant A 2009, Polley 2009).

Polley built his "green" house more out of personal interest and for learning purposes. Paloheimo's experience differed from Polley's in that his house was part of a competition, although he was not involved in the Healthy House project from the beginning. Paloheimo took over the project when it became stalled due to "business problems". The house's original plans were for a small structure "more like a one bedroom apartment", making it more difficult to distribute costs over the dwelling (Paloheimo 2009). To make the project a more practical venture that was more appealing to consumers, the design became a semi-detached dwelling. The land on which the house was built was bought "cheaply" compared to the neighbouring properties since there was no need to pay to have municipal services (Paloheimo 2009). Other urban infill projects might significantly benefit from technologies similar to those in the Healthy House, which allow the house to be "off the grid".

The inability to justify the cost of a RWH system for indoor use is magnified in the case of retrofits. It is far more expensive to retrofit an existing house with a RWH system for indoor uses than it is to include such a system in a new build (Despins 2009, Henderson 2009, Leidl 2009, Paloheimo 2009, Polley 2009). The cost of the cistern itself remains the same, but parallel plumbing must be installed with all its attendant costs, to supply the rainwater. Because it is likely that space for additional pipes would have to be found and some walls rebuilt to accommodate the parallel plumbing, it takes substantially longer to recover the investment for a retrofit, perhaps up to a 20 year pay back period compared to 10 years for new builds (Despins 2009, Henderson 2009, Leidl 2009). Typically, underground cisterns are more expensive since they must be below the frost line (Despins 2009, Polley 2009). Basement tanks exist (Leidl

2009, Despins 2009), but some might consider basement space too valuable in which to put a cistern.

Regulations also influence cost considerations: restricting rainwater uses to outdoors and toilet flushing negatively affects the financial viability of RWH systems and the associated market potential (Polley 2009). The installation of year-round systems is expensive, and if the system can only provide water for very limited uses, it makes that rainwater very expensive, since the cost of the system cannot be spread over a number of potential uses (Polley 2009). Some participants felt that cost was more of a barrier in areas with less water scarcity (Ellison 2009, Henderson 2009, Paloheimo 2009). Participants cited Australia as an innovative leader in RWH, fueled by scarcity.

A disincentive to conservation and RWH systems from the municipalities' perspective is that less water used means less revenue. Water revenues provide the funding necessary to provide water services, maintain infrastructure and fund conservation efforts (Henderson 2009, Meagher 2009, Participant A 2009). Participant A (2009) suggested that it is ideal to plan water service related budgets, including conservation, based on baseline water use and its revenue. Baseline water use represents a relatively constant and more predictable indicator of revenues year-round than seasonal water uses, which change given the climate and local weather (Participant A 2009). Budgeting based on baseline water use would help reduce municipalities' dependence on seasonal water use so they are more likely to accept less water use and resulting lower water revenue.

6. Low risk tolerance: The matter of risk tolerance is interesting. Ellison (2009) suggested that in many aspects of daily life, individuals embark in risk-taking behaviour that could have much more serious negative implications than using rainwater for non-potable activities within the house. Such risk tolerance varies based on perceived acceptable risks; for example, leisure travel was cited as an acceptable risk; yet travel to different locations can expose one to foreign pathogens to which the body is not accustomed and this exposure could be fatal. This line of reasoning is based on risk perception and acceptance, indicating that risk associated with travel or health is more common or acceptable than the introduction of non-potable water into households.

9. Lack of support: One participant used France as an example of a supportive system, where RWH systems are supported and maintained by the system installer or company, resulting in a contract and regular contact with the user to provide continued support for system responsibilities. Ellison (2009) compared France and Australia's RWH situation, where, in the participant's experience, most Australians tend to be "notorious do-it-yourself kind of people" so most people would do their own maintenance rather than rely on an outside source like in France (Ellison 2009).

   Leidl (2009) and Despins (2009) found in their experiences that there is not a clear connection between the provider of RWH systems and the user in Ontario. Perhaps since many of these systems are highly customized across locations with individual components being supported, but not the system as a whole, making troubleshooting and other support efforts difficult to access and information-finding burdensome for the user.

10. Lack of standardized systems: Leidl suggested a stronger RWH market presence would be advantageous in order to distribute responsibility and support users: "complete onus is on the homeowner and there are no real support systems for them. We would like to see a commercial sector where the distributors of cisterns or pumps, etc. have a stronger role in that management, providing technical servicing" (Leidl 2009).

### *5.3.3. Lessons from the Westvale cistern pilot project*

The Westvale cistern pilot project was an innovative attempt to expand the non-conventional local water supply paradigm. However, the opportunity to learn from this example has been essentially lost since it received little attention or follow up despite the fact that it was a "visible demonstration project" (Henderson 2009) with media outreach. McMahon (2007) stated that he was able to access a report detailing builders' experiences. The participants interviewed were unable to supply any documentation about the cistern pilot project. City and regional clerks and the archives department were unsuccessfully approached for such a report. Even a senior municipal water official (Participant A) was unable to access any reports regarding the project. Participant A approached his or her predecessor for information regarding the pilot, but to no avail. "It was even before my predecessor's time, she couldn't provide much information either. I guess they thought that perhaps it was too expensive, not sure, what all the conclusions were. Definitely didn't go anywhere" (Participant A 2009). Participant A indicated that occasionally individuals share information about their RWH efforts. "I have been unable to find any written information, a couple of people have told me about it over the phone. Occasionally, someone will call and live in the home or there was a consultant who talked to me about it years ago" (Participant A 2009). Perhaps the lack of documentation was because the project's lack of success and individuals just wanted it to go away. Such a conclusion fits Galliher's (2009) opinion that a significant shortcoming with governments is "we don't talk of our failures enough", since it could negatively impact future projects, funding and personnel allocations.

The pilot project was a City effort the RMoW supported (Henderson 2009). Henderson worked with the RMoW, through her company Commexus Inc., and essentially acted as its water conservation department from 1982 to 1993. The loss of documentation might have been influenced by internal city politics that accompanied by a new director. Eventually, a permanent, official RMoW conservation department replaced Henderson's consulting company. "[T]he concept of new broom, a new director comes in and past was ok, but we are going to start anew. A lot of the information was lost. It disappeared" (Henderson 2009). Henderson went on to explain that during Commexus' role as the RMoW's conservation expert, their office served as a public library holding all relevant documentation. "When the [new] director came in, he said, 'no, give it all back'. So everything we collected over five years went back [to the RMoW] and then nothing. We are the only ones who have the memories since we were there from the beginning" (Henderson 2009). This information indicates that, at one time, there was documentation regarding the pilot.

Henderson believed that the City of Waterloo and RMoW's support for the non-conventional cistern pilot was motivated by water scarcity. Previously, the Region relied solely on groundwater for supply. Henderson (2009) recalled that 1988 was a long, hot, dry summer, which resulted in citizens using lots of water. The RMoW had yet to finish the Mannheim project (a water treatment plant that also does "aquifer storage and recovery") (Regional Municipality of Waterloo 2000). It seemed to her that the earlier conservation efforts were more of a temporary fix for water shortages until Mannheim was operational rather than being long-term projects to reduce water consumption.

> Then, as Mannheim came on stream, their interest in conservation waned; because it cost a lot of money and it is the revenues that fund conservation, it is a terrible vicious cycle. If you save too much water, then [there is] not enough money [for conservation efforts] and around you go. Later, they picked things up and did more work as the 1990s went on. There was a different head of engineering then and he didn't believe in conservation at all, he cut the program drastically (Henderson 2009).

The City of Waterloo's planning department first conceived the Westvale cistern pilot project in 1989 through its "environment first strategies" (Rapp 2009). Currently, there are few remaining individuals from the department to share their experiences (Henderson 2009, Participant A 2009, Rapp 2009). This difficulty is due to a change in personnel (Henderson 2009, Rapp 2009).

The City of Waterloo worked with developers to install cisterns for outdoor uses. Cisterns were placed under garages so they could provide enough capacity without infringing on the lot. Rapp, now the General Manager of development services for the City, was involved in the pilot but in a junior capacity; he knew of only the Westvale pilot site.

Rapp (2009) recollected that 25% of the houses in Westvale built in the early 1990s had cisterns. The houses with cisterns were the last ones sold since the feature added $5,000 to the cost to build the house and builders passed the cost on to buyers. Buyers were "forced" into purchasing the lots with cisterns if they wished to be in Westvale, as these were the last lots available (Henderson 2009, Rapp 2009). When asked what the builders did to convince the City to terminate the cistern project and any future efforts, Rapp appealed to the logic of the market and a lack of demand for the systems.

> I understand that they [the builders] demonstrated that whether it was a couple of people or not, it [demand for cisterns] just wasn't there. And now we have got 25% of lots sitting with a requirement that people had to spend an extra X dollars to get a home built. That did seem unreasonable, we are not in a communist state, right? We tried and they tried, but there was not uptake at that time (Rapp 2009).

Rapp (2009) also indicated builders are very much attuned to market forces. That is, if there were a demand for a feature, like RWH, builders would gladly meet the demand in order to make a profit. However, since there has not been a demand for RWH systems, there has been no driver for their adoption by builders. "My experience with builders or developers is that, if there is a market, they will provide it. They have no issue with it, they are there to make money as most business, nothing wrong with that" (Rapp 2009).

Rapp (2009) further surmised that most individuals buying in the neighbourhood were first-time homebuyers and would have rather have spent any "surplus" money on aesthetic upgrades for their houses (e.g. hardwood flooring, fire places) rather than obscure "green systems". Henderson (2009) agreed that people were not willing to pay the extra costs associated with having a cistern, but she also believes the builders did not receive adequate support from the municipality to promote successfully an unknown and non-conventional system like RWH.

When participants with knowledge of the Westvale cistern project were asked why they thought the builders were willing to participate in the pilot, many participants struggled to answer. Henderson indicated that Thomasfield Homes was a particularly innovative company. They were the first builders in the area that came out with water efficient fixtures (Henderson 2009).

Krizsan, of Thomasfield Homes, was an invaluable source of information since his direct involvement represented the best link to the Westvale cistern project. Unfortunately, almost 20 years have elapsed since the “failed” project and there was little reason for him to remember details. He recounted that it was the City who initially approached him and requested some, either 25% of the new buildings or 25 houses in the subdivision, have cisterns for outdoor uses. The builders requested the project’s cancellation after two years, probably due to lack of profitability. There seemed to be confusion among participants about the number of builders involved in the initial cistern pilot project. Krizsan (2009) indicated there were approximately three or four builders and sites involved in the RWH pilot project (Krizsan 2009). “There were a number of builders who, after doing this, had some serious concerns: substantial added cost to homes, customers didn’t particularly appreciate them, some concern of children not being able to read ‘non-potable water’. The project did not see itself to fruition” (Krizsan 2009). Participant A knew of the RWH pilot project but thought it was conducted in Kitchener and was unaware of the Westvale location.

When asked about follow-up to the pilot project, Krizsan (2009) indicated he had been disappointed with the lack of it. He surmised that perhaps the timing for the project was wrong as it coincided with an economic downturn; “that whole project just faded away. I felt there was very little follow-up. I do not recall seeing any report, but it was just sort of wrapped up and went away in the night” (Krizsan 2009).

The City of Waterloo and RMoW’s hesitation regarding the promotion of rainwater for indoor use was evident in the interviews. Perhaps after the Westvale cistern project was deemed a “failure”, support for RWH in Waterloo was weakened. It seemed to pick up again through the promotion of rain barrels, but the RMoW and City of Waterloo seem reluctant to encourage greater uses of rainwater in the house. Since the Westvale cistern project, the City of Waterloo and RMoW have taken “baby steps” towards incorporating RWH in the residential setting.

Meagher (2009) and Participant A (2009) mentioned that the RMoW was interested in gathering more information about RWH and potential water savings “without diving in head first” (Meagher 2009), meaning to avoid the installation of underground cisterns or encouraging the use of rainwater inside the house (Meagher 2009, Participant A 2009). The most recent alternative water supply options offered by the RMoW involves a test group established for a range of "giant" aboveground rain barrels. The RMoW will monitor the sizable barrels' (1150 l) use for three years and get user feedback. The Region sees the system as a less risky venture since liability issues are reduced, because rainwater is not being used indoors and the tops of the barrels are sealed off from mosquitoes that might lay their eggs in the barrels. However, this approach has limited year round benefits as these above ground water storage containers are only appropriate for seasonal use, and be drained and stored in the cold weather (Meagher 2009, Participant A 2009). Individuals' participating in the "giant" rain barrel pilot must display interest and some level of commitment to the program. Simple waivers also highlight the RMoW's expectations (e.g. rainwater for outdoor use only) to minimize any liability.

Waterloo's failure to document and learn from the Westvale cistern project contributed to the barriers to the adoption of RWH. Ignoring the project and its outcomes reinforces the practice as being taboo and undermines efforts to increase trust in the systems. Opportunities are thus limited for potential users and municipal officials to become familiar and more knowledgeable of the practice and create best practices to benefit future applications.

#### *5.3.4. The City of Guelph*

During the course of this research, the City of Guelph was repeatedly mentioned as a leader in residential water innovation, particularly regarding their recent efforts to diversify the residential non-potable water supply. Guelph's long-term water strategy offers incentives in the form of rebates for greywater recycling and RWH systems (RMSi 2009). Each year, for the next ten, Guelph expects to offer 20 greywater rebates a year (10 for retro-fits and 10 for new builds) and 20 RWH rebates a year (10 for retro-fits and 10 for new builds) (RMSi 2009: A48, A49). The RWH program will be rolled out in 2010. The greywater system started earlier since there is already an accepted and standardized system on the market, while the RWH systems tend to be custom-built and are less familiar or "tangible". "RWH systems have not been out in the public eye as long (at least as a standardized system). … "Its delivery is not as clean; although there are some RWH projects that have done a lot locally" (Galliher 2009). For further details regarding Guelph, please see the appendix.

Guelph's current approach and actions offer some important lessons that could benefit Waterloo, which, like Guelph, has a number of post-secondary institutions within the City. Waterloo could benefit from the innovative efforts of these institutions through partnerships and collaboration between the university, local builders and municipal officials as Guelph has done (Despins 2009, Galliher 2009, Leidl 2009). Galliher (2009) and Leidl (2009) highlighted the importance of having progressive officials (e.g. the chief plumbing official) in order to accommodate innovation. These innovative officials were guided by hands-on learning provided through the University of Guelph's test RWH sites. It allowed officials to become more accustomed to and thus more comfortable with the systems (Galliher 2009). One much publicized example of RWH that municipal officials worked closely on was a LEED platinum rated house in a conventional Guelph subdivision, constructed by a previously conventional builder (Reid's Heritage Home). Galliher (2009) also suggested that the existing experiences through the City's back-flow prevention programs have given officials relevant experience.

Considering Waterloo's concern for liability, particularly when endorsing efforts that go beyond current Code, Guelph offers an interesting alternative. Galliher (2009) noted "RWH is an old technology, but is taboo in a lot of municipalities today". To overcome this fear and uncertainty, a clear and truthful dialogue with the public and the City clearly acknowledges the systems are not "hands-off technologies". Galliher (2009) stated there would be full disclosure to the participants who will have to sign an indemnity statement, where "legalese is still involved" (Galliher 2009). The statement clearly acknowledges the user's understanding that the system requires maintenance and that the system's water is not of potable quality. The conditions of obtaining the rebate also clearly state the various relationships between user and manufacturer with the City contributing only guidance, education and best practices. "Deficiency responsibilities lie with the producer and/or supplier" (Galliher 2009). For peace of mind, the City will come in, for a period, and test the water quality to ensure they are off to a good start and so the City can then step away. "The City will act as a resource providing high level guidance" (Galliher 2009). The onus will be on participants to choose the system and ensure its proper installation by a qualified plumber in order to receive the rebate.

### 5.4. Summary of results

The compilation of surveys and interviews has clearly identified the main drivers and barriers to RWH in Ontario. It appears that there are currently more barriers than drivers to residential urban RWH. The drivers and barriers are evident in the practical applications and experiences of participating builders and practitioners. Despite the perceived barriers to RWH a number of respondents indicated that more intensive water conservation efforts, like the greater adoption of RWH systems, could delay the construction of the pipeline to Lake Erie (Henderson 2009, Meagher 2009, Participant A 2009, Rapp 2009). However, for this delay to happen, change must occur in behaviours and regulations to encourage alternatives to supply sided solutions. "Personally I think there is an opportunity to (depending on how far we go with RWH, education and other conservation methods) to push it way off further into the future than we have planned or potentially eliminate the need" (Meagher 2009). This chapter recognizes Guelph as an agent of change, by demonstrating that it is possible to adopt more innovative residential water supply practices despite the barriers identified in this study. The drivers, barriers and the example of Guelph serve as important points of reference for individuals and municipalities who seek to encourage local innovation rather than immediately relying on conventional water supply measures. Since tapping ground water or surface water bodies and new infrastructure should be a last resort and avoided. The Region's current approaches to water management and use do not realize very much of the possible potential savings from various conservation strategies.

## 6.0. Discussion and Conclusion

### 6.1. Introduction

The main research question this study sought to answer was: "what are the current and likely future drivers of and barriers to innovation in urban residential water demand management, specifically with respect to the use of cisterns for RWH in mid-sized urban areas, such as the Region of Waterloo?" Additional research questions were: "what is the utility of cisterns as a method of water conservation?"; "what is the level of social acceptability of cisterns as a water conservation method?" and "what is the feasibility of cisterns as a method of residential water conservation?"

The continued reliance on the conventional water supply approach of new water supplies, with minimal expectations for savings from conservation and innovation lead to typical "solutions", such as pipelines to meet demand rather than explore other "soft" options. The current water supply paradigm has resulted in infrastructure systems with a capital investment gap worth billions of dollars and minimal incentives to reduce heavy per capita use. RWH has a substantial history worldwide and offers a strategy to manage some contemporary supply problems for future benefit. To promote a shift in the urban water supply paradigm towards one that is more conserving and sustainability oriented requires that populations pay the true cost of water to realize its' full value. This substantial objective will be a gradual effort that is strongly dependent on political will; some Provincial planning frameworks call for true value pricing to achieve sustainability.

The City of Waterloo took a lead role in residential water innovation with the Westvale pilot project in the early 1990s. Perhaps the perceived lack of success of this project hampered further innovative efforts in the area. After the Westvale project, the City continued with potable water conservation efforts, but with less aggressive strategies thus stunting potential water savings. Despite Westvale early contribution to urban sustainability efforts, the case study was more difficult to investigate than was initially anticipated. It was truly surprising how difficult it was to obtain, from either the City of Waterloo or RMoW, any documentation with respect to the Westvale pilot project. According to McMahon (2007, 2009), there was some sort of documentation to which he had access in 2007. Unfortunately, it was not made available during the research for this study, despite inquiries of a number of City of Waterloo and RMoW sources.

### 6.2. Compatibility of RWH

This study's findings did not significantly deviate from the literature. Household RWH upholds the sustainability criteria mentioned in the literature review (e.g. Gibson *et al*. 2005) in that RWH reduces energy costs and conserves conventional freshwater sources for ecosystem functions and future use. RWH involves at least a partial re-evaluation of the conventional approach to water supply, its infrastructure and our accepted norms as water consumers, as would be expected of a sustainability process (Gibson *et al*. 2005).

This section is organized into two sections. The first section (6.2.1) examines the five characteristics of innovation identified by Rogers (1983) and applies these characteristics to the drivers of and barriers to RWH. The second section (6.2.2) considers the Building Code and the municipalities' influence upon the acceptance of RWH.

### *6.2.1. Diffusion of Innovation and RWH*

Rogers' (1983) descriptions of characteristics of innovation are an important research base for evaluating the likelihood of adoption for RWH within this study's current context. It is noteworthy that each of the characteristics identified by Rogers is not a "Yes/No" situation, but rather a scale, at one end of which is "positive" for diffusion and at the other end "negative". The important consideration is the relative positioning along the scale for each characteristic. Before considering the specifics, it is well to consider the following points: Rogers' characteristics are being evaluated against the current "all water going into a house must be potable" paradigm; and given that sustainability is to be "a challenge to conventional thinking and practice" (Gibson *et al*. 2005:62) RWH challenges this existing paradigm.

The current situation with respect to RWH in urban Ontario is definitely a lack of "positives" according to Rogers' (1983) "characteristics of innovations" (14), thus acting as barriers, as can be seen in Table 6.1.

Table 6.1: Characteristics of Innovation and RWH

| Characteristics of innovation | Positive findings for RWH | Negative findings for RWH |
|---|---|---|
| Relative advantage | Home owner acceptance | |
| | | Perceived cost of systems, technical realities, rainwater quality adequacy |
| | | User involvement- contrast to the existing "hands off approach" of our current water systems |
| Compatibility with existing norms and values | | Resistance to in house non-potable water supply |
| Complexity | | Systems perceived as difficult to operate and maintain |
| Triability | | Substantial early-on commitment |
| Observability | Can be observable in test or demonstration sites | Not easily visible unless direct effort to market the systems. |

The first characteristic is "relative advantage". Based on this research, willingness acts as a driver to the adoption of RWH systems. As the majority water users in single-family houses indicated that using rainwater to supplement, and thus reduce the need for, municipal water supply has a relative advantage over greater use of municipal water and its implications. On the other hand, RWH was viewed as inaccessible considering cost, technical realities, user involvement and the perception that rainwater might not be as clean as it "should" be, given current water supply norms, acting as a barriers. The addition of non-potable sources of water to residences is not compatible with the current water supply paradigm, thus acting as a barrier. Another barrier to RWH emphasized by Roger's is complexity. RWH systems are viewed as complex, and therefore, perceived as difficult to operate and maintain, particularly given a lack of reliable information or technical support. RWH systems lack of "triability" (Rogers 1983:14) represents another barrier to RWH systems, since they require a substantial level of commitment early on again representing a barrier. Rogers' indicated those innovations more visible to individuals are more likely to be adopted. The barrier of early and significant commitment (a lack of triability) of the systems and the importance of observability emphasize the importance of "test sites" as used in Guelph for potential users.

### *6.2.2. Building code and municipal officials*

Section 5.3 identified and explained a number of barriers to the residential adoption of RWH as evident in the interviews. The following Table 6.2 is a brief summary of these barriers; and is broken down into the perspectives of homeowners and building code or municipal officials. Local governments, under the direction of higher levels of government, are planning initiatives for more sustainable communities; however, these efforts can be impeded by local fear of the unknown, liability concerns and complacency. Strategies that encourage sustainability and ultimately result in a population using less are key to provide for more people. Ideally, the exploration of alternative 'greener' household features will make for the construction or retro fitting of houses to create more sustainable housing stock.

Local governments are often unwilling to go beyond the standard building code, due to liability fears. These fears could be heightened by fear of personal responsibility or liability, a lack of information, and the formation of conclusions based on personal perception or is influenced by municipal water practitioners personality type. The limited promotion or existence of successful Canadian urban RWH examples and lack of RWH regulatory frameworks might also contribute to institutional hesitancy in adopting the practice.

Table 6.2: Barriers and perceptions

| Barrier Categories | Homeowners | Building Code/Municipal Officials |
|---|---|---|
| 1. Trust | Do I trust the rainwater to be used in my house? | Do I trust that the systems are safe and will not cause harm? |
| | | Do I trust users to follow maintenance and operational guidelines to ensure safe use of rainwater? |
| 2. Regulations | Beyond Code requires applications to municipality, impact on additional costs, time lost? Rejection of RWH? | Code limits applications to outdoor use and toilet flushing. |
| | | Beyond Code requires applications to municipality, extra resources to handle. |
| | | Public health authorities and health related concerns |
| | | Other regulations: Occupational Health and Safety, CSA Standard |
| 3. Liability | | Permission beyond Code or promotion of RWH resulting in liability for municipality? |
| 4. Cost | Hard to justify, low price for municipal water. | Costs incurred through incentives to promote RWH. |
| | Cost of RWH system. | Costs to start and staff office to monitor and regulate RWH. |
| | Code limits uses, making RWH output more expensive per unit, since fewer uses to spread the cost over. | Less municipal water used results in less revenue. |
| | Higher cost for retrofit. | |
| 5. Knowledge/ understanding | Lack of knowledge. | Lack of knowledge. |
| 6. Risk tolerance | | Low risk tolerance and unattainable expectations. |
| 7. Building officials | | Limiting points in the acceptance of innovation. |
| | | Personal or professional liability |
| 8. Location | Does RWH belong in an urban setting? | Does RWH belong in an urban setting? |
| 9. Support | | |
| a. Standards | Virtually non-existent. | Virtually non-existent, inspires even less confidence. |
| b. Technical | Virtually non-existent. | Virtually non-existent, inspires even less confidence. |
| 10. Standardized systems | Virtually non-existent, making the systems even more isolated. | Virtually non-existent, inspires even less confidence. |

The Building Code is the building industry standard and has significant potential to motivate or hinder innovation. Interview participants noted that the Building Code was a limiting factor with respect to indoor uses of RWH, as were other Acts and regulations (Despins 2009, Ellison 2009, Galliher 2009, Henderson 2009, Leidl 2009, Paloheimo 2009, Polley 2009). Provincial policies exist to help support sustainable change, particularly in the Growth Plan for the Greater Golden Horseshoe (2006). The Ontario government encourages innovative stormwater management, which can include RWH and has the potential to reduce demand on potable water supply. "Municipalities are encouraged to implement and support innovative stormwater management actions as part of redevelopment and intensification" (MMAH 2006: 27). The Provincial endorsement of innovative waste and stormwater management is positive from a municipal driver point of view; particularly if one considers that, the municipality is key in informing and encouraging its electorate to participate in innovative practices. However, this research has indicated that despite the broad Provincial endorsement of innovative stormwater management efforts, urban municipalities thus far have not been active innovators.

The barriers to RWH presented in Table 6.1 and Table 6.2 might initially lead one to think that the adoption of RWH is unlikely. Particularly since the drivers of RWH reviewed in the previous section, do not present a strong list compared to the list of barriers. To this point in the study, possible drivers are more philosophical in nature with few tangible benefits. However, many of the barriers to RWH from a municipal and homeowner's perspective are surmountable.

Efforts to overcome these erroneous perceptions and knowledge gaps towards RWH among citizens and municipal officials would benefit from education or awareness campaigns. The campaigns could inform citizens of the need for changes to the conventional approach to water services, this includes the acceptance of "hard" strategies as "normal". Individuals do not perceive the high cost of "hard" strategies or possible alternatives; a perception reinforced by the low price of water and the perception of water abundance in Ontario. If users were charged the full cost of municipally treated water it would act as an incentive to save expensive potable water and perhaps help counter the fallacy of water abundance, which is not conducive to conservation.

Municipalities have limited funding; water departments' budgets are decreased if less water is used, so less funding might be available for conservation efforts if they are successful. Local government's limitations highlight the importance of a local RWH industry, in pushing innovation forward and developing a service industry to adequately meet users needs.

The lack of a RWH industry is problematic for government and potential RWH users, since there is a lack of visible examples or businesses to provide familiarity, support or maintenance services for systems that people can employ should they feel they themselves are unable to care properly for their system. The lack of support for the systems results in users' sole responsibility for the system despite their lack of experience, hindering adoption. The presence of an industry could also motivate or lobby government and regulatory bodies towards acceptance and regulation of the industry. The establishment of an industry would also encourage the creation of a certification program for technicians. It would help standardize and legitimize the field, its businesses and practitioners, ultimately making the systems' and their use more inviting so users can seek support for these relatively new systems.

## 6.3. Key findings

This section analyzes whether the perceived barriers to RWH identified in this study really do outweigh the practice's positive implications in a significant sense. It is likely that barriers to RWH can be overcome given the numerous examples of successful urban RWH applications worldwide, but, most interestingly from this study's perspective, in Guelph, a similar mid-sized urban area in Southwestern Ontario. Participants identified a number of common themes regarding perceptions of RWH. The majority revolved around the concepts of knowledge, training and understanding regarding RWH. Education or awareness campaigns and supportive economic signals could help overcome many of the barriers this study identified. By acknowledging these barriers and looking for incentives and motivators that encourage the adoption of RWH, as demonstrated in Guelph, greater progress towards more sustainable urban water use can occur in Waterloo.

This research has established there can be a significant difference in willingness to use or encourage urban residential cisterns between potential residential users and regulatory bodies. Based on the surveys, participants were generally willing to consider adopting RWH systems and a greater use of rainwater in the house, although a lack of information acts as significant barrier. However, Waterloo municipal officials who participated in the interviews described a much less enthusiastic attitude towards RWH than potential users. In fact, the most significant underlying barrier to RWH that the surveys and interviews emphasized was a lack of understanding or awareness of RWH systems. This lack of knowledge is widespread, extending to homeowners, builders, trades people, Building Code enforcers and municipal officials. Nobody, whether it is municipal officials, trades people or homeowners, will trust a process or technology that they do not understand.

The survey responses and interviews with participants who did not have practical RWH experience indicated a negative perception of RWH systems in that they are viewed as complex and, therefore, difficult to operate and maintain. Many respondents felt that they lacked familiarity with the systems or "*how-to knowledge* [original emphasis]" (Rogers 1983: 166). Innovations that are more intricate require a greater level of "how-to knowledge"; perhaps the perceived complexity of RWH systems could be alleviated through service businesses that could be employed by users to maintain RWH systems, as one would employ a mechanic to service their car.

To overcome this lack of understanding and trust, an awareness campaign tailored to meet two audiences must occur. These audiences are home occupants and municipal officials. These groups must come to understand the concept of fitting water quality for its purpose. RWH is one example of a strategy to reduce demand on potable water by using harvested rainwater for lower risk activities (Despins 2009, Henderson 2009, Leidl 2009, Paloheimo 2009, Participant A, Polley 2009). The lack of understanding regarding RWH demonstrated in this study is implicitly linked to a lack of awareness or acceptance of the "fit for purpose" approach, so its validity must be explicitly emphasized in partnership with the value or potential of RWH.

#### *6.3.1. Lessons learned from Guelph*

The City of Guelph is an important municipality pushing water innovation in the residential setting. As is evident in their aggressive approach to water conservation in order to accommodate the anticipated increase in population for the area by decreasing per capita water consumption. The first significant lesson learned from Guelph is that very little will happen regarding the acceptance of an innovation without leadership and commitment, which Guelph has demonstrated in recent years and Waterloo has not demonstrated to the same extent in the last 15 years. Guelph has a long-term water strategy with the specific objective of diversifying residential water supply to include non-potable sources. Promotion of innovation will not occur without a similar earnest commitment on paper and in actions. Guelph has shown the importance of partnerships and education when adopting RWH efforts.

Effective education regarding RWH for ultimately a shift in individuals' approach to residential water supply requires more than just passive brochures; demonstration sites can exhibit innovative technologies. Effectively, demonstration sites act as a means of communication. This study supports the importance of "communication channels" (Rogers 1983: 17) within a "social system" (Rogers 1983: 11) also identified by Wolfe and Hendriks *(under review)*. The importance and benefit of information sharing among and by builders, academics and municipalities was particularly evident when examining successful examples of RWH, like Guelph. In addition, this research clearly demonstrated that, for broader adoption of RWH, greater dissemination of information about RWH and the availability of projects for inspected by the public are necessary.

It is probable that both "mass media channels", local social systems or interpersonal channels will be required to publicize RWH; to create awareness, education and "comfort" with the concepts. Interpersonal channels will be of major importance in overcoming the negative rating on Rogers' "triability" scale. Rogers (1983) indicated that "interpersonal [communications] are more effective in persuading" (18). The "visible demonstration projects" e.g. Toronto's Healthy House, Reid's Heritage House (a publicized RWH site in Guelph) have been important environments for interpersonal information sharing by opening innovation to the public for tours and open houses.

Demonstration sites are valuable tools to effectively address this lack of knowledge and understanding in large segments of the population, to ultimately aid in the paradigm shift from conventional residential water supply. Numerous participants demonstrated that practical experience greatly benefited users' comfort level with RWH systems (Despins 2009, Galliher 2009, Leidl 2009, Paloheimo 2009, Polley 2009). Guelph has used demonstration sites to promote innovative technologies by providing "hands on" learning to ensure municipal officials, homeowners and builders are well informed about RWH. Allowing average individuals to become more familiar and comfortable with the concept of RWH, how the systems works, applications of rainwater, built-in safeguards to prevent cross contamination of municipal water, water saving potential and, finally what this means for the larger picture, how RWH helps to accommodate future growth and sustainability efforts is important. Practical experience also allows builders and trades people the opportunity to understand the technical installation, operation and maintenance of the systems, which are perhaps beyond the average homeowner's scope.

RWH in Guelph significantly benefited from the involvement of the University of Guelph. All of the builders and municipal officials indicated, in various ways, the importance of educational institutions in encouraging innovation and building capacity. Polley (2009) and Paloheimo (2009) mentioned the direct involvement of university students and faculty assisting in the initial planning and design of their systems, testing or assisting with practical RWH applications as part of students' degree.

The University's involvement in the Guelph demonstration sites through testing and research contributed to the success of the urban RWH strategy since they provided valuable information, troubleshooting and (non-certified) training for system maintenance workers (Despins 2009, Galliher 2009, Leidl 2009, Polley 2009). The involvement of conventionally-trained experienced builders and trades people in these systems allowed for the application of conventional knowledge to innovative systems; increasing the likelihood, of the builders or trades being willing and able to install or service a RWH system.

The Guelph researchers were able to adjust the systems for maximum to effectiveness while keeping a record of lessons about the systems for future use and best practices given their practical experiences with RWH. By generating information, familiarity, practical experience, best practices and troubleshooting abilities for an innovation, post-secondary institutions can reduce the initial development burden on municipalities and the involved private sector players. Furthermore, participation by educational institutions in supporting the promotion of an innovation will help increase the level of adoption given the greater certainty and local capacity (Galliher 2009, Henderson 2009, Meagher 2009).

The University of Guelph's participation in supporting promotional RWH activities and their expertise helped increase openness to the adoption of RWH locally by increasing the "trust" factor in municipal officials and homeowners. Trust was developed by displaying local knowledge and capacity but also through the University's rainwater quality testing, which indicated that the harvested rainwater was of sufficient quality for lower risk activities. The knowledge base provided by the University's can help develop a local business competence to further promote or create a market opportunity in the installation, operation, maintenance and troubleshooting of RWH systems. The University's significant role in resolving issues of trust by testing rainwater quality and creating a knowledge base is advantageous since the City can utilize this base to support early adaptors RWH for some indoor uses.

Guelph's ability to overcome many of the barriers to innovative water conserving initiatives identified in this research is important to communities that are interested in achieving greater residential water savings but struggle with the perceived barriers. Guelph will be an important example to follow and learn from as other communities in the area seek alternatives to the status quo given ecologic limits.

### *6.3.2. Educating to overcome barriers*

The barriers to RWH as displayed in Tables 6.1 and 6.2 can be related and dealt with together. For example, homeowner acceptance, perceptions of rainwater quality and, ultimately, the provision of in-house non-potable water supply are trust related. Demonstration sites, supported by water quality testing go a long way toward resolving the water quality "trust" issue and improving the relative advantage of a RWH system.

Educational efforts directed at municipal officials and homeowners are important for the advancement of RWH and, ultimately, sustainability efforts. Municipal officials are an important group on which to focus educational efforts, since they are key players in local planning initiatives, strategies, and regulatory enforcement, e.g. the Building Code and what special allowances to the Code are permitted. As a result, the importance of municipal "buy in" or support for RWH was a common theme identified by participants. Local Council is the top of the local authority structure, creating and approving local legislation and plans, and therefore can provide direction and approval with which supportive officials can encourage the adoption and promotion of new and innovative programs (Galliher 2009, Henderson 2009, Leidl 2009, Meagher 2009, Polley 2009). Participants identified municipal officials, particularly Code officials, to be negative influences on innovation and they likely are; although their choices are influenced by the Code and level of support from the entire municipal government (Galliher 2009, Henderson 2009, Leidl 2009, Paloheimo 2009, Polley 2009, Rapp 2009). Building Code Officials, effectively act as gatekeepers as to what can or cannot be done. The strictness of enforcement by municipal officials is connected to issues of liability and risk tolerance. One could argue, a narrow or "letter of the law" interpretation of the Building Code that does not accommodate innovation is effectively undermining Provincial legislation promoting sustainability.

The Guelph example showed that many of the barriers to RWH first identified regarding trust, regulations, liability, cost, knowledge, risk and code enforcers are surmountable. The perceived risks to RWH identified in the surveys and interviews do not seem to be as severe as one might have initially thought. The extent of support by the City of Guelph for RWH combined with the knowledge and understanding that the City's support was valid and that municipal building officials were not compromising their professional opinions or responsibilities has created a more accepting and less fearful approach to RWH.

Paloheimo (2009) and Polley (2009) felt that municipalities should lead in getting the province to liberalize its regime in accordance with the "fit for purpose" concept. Polley (2009) considers municipalities as having "a loud voice", capable of "bring[ing] other partners to the table to influence change to regulations". Paloheimo (2009) mentioned the need for a RWH champion; and indicated that municipalities could be administrative champions. On the other hand, municipal interviewees did not see such "lobbying" as their role at all. One municipal official stated, "I think our general feeling around here, from the commissioner on down, is that it is not really our role to lobby the province on their regulations and rules" (Meagher 2009).

The second important group to focus educational efforts on consists of homeowners, builders and trades people, since they are mutually dependent groups who shape the housing market. The interviews and surveys indicated a lack of understanding regarding RWH. The lack of understanding was particularly evident in respondents' awareness of safeguards emplaced for their safety. It was interesting that respondents were less inclined to include activities such as bathing, laundry or dishwashing as acceptable uses of rainwater, compared to toilet flushing. These activities could use hot water. The literature indicated that rainwater stored in hot water heaters at a temperature between 50-70 degrees Celsius could provide rainwater that meets Australian potable water standards (Coombes 1999, Coombes *et al*. 2000, Despins *et al*., 2009: 20). A number of respondents, who indicated they would be willing to expand their utilization of rainwater, also wrote in the surveys how their use would increase if the rainwater were treated to prevent any type of illness.

A more complete understanding of RWH would help homeowners and other involved parties make informed decisions and start to create a more knowledgeable potential market for an industry to service and develop. If RWH service and support were offered by a system distributor, it would reassure users and provide them practical experience and access to skilled individuals so they might eventually develop the confidence to service their own systems. Exposure to RWH, new demonstration sites and experts provides a way around the problem of lack of knowledge and experience for the average user. The value of practical experience is evident at the individual household and municipal level; for example, Guelph's openness to RWH and greywater systems, particularly for those at the Building Code approval level, was credited to the early and active involvement of some officials in local innovative RWH programs (Despins 2009, Galliher 2009, Leidl 2009).

### *6.3.3. New business opportunities*

The previous paragraph considered the perceived barriers of RWH resulting from the technical realities of the systems, the level of user involvement, the difficulty in systems' operation and maintenance from the point of view of the homeowner. This section looks at the same set of barriers and means to overcome them from the point of view of potential service providers. As pointed out in the previous paragraph, builders and trades people could fill this technical gap for RWH system owners; the questions are what support and what incentives are there or might there be to make this an attractive business proposition.

The establishment of standards and best practices would provide a firmer technical base for trades or other RWH system service providers. Particular attention would be required for the municipal requirements to deal with potential risks regarding cross-contamination; these features would have to be an integral part of the demonstration sites. Builders and trades people have a knowledge base and experience with conventional systems that is applicable to RWH systems (Polley 2009, Paloheimo 2009). This knowledge can be used for a range of services, from installation to offering regular and continued "technical assistance" or "initial help get started" packages for a set time period to providing regularly scheduled operating care and maintenance on an ongoing basis.

This brings us to the point raised above as to the incentives to establish a "market" for RWH, to make it profitable for service providers to establish a business to relieve RWH system owners from the technical burdens associated with their systems. There also must be a "critical mass" of potential business to encourage an industry. The incentive to participate in the market will grow as the demand for RWH servicing grows. Presenting a "chicken and egg" situation where both demand and supply will grow together. The following paragraphs consider some of the incentives that would assist in creating such a demand and supply situation.

The current Building Code restricts the uses of harvested rainwater in the house to outdoor irrigation and toilet flushing. RWH is technically feasible and likely socially acceptable as a tool of residential water conservation for many more applications. For RWH to achieve its full potential and encourage a greater adoption rate, the Code must permit the use rainwater for more residential activities. The municipality plays an important role in accommodating innovation by encouraging future Code changes, by encouraging allowances within the existing Code since municipalities enforce the Code and through pricing.

Price is an important variable that can dramatically influence the significance of drivers or barriers. Price is important to RWH in two ways, first the price of potable water and secondly of RWH systems. Coombes (2005) indicated that the economic benefits of RWH are "dependant on synergies with other strategies" (4). As water rates increase in the City of Waterloo, to reflect the full value of water, as some provincial legislation calls for, it might strengthen the drivers to RWH. If sufficient demand for RWH systems and system servicing packages were established, system prices could be reduced over time through economies of scale or through marketplace competition lowering cost.

Krishna (2005), Rogers (1983) and Vickers (2001) emphasized the importance of offering incentives to encourage the adoption of an innovation. A number of survey respondents indicated an incentive such as tax break or rebate would encourage their adoption of RWH. The success of Guelph's RWH and greywater systems rebate program, confirmed this sentiment, although other factors, like the media, have influenced acceptance as well. Rebates or subsidies have been used in Ontario and around the world as incentives to promote other water conservation technologies, e.g. cities offering rebates for low flow toilets and subsidized rain barrels (Vickers 2001). To encourage the adoption of these more complex RWH systems, a monetary incentive to lessen the initial investment in the systems are necessary. However, as Rogers (1983), Vickers (2001) and the interviews indicated, offering incentives results in the offering body assuming some sort of liability or, at the very least, ethical concern, which can act as a deterrent to offering incentives.

#### *6.3.4. Additional practical lessons*

The builders' (Polley and Paloheimo) practical experiences with residential RWH were valuable and contributed knowledgeable perspective towards the fact that the perceived barriers associated with RWH are really not all that significant since both builders' houses rely on rainwater as the only input of water. The houses are a decade old and have not experienced problems that they or a plumber has not been able to deal with. These individuals possessed familiarity and hands-on experience with these systems, creating a knowledge base that the average person does not have. As a result, troubleshooting or fixing a problem with a RWH system did not come across as a significant barrier to these individuals. The average user does not benefit from such experience and lacks a sense of comfort or assurance in the system and their personal ability to manage it safely and effectively. However, this experience can be developed through familiarity with visible demonstration projects and with users' hands-on experience with their own systems and with the help of experienced persons.

Perceptions that "experienced persons" are difficult to come by are misleading. "Green" efforts are possible without any specific "green" training (Despins 2009, Ellison 2009, Leidl 2009, Paloheimo 2009, Polley 2009; also Wolfe and Hendriks *under review*). It is a matter of applying the technical expertise and competence of organizations and individuals to new, but related applications; essentially applying conventional skill sets to non-conventional systems. The ability to apply conventional trades knowledge in green and innovative residential buildings was evident in the builders' interviews. "Where we could, we would hire people who were more experienced than ourselves, usually in what would have been a conventional substitute, and they would apply the conventional knowledge to the alternative product, if there were some equivalencies" (Polley 2009). This indicates that there is sufficient basic knowledge in the existing trades to develop a RWH servicing industry.

A number of participants in this research indicated that both outdoor and indoor uses of rainwater were necessary to make the economic investment in a RWH system worthwhile (Despins 2009, Leidl 2009, Paloheimo 2009, Polley 2009). Coombes (2005) supported this requirement for indoor and outdoor use, particularly since it is ideal to have frequent drawdown of the tank. However, to permit indoor and outdoor use, there must be a greater focus on acceptance of "fit for purpose" (Coombes 2005), so that users or potential users are comfortable and willing to use rainwater indoors.

## 6.4. Recommendations

RWH is one example of a viable strategy to reduce urban potable water demands and ultimately contribute to a more sustainable society. Information sharing or awareness campaigns are vital to the adoption of RWH or any new effort that seeks to challenge the conventional approach to meet sustainability goals.

### *6.4.1. Practical*

The formation of a standardized RWH system that can be serviced by professionals would alleviate potential user concern about the responsibilities of RWH being beyond the skill set of the average user. If communities around Guelph adopted similar innovative water savings, it could create a "critical mass" or profit potential sufficient to sustain an industry that installs or services RWH systems, while also benefiting from existing local experience and knowledge. Greater acceptance and municipal support for RWH could result in more research and the development of better-standardized RWH systems, possibly inspiring RWH related regulatory frameworks and support.

The following paragraph suggests a way to create this critical mass to develop a RWH industry so that communities in the Greater Golden Horseshoe can benefit from RWH and accommodate growth with minimal infrastructure expansions. Guelph's success with promoting innovative decentralized residential water systems seemed to have been greatly influenced by the University of Guelph's contributions and their ability to inform, educate or answer the questions of local stakeholders including builders, developers, municipal government officials, skilled labour and the general public.

The CMAs of Guelph, Kitchener (includes Waterloo), London and Hamilton are similar in size and are each home to at least one university and community college, which would provide strong hubs for research, monitoring programs and the training of skilled trades. These cities have builders, entrepreneurs, academics, skilled trades and government officials who are key in developing communities that are able to sustainably accommodate anticipated growth. If the communities mentioned above were to all adopt a RWH program or a long-term pilot like Guelph, it could encourage the development of a local RWH industry. Municipal endorsement of the innovation would likely validate it from the public's perspective and make individuals more willing to consider adoption. If local government acted as an information source for RWH and offered a rebate to lessen the cost of installing a RWH it might further prompt adoption; particularly in new houses since it is less expensive or onerous than a retro fit. This type of municipal endorsement might also make the projects more visible and increased the likelihood of adoption.

Implementing RWH projects in the four CMAs of Guelph, Kitchener, London and Hamilton would be beneficial since the combined area has a population of almost two million people within a 75 km radius in an area expected to experience growth (Ministry of Public Infrastructure Renewal (now Ministry of Energy and Infrastructure) 2006). In addition, London is home to the head office of EMCO, a major distributer of a number of systems including plumbing and waterworks for the construction industry. The presence of such a large company might contribute to the development of a standardized system and encourage information sharing within the forming industry.

The provision of information sharing opportunities is key to the adoption of new products. Toole (1998) found that builders, an important stakeholder, considered other industry experts as important information sources. Builders more likely to "adopt high uncertainty, non-diffused innovations were those who considered other builders, in-house testing, and sub contractors to be important sources of innovation" (Toole 1998: 328). Paloheimo (2009) and Polley (2009) reinforced Toole's research by emphasizing the importance of and participation in information sharing and in-house testing with the public, government officials and other builders.

### *6.4.2. Future research*

Future RWH research should continue to follow and examine the innovative RWH efforts that Guelph has undertaken as part of their long-term water strategy. It would be advantageous to research the program's implementation from a municipal perspective, gather user feedback and water savings resulting from the systems use. Ultimately, evaluating the RWH program and process would help inform and encourage effective replications of the project if it is deemed a worthwhile venture. It would be interesting to examine how homeowners' perceptions of the RWH systems developed over the course of the project. It would also be logical to develop some indicators to examine the greater hydrologic impacts of RWH on the surrounding ecosystem.

Observing the uses of RWH systems and water savings is advantageous in order to examine if the presence of RWH systems actually decreases water use. One can postulate a situation where the perceived "free" rainwater water is used heavily. If rainwater from cisterns were used indiscriminately without any concern for efficiency e.g. watering ones lawn everyday, where the contents were frequently lowered to engage the cisterns being refilled by municipal water reducing positive benefits of the practice. By simply assuming harvested rainwater can be used carelessly could result in no reduction in the municipal water used or even, potentially, an increase in water used; as the Jevons Paradox indicates, where increased efficiencies can ultimately lead to an increase in total consumption of a resource (Polimeni & Polimeni 2007, Sorrell 2009).  Such behaviour is beyond the scope of this thesis, but a study of consumer behaviour and attitude to rainwater would be crucial to ensure sustainability.

The interviews and literature suggests that for conservation efforts to be successful there must be a personal or civil willingness to push innovation. Future research could also investigate the relationship of civic willingness to innovation. Something not explored in this research but would be beneficial to further study is individuals' willingness to pay for a RWH system. Perhaps if the RWH systems had an attached cost, it would make the systems less abstract, allowing for participants and researchers to better gauge citizens' actual willingness to adopt the systems and practice.

## 6.5. Conclusion

There is a need for a change in urban water planning and management that reflects natural processes and ecosystems as urban areas continue to grow in Southern Ontario. Sustainability calls for a change from the status quo (Gibson *et al.* 2005), something that urban Ontario's municipalities would benefit from given current strains on water infrastructure and sources; strains which are only expected to increase with anticipated growth. Numerous strategies exist to reduce water consumption; RWH is one option that could help alleviate the need for increased municipal water infrastructure capacity.

To achieve greater water savings, and to delay the need for a pipeline to Lake Erie to supply municipal water, the RMoW must endorse conservation and efficiency efforts that are more rigorous. It is an ideal time to investigate the potential for RWH cistern systems which have greater capacity and potential uses than rain barrels, as the RMoW develops new Official Plans and strategies to meet local fresh water needs. The pipeline to Lake Erie should be considered only once all other efficiency and conservation efforts are exhausted. The adoption of urban RWH would begin the process of challenging the status quo and questioning the current water supply paradigm, ideally while moving towards building sustainable communities.

The barriers to urban RWH are possible to overcome, particularly when one considers the drivers. In fact, the growing numbers of examples of RWH in the developed world indicate that RWH is one example of an important strategy for greater sustainability. The education of homeowners and municipal officials about fitting water quality for purpose is an important means to overcome barriers. Realistic pricing, incentives and technical support for homeowners and their RWH system are also important in overcoming barriers to RWH. The Province and municipalities must work together in their legislation and policy implementation to ensure meaningful efforts to encourage openness to innovation.

The builders interviewed and Guelph's innovative efforts demonstrate that it is possible to implement residential urban RWH as a supply of water for non-potable activities to reduce municipal water withdrawals. Guelph's openness represents change and a willingness to be part of the push for more sustainable living. The ongoing work in Guelph to diversify residential water supply sources will remain an important learning experience for diffusion among the public through effective media; from mass media efforts to reach large segments of the population to more personal outreach efforts for additional individuals impact. Some examples of personal outreach include personal consultations, whether that is at building sites or sales centers for new house buyers or in-house consultations for those interested in retrofitting a RWH system.

**References**


AbdelKhaleq, R. A., and Ahmed, I. A. (2007). Rainwater harvesting in ancient civilizations in Jordan, *Water Science & Technology: Water Supply, 7*(1), 85-93.

Anderson, B. (2009). *Interview proceedings, January 23, 2009*. President of Nexus Inc. (A social marketing company). Unpublished manuscript.

Babbie, E. (2002). "Chapter four: Research design", *Fundamentals of Social Research*, Nelson Thomson Learning: 76-103.

Bakker, K. (2007). "Introduction", *Eau Canada: The Future of Canada's Water*, ed. Karen Bakker. Vancouver: UBC Press: 1-20.

Baruch, Y. (1999). Response rate in academic studies — A comparative analysis, *Human Relations,* 52(4), 421-438.

Brandes, O. and Brooks, D. (2005). *The Soft Path for Water in a Nutshell*. Victoria: POLIS Project.

Brandes, O. and Brooks, D. (2007). Ingenuity trumps hard tech. *Alternatives*, 33(4), 10-14.

Brandes, O., Maas, T., and Reynolds, E. (2006). *Thinking Beyond Pipes and Pumps: Top 10 Ways Communities Can Save Water and Money*. Library and Archives Canada.

Brooks, D. (2005). Beyond greater efficiency: The concept of water soft paths, *Canadian Water Resources Journal*, 30(1), 1-10.

Brooks, D. (2006). An operational definition of water demand management, *International Journal of Water Demand Management,* 22(4), 521-528.

Canada Green Building Canada (CaGBC). (2009). *LEED Canada rating systems: Homes*. Retrieved March 15, 2009, from http://www.cagbc.org/leed/systems/homes/index.php#Rating_system

Canada Mortgage and Housing Corporation. (2010). *Water and Wastewater Management*. Retrieved November 2008 from http://www.cmhc-schl.gc.ca/en/co/maho/yohoyohe/heho/hehoto/wawawama/index.cfm

Canadian Environmental Law Association. (2004). *Canadian Water Legislation FAQ*. Retrieved February 17, 2008 from http://www.cela.ca/faq/cltn_detail.shtml?x=1343.

Canadian Home Builders' Association, National Research Council, and Canadian Mortgage and Housing Corporation. (n.d.). *What will objective-based Building Codes mean for me?* Retrieved November 10, 2009 from http://www.google.ca/search?hl=en&client=firefox-a&rls=org.mozilla:en-US:official&hs=h7v&ei=5OpyS9zrDc20tgfeubGHCg&sa=X&oi=spell&resnum=0&ct=result&cd=1&ved=0CBIQBSgA&q=what+will+objective+based+building+code&spell=1

Canadian Standards Association. (2006). B128.1-06/B128.2-06 Design and Installation of Non-Potable Water Systems/ Maintenance and Field Testing of Non-Potable Water Systems. Mississauga: Canadian Standards Association.

Canadian Standards Association. (2009). *About CSA standards*. Retrieved September 10, 2009 from http://www.csa.ca.proxy.lib.uwaterloo.ca/cm/ca/en/about-csa

Carter, C., Leuschner, R. and Rogers, D. (2007). A social network analysis of the journal of supply chain management: Knowledge generation, knowledge diffusion and thought leadership, *Journal of Supply Chain Management*, 43(2), 15-28.

Clarke, S. 2000, *Recommendations on the Long Term Water Strategy*, Regional Municipality of Waterloo Council Report. Retrieved October 10, 2007 from http://www.region.waterloo.on.ca/web/region.nsf/8ef02c0fded0c82a85256e590071a3ce/e77309912793793c85256c13006a214e!OpenDocument.

Clemens, R. 2010. *Water and Sewer Rate Information for Residents of Waterloo, Ontario, Canada*. City of Waterloo. Retrieved January 3, 2010 from http://www.city.waterloo.on.ca/DesktopDefault.aspx?tabid=389

Cook, C., Heath, F., and Thompson, R. (2000). A meta-analysis of response rates in web- or internet-based surveys, *Educational and Psychological Measurement*, 60(6), 821-838.

Coombes, P., Argue, J. R., and Kuczera, G. (1999). Figtree place: A case study in water sensitive urban development (WSUD), *Urban Water,* 1(4), 335-343.

Coombes, P., Kuczera, G., Kalma, J. D., and Argue, J. R. (2002). An evaluation of the benefits of source control measures at the regional scale, *Urban Water,* 4(4), 307-320.

Coombes, P. (2005). *Rainwater harvesting: Implementation and economic issues*. Toronto: Rainwater Harvesting Workshop.

Coombes, P., J., and Kuczera, G. (2003). A sensitive analysis of an investment model used to determine the economic benefits of rainwater tanks. *28th International Hydrology and Water Resources Symposium,* Wollongong, New South Wales.

Corral-Verdugo, V., Bechtel, R. B., and Fraijo-Sing, B. (2003). Environmental beliefs and water conservation: An empirical study, *Journal of Environmental Psychology*, 23(3), 247-247.

Corral-Verdugo, V., Carrus, G., Bonnes, M., Moser, G., and Sinha, J. B. P. (2008). Environmental beliefs and endorsement of sustainable development principles in water conservation: Toward a new human interdependence paradigm scale, *Environment and Behavior,* 40(5), 703-725.

Corral-Verdugo, V., and Frías-Armenta, M. (2006). Personal normative beliefs, antisocial behavior, and residential water conservation, *Environment and Behavior,* 38(3), 406-421.

Corral-Verdugo, V., and Pinheiro, J. Q. (2006). Sustainability, future orientation and water conservation, *European Review of Applied Psychology,* 56(3), 191-198.

de Loë, R. and Kreutzwiser, R. (2007). "Challenging the status quo: The evolution of water governance in Canada", *Eau Canada: The Future of Canada's Water*, ed. Karen Bakker. Vancouver: UBC Press: 85-103.

De Oliver, M. (1999). Attitudes and inaction: A case study of the manifest demographics of urban water conservation, *Environment and Behavior,* 31(3), 372-394.

Despins, C. J. (2008). *Building capacity for rainwater harvesting in Ontario: Rainwater quality and performance of RWH systems*. University of Guelph, School of Engineering, Guelph, Ontario: University of Guelph.

Despins, C.J. (2009). *Interview proceedings, February 17, 2009*. Unpublished manuscript.

Despins, C., Farahbakhsh, K., and Leidl, C. (2009). Assessment of rainwater quality from rainwater harvesting systems in Ontario, Canada. *Journal of Water Supply Research and Technology,* 58(2), 117-129.

Dey, E. L. (1997). Working with low survey response rates: The efficacy of weighting adjustments, *Research in Higher Education,* 38(2), 215-227.

Diaz Andrade, A. (2009). Interpretive research aiming at theory building: Adopting and adapting the case study design, *Qualitative Report,* 14(1), 42-60.

Dolan, A. H., Kreutzwiser, R., and de Loë, R. (2000). Rural water use and conservation in Southwestern Ontario, *Journal of Soil & Water Conservation,* 55(2), 161-171.

Doon Heritage Site. (2009). *Heritage site tour*, September 2009. Region of Waterloo.

Dupont, D. P., and Renzetti, S. (2008). Good to the last drop? An assessment of Canadian water value estimates, *Canadian Water Resources Journal,* 33(4), 369-381.

Ellison, D. (2008). "Rainwater harvesting and greywater reuse: Examining the benefits and limitations", *Drinking Water Quality Management,* January 28, 2008, Toronto: The Canadian Institute.

Ellison, D. (2009). *Phone interview proceedings, March 12, 2009*. Executive Director of the Canadian Water and Wastewater Association. Unpublished manuscript.

Environment Canada. (2005). *Water Use*. Government of Canada. Retrieved April 1, 2008 from http://www.ec.gc.ca/water/en/manage/use/e_use.htm.

Environment Canada. (2007). *How much do we have?* Government of Canada. Retrieved March 18, 2008, from http://www.ec.gc.ca/water/en/info/facts/e_quantity.htm#canada.

Environment Canada. (2007a). *Municipal water use statistics*. Government of Canada. Retrieved March 18, 2008, from http://www.ec.gc.ca/water/en/manage/use/e_use.htm.

Environmental Commissioner of Ontario. (2008). *"MOE's financial plans regulation for municipal drinking water systems", Getting to K(no)w, ECO annual report, 2007-08*. Toronto: Queen's Printer for Ontario, 90-94.

Exall, K. (2004). Review of water reuse and recycling, with reference to Canadian practice and potential: Applications, *Water Quality Research Journal of Canada*, 39(1), 13-28.

*Fachvereinigung Betriebs- und Regenwassernutzung* e.V. (2001). Translation of DIN 1989-1. Darmstadt, Germany. Retrieved October 10, 2009, from http://74.125.113.132/search?q=cache:rOZoHDB_tQYJ:www.ecoagua.pt/sbo/files/DIN1989.pdf+DIN+1989&cd=1&hl=en&ct=clnk&gl=ca&client=firefox-a.

*Fachvereinigung Betriebs- und Regenwassernutzung* e.V. (2007). *Introduction* (English translation). Retrieved October 10, 2009 from http://www.fbr.de/english0.html.

Falkenmark, M. (2001). The greatest water problem: The inability to link environmental security, water security and food security, *International Journal of Water Resources Development*, 17(4), 539- 554.

Farahbakhsh, K. (2007). *Guelph engineering: rainwater harvesting*. Retrieved November 10, 2007 from http://www.soe.uoguelph.ca/webfiles/khosrow/rainwater.htm.

Fitzhugh, T. W., and Richter, B. D. (2004). Quenching urban thirst: Growing cities and their impacts on freshwater ecosystems, *Bioscience,* 54(8), 741-754.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C., and Walker, B. (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations, *Ambio,* 31(5), 437-440.

Furlong, K. and Bakker, K. (2007). *Water Governance in Transition: Utility Restructuring and Water Efficiency in Ontario*. UBC: Program on Water Governance.

Galliher, W. (2009). *Phone interview proceedings, March 23, 2009*. Water Conservation Project Manager, City of Guelph. Unpublished manuscript.

Geller, E. S, Erickson, J. and Buttram, B. (1983). Attempts to promote residential water conservation with educational, behavioral and engineering strategies, *Population and Environment,* 6(2), 96.

Geller, E. S., Winett, R. A. and Everett, P. B. (1982). *Preserving the Environment: New Strategies for Behavior Change*. New York: Pergamon Press.

Gerretsen, J. (2008). *The Ontario Minister of the Environment's Annual Report on Drinking Water 2008*. Government of Ontario. Queen's Printer for Ontario.

Gibson, R. B., and Hassan, S. (2005). *Sustainability Assessment: Criteria and Processes*. Sterling, VA: Earthscan.

Gleick, P. (2000). The changing water paradigm: A look at twenty-first century water resource development, *International Water Resources Association*, 25(1), 127- 138.

Google Maps. (2009). *Westvale Boundaries*. Retrieved October 2009 from http://maps.google.com/.

Hamlin, C. (2000). 'Waters' or 'water'? - master narratives in water history and their implications for contemporary water policy, *Water Policy, 2*(4-5), 313-325.

Harlan, S. L., Yabiku, S. T., Larsen, L., and Brazel, A. J. (2009). Household water consumption in an arid city: Affluence, affordance, and attitudes, *Society and Natural Resources, 22*(8), 691-709.

Herrmann, T., & Schmida, U. (1999). Rainwater utilization in Germany: Efficiency, dimensioning, hydraulic and environmental aspects, *Urban Water,* 1(4), 307-317.

Hill, C., Furlong, K., Bakker, K. & Cohen, A. (2007). “A survey of water governance legislation and policies in the Provinces and Territories”, *Eau Canada: The Future of Canada’s Water*, ed. Karen Bakker. Vancouver: UBC Press: 369-392.

Juuti, P. (2007). “First innovations of water supply and sanitation, *Environmental History of Water: Global Views on Community Water Supply and Sanitation,* eds. P. Juuti, T. S. Katko & H. S. Vuorinen. London: IWA Publisher: 17-44.

Juuti, P., Katko, T. S., and Vuorinen, H. S. (2007). "Water is the beginning of all: Global water services and challenges”, *Environmental History of Water: Global views on Community Water Supply and Sanitation,* eds. P. Juuti, T. S. Katko & H. S. Vuorinen. London: IWA Publishers: 3-8.

Juuti, P., Katko, T. S., & and Vuorinen, H. S. (2007). “Introduction: Early cultures and water”. *Environmental History of Water: Global views on Community Water Supply and Sanitation,* eds. P. Juuti, T. S. Katko & H. S. Vuorinen. London: IWA Publishers: 11-16

Kay, J. and Schneider, E. (1994). Embracing complexity: the challenge of the ecosystem approach, *Alternatives*, 20(3), 32-37.

Kay, P., Hendricks, E., and Rahman, N. (2007). “Provincial paths: Planning for Ontario’s future”, *Alternatives*, 33(4), 16-17.

Kay, P. and Mitchell, B. (1998). Performance of Israel’s water system under a new master plan: Post-audit and implications for the future, *Water Resources Development,* 14(1), 107-119.

Kenney, D., Goemans, C., Klein, R., Lowrey, J., and Reidy, K. (2008). Residential water demand management: Lessons from Aurora, Colorado, *Journal of the American Water Resources Association,* 44(1), 192-207.

Kirkland, L., Wolfwillow Environmental, and Thompson, D. (2002). "Chapter 4: Analysis of barriers", *Tools for Environmental Management : A Practical Introduction and Guide, ed*. D. Thompson. Gabriola Island, B.C.: New Society Publishers, 60-80.

Koebel, C. T. (2008). Innovation in homebuilding and the future of housing, *Journal of the American Planning Association,* 74(1), 45-58.

König, K. W. (2001). *The Rainwater Technology Handbook: Rain harvesting in Building*. Germany: WiloBrain.

König, K. W. (2005). *Rainwater Harvesting in Germany- Case Studies and State of the Art*. Toronto: Rainwater Harvesting Workshop.

Krishna, H. J. (2005). *Rainwater harvesting in the USA*. Toronto: Rainwater Harvesting Workshop.

Krizsan, T. (2009). *Interview proceedings, March 10, 2009*. President of Thomasfield Homes (residential building company). Unpublished manuscript.

Lee, A. S. (1989). Case studies as natural experiments, *Human Relations,* 42(2), 117-137.

Leidl, C. (2009). *Interview proceedings, February 3, 2009*. Graduate student on the University of Guelph's RWH study. Unpublished manuscript.

Leidl, C. M. (2008). *Building Capacity for Rainwater Harvesting in Ontario: Policy and Economic Considerations*. University of Guelph: Master's Thesis.

Llop, M. (2008). Economic impact of alternative water policy scenarios in the Spanish production system: An input-output analysis, *Ecological Economics, 68*(1-2), 288-294.

Loucks, D. (1997). Quantifying trends in system sustainability, *Hydrological Science Journal*, 42(4), 513-530.

Loucks, D., Stakhiv, E., and Martin, L. (2000). Sustainable water resources management, *Journal of Water Resources Planning and Management,* 126(2), 43-47.

Lundin, M. and Morrison, G. M. (2002). A life cycle assessment based procedure for development of environmental sustainability indicators for urban water systems, *Urban Water,* 4(2), 145-152.

Maas, C. (2009). *Greenhouse gas and energy co-benefits of water conservation*. University of Victoria: Water Sustainability Project.

Mays, L. W., Koutsoyiannis, D. and Angelakis, A. N. (2007). "A brief history of urban water supply in antiquity", *Water Science and Technology: Water Supply, 7*(1), 1-12.

McBean, E., and Motiee, H. (2008). "Assessment of impact of climate change on water resources: A long term analysis of the great lakes of North America", *Hydrology and Earth Systems Sciences,* 12(1), 239-255.

McClenaghan, T. (2008). "Soft path- The provincial perspective", *Soft Path Colloquium,* January 17, 2008. Fergus: Briarhurst Institute,.

McKenzie-Mohr, D. (1999). "Quick reference: Community-based social marketing", *Fostering Sustainable Behaviour*, McKenzie-Mohr & Associates, Retrieved February 18, 2008 from http://www.cbsm.com/ReportsDatabase/Detail.lasso?-KeyValue=105&-KeyField=ID.

McMahon, T. (2007). "Going green in the subdivision", *University of Guelph: School of Engineering*, June 2, 2007, Retrieved October 29, 2007 from http://www.soe.uoguelph.ca/news/housejune07.htm.

Meagher, D. (2009). *Interview proceedings, April 20, 2009*. Communications coordinator of water efficiency for the Region of Waterloo. Unpublished manuscript.

Metroline Research Group Inc. (2005). *Water Efficiency: A Comprehensive Research Study with Residents of Waterloo Region*.

Ministry of Municipal Affairs and Housing. (2006). "Ontario regulations 349/06 and 350/06: Introduction of the 2006 Building Code", *Questions and Answers*. Government of Ontario. Retrieved February 10, 2008 from http://www.obc.mah.gov.on.ca/Page1402.aspx.

Ministry of Municipal Affairs and Housing. (2009). “Provincial policy statements”, *Land Use Planning*. Government of Ontario. Retrieved November 1, 2009 from http://www.mah.gov.on.ca/Page215.aspx.

Ministry of Municipal Affairs and Housing. (2009a). *Municipal Act (2001):* E-laws. Government of Ontario. Retrieved September 13, 2009 from: http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_01m25_e.htm.

Ministry of Municipal Affairs and Housing. (2006). *2006 building code compendium*. Government of Ontario. Building and Development Branch. Toronto]: Queen's Printer for Ontario.

Ministry of Public Infrastructure Renewal. (2006). *Growth Plan for the Greater Golden Horseshoe*. Government of Ontario. Retrieved February 10, 2008 from https://www.placestogrow.ca/index.php?option=com_content&task=view&id=9&Itemid=14.

Ministry of Public Infrastructure Renewal. (2009). *Places to Grow Act, 2005: E-laws*. Government of Ontario. Retrieved September 2009 from: http://www.search.e-laws.gov.on.ca/en/isysquery/3b535c4a-3e5e-454a-b464-f810649d0267/1/frame/?search=browseStatutes&context.

Ministry of the Environment. (2009). *Sustainable Water and Sewage System Act*: E-laws. Government of Ontario. Retrieved September, 13, 2009 from: http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_02s29_e.htm#BK7

Mitchell, V., Deletic, T., Fletcher, B., Hatt, B. and McCarthy, D. (2007). Achieving multiple benefits from stormwater harvesting, *Water Science & Technology*, 55(4), 135-144.

Mohamed, R. (2006). The psychology of residential developers - lessons from behavioral economics and additional explanations for satisficing, *Journal of Planning Education and Research*, 26(1), 28-37.

Morgan, A., Branfireun, B., and Csillag, F. (2004). An evaluation of the contributions of urbanization and climatic change to runoff characteristics in the laurel creek watershed, Ontario, *Canadian Water Resources Journal*, 29(3), 171-182.

Morris, T., Boyd, D., Brandes, O., Bruce, J., Hudon, M., Lucas, B., Maas, T., Nowlan, L., Pentland, R. and Phare, M. (2007). *Changing the Flow: A Blueprint for Federal Action on Freshwater,* The Gordon Water Group of Concerned Scientists and Citizens.

Muldoon, P. and McClenaghan, T. (2007). “A tangled web: Reworking Canada’s water laws”, *Eau Canada: The Future of Canada’s Water*, ed. Karen Bakker. Vancouver: UBC Press, 245-261.

National Research Council. (2009). *Model Code Adoption Across Canada*. Government of Canada. Retrieved April 2, 2009 from http://www.nationalcodes.ca/ncd_model-code_e.shtml.

Northway Map Technology Ltd. (1990). *The Regional Municipality of Waterloo: 1990 Aerial Photography*. The Regional Municipality of Waterloo.

Northway Map Technology Ltd. (1995). *The Regional Municipality of Waterloo: 1995 Aerial Photography*. The Regional Municipality of Waterloo.

Paloheimo, R. (2009). *Interview proceedings, January 20, 2009*. Owner of Creative Communities Inc. Unpublished manuscript.

Paloheimo, R. (n.d.). *The Toronto demonstration house*. Retrieved December, 2008, from http://healthyhousesystem.com/toronto.html

Palys, T. S. (1997). *Research decisions: Quantitative and qualitative perspectives* (2nd ed.). Toronto: Harcourt Brace & Company Canada.

Pandey, D., Gupta, A., and Anderson, D. (2003). Rainwater harvesting as an adaptation to climate change. *Current Science,* 85(1), 46-59.

Participant A. (2009). *Interview proceeding, March 11, 2009*. Unpublished manuscript.

Patz, J. A., Vavrus, S. J., Uejio, C. K., and McLellan, S. L. (2008). Climate change and waterborne disease risk in the great lakes region of the US, *American Journal of Preventive Medicine,* 35(5), 451-458.

Polimeni, J. M., & Polimeni, R. I. (2006). Jevons' paradox and the myth of technological liberation, *Ecological Complexity,* 3(4), 344-353.

Polley, B. (2009). *Interview proceedings, February 17, 2009*. Owner of Evolve Builders (residential builders*)*. Unpublished manuscript.

Rapp, C. (2009). *Interview proceedings, January 15, 2009*. General Manager of Development Services for the City of Waterloo. Unpublished manuscript.

Region of Waterloo. (n.d.). Supply and Distribution Systems, Water Services, Region of Waterloo. Retrieved April 5, 2010 from http://www.region.waterloo.on.ca/web/region.nsf/8ef02c0fded0c82a85256e590071a3ce/33818f93f2f55d328525734800627080!OpenDocument

Region of Waterloo. (2008). Rain barrel distribution program, *Region of Waterloo*. Retrieved December 11, 2008 from http://www.region.waterloo.on.ca/web/region.nsf/8ef02c0fded0c82a85256e590071 a3ce/ef0dac1e32543d6185256b05005a2bfa!OpenDocument.

Region of Waterloo. (2009). Water conservation welcome*, Water Services*. Retrieved January, 10, 2010 from http://www.region.waterloo.on.ca/web/region.nsf/8ef02c0fded0c82a85256e590071a3ce/3e36d166c2b0c9988525731600451fee!OpenDocument

Region of Waterloo. (2010). "Environment", *Region of Waterloo*. Retrieved April 5, 2010 from http://www.region.waterloo.on.ca/web/region.nsf/DocID/DBC716A88FB32633852574570045F198?OpenDocument

Renzetti, S. (1999). Municipal water supply and sewage treatment: Costs, prices, and distortions. Canadian Journal of Economics, 32(3), 688-704.

Respondent 5. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 6. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 15. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 17. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 18. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 20. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 21. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 25. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 52. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 53. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 61. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 64. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 76. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 78. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 87. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 94. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 96. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 100. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 101. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 112. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 116. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 118. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 133. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 139. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 140. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 142. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 143. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Respondent 144. (2009). *Responses from cistern use survey*. Unpublished manuscript.

Reynaud, A., Renzetti, S., and Villeneuve, M. (2005). Residnetial water demand with endogenous pricing: The Canaidna case. Water Resoruces Research, 41(11).

Robinson, J., Francis, G., Legge, R., and Lerner, S. (1990). "Defining a sustainable society: Values, principles and definitions", *Alternatives* 17(2), 36-46.

Rogers, E. (1971). "Social structure and social change", *American Behavioral Scientist* 14(5), 767-743.

Rogers, E. (1976). "New product adoption and diffusion", *Journal of Consumer Research*, 2(4), 290-301.

Rogers, E. M. (1983). *Diffusion of Innovations* (3rd ed.). New York, London: Free Press Collier Macmillan.

Russell, P. (1999), *Case study of potential applications of innovative residential water and wastewater technologies*. Ottawa: Canada Mortgage and Housing Corporation.

Saunders, J. and Weing, M. (2007). "Whose water? Canadian water management and the challenges of jurisdictional fragmentation". *Eau Canada: the Future of Canada's Water*. Ed. Karen Bakker. Victoria: UBC Press, 119-141.

Schwarz, N., and Ernst, A. (2009). Agent-based modeling of the diffusion of environmental innovations -- an empirical approach. *Technological Forecasting and Social Change,* 76(4), 497-511.

Sellinger, C. E., Stow, C. A., Lamon, E. C., and Qian, S. S. (2008). Recent water level declines in the lake Michigan-Huron system. *Environmental Science & Technology,* 42(2), 367-374.

Shields, D., Solar, S., and Martin, W. (2002). The role of values and objectives in communicating indicators of sustainability. *Ecological Indicators,* 2(1-2), 149-160.

Shrubsole, D. and Draper, D. (2007). "On guard for thee? Water (ab)uses and management in Canada". *Eau Canada: the Future of Canada's Water*. Ed. Karen Bakker, Vancouver: UBC Press, 37-54.

Smith, W. J., Jr, and Wang, Y. (2008). Conservation rates: The best 'new' source of urban water during drought. *Water and Environment Journal, 22*(2), 100-116.

Sprague, J. 2007. "Great wet north? Canada's myth of water abundance". *Eau Canada: The Future of Canada's Water*. Ed. Karen Bakker. Victoria: UBC Press: 23-36.

Sorrell, S. (2009). Jevons' paradox revisited: The evidence for backfire from improved energy efficiency. *Energy Policy,* 37(4), 1456-1469.

Spinks A.T., Coombes P.J., Dunstan R.H. and Kuczera G. (2003). Bacterial water quality of rainwater fed domestic hot water systems. *28th International Hydrology and Water Resources Symposium,* Wollongong Australia.

Spinks A., Dunstan H., Coombes P. and Kuczera G. (2006). Urban rainwater harvesting: A comparative review of source water quality. *Water Intelligence Online,* 5(5).

Statistics Canada. (2009). *Household size, by census metropolitan area (2006 Census),* (Hamilton, St. Catharines-Niagra, Kitchener, Bradford, Guelph). Retrieved April 5, 2010 from http://www40.statcan.gc.ca/l01/cst01/famil122d-eng.htm

Statistics Canada. (2009a). *2006 census: CT profile for 0109.02 (CT), Kitchener (CMA) and Ontario*. Retrieved January, 10, 2010 from http://www12.statcan.ca/census-recensement/2006/dp-pd/prof/92-597/P3.cfm?Lang=E&CTCODE=4751&CACODE=541&PRCODE=35&PC=N2T2P4

Statistics Canada. (2010). 2006 Community Profiles, All data: Kitchener, Ontario Census Metropolitan area.

The Union of Concerned Scientists and the Ecological Society of America. (2005). *Confronting climate change in the Great Lakes Region: Impacts on our communities and ecosystems (executive summary)*. Retrieved September 10, 2009 from http://www.ucsusa.org/greatlakes/.

Thomas, T. (1998). “Domestic water supply using rainwater harvesting”, *Building Research and Information*, 26(2), 94-101.

Thompson, D., Kirkland, L., and Wolfwillow Environmental. (2002). "Chapter 3: Analysis of driving forces". *Tools for Environmental Management : A Practical Introduction and Guide*. Ed. D. Thompson. Gabriola Island, B.C.: New Society Publishers, 43-59.

Toole, T. M. (1998). Uncertainty and home builder's adoption of technological innovations. *Journal of Construction Engineering and Management,* 124(4), 323-332.

Toronto and Region Conservation Authority. (2008). *Performance Evaluation of a Rainwater Harvesting System,* Interim Report. Retrieved April 5, 2010 from http://docs.google.com/viewer?a=v&q=cache:-Sj9TsHmPUUJ:www.sustainabletechnologies.ca/Portals/_Rainbow/Documents/Cistern_fullreport_2007_final.pdf+toronto+and+region+conservation+rainwater+harvesting+high+rise&hl=en&gl=ca&pid=bl&srcid=ADGEESgcrDTX5VzlSOD6YCkUNVpZ3A7vWit1-jnflpRDGnYjTwaMWgLUHwWePFaTC089rsUMzsF_M6mMjrdLvJGQzE9U-WcTJ8JEDNhcrgR8FWQUaGXC61eX2c0ppTsz9FsePDrO-pos&sig=AHIEtbRVLju8GwzMHQcwOLFRHenXBak42w

Townshend, A. R., Jowett, E. C., LeCraw R.A., Waller, D. H., Paloheimo, R., Ives, C., Russell, P. and Liefhebber, M. (1997). “Potable water treatment and reuse of domestic wastewater in the CMHC Toronto ‘Healthy house’”. Eds. M.S. Bedlinger, & J.S. Fleming and A.I. Johnson. *Site characterization and design of on-site septic systems* (pp. 176). Fredericksburg, VA: American Society for Testing and Materials.

Vickers, A. (2001). *Handbook of water use and conservation : Homes, landscapes, businesses, industries, farms*. 1st ed. Amherst, Massachusetts: Waterplow Press.

Vuorinen, H. S., Juuti, P. S., and Katko, T. S. (2007). History of water and health from ancient civilizations to modern times. *Water Science and Technology: Water Supply, 7*(1), 49-57.

Waller, D., Mooers, J., Samostie, A., Sahely, B., and Soroczan, C. 1998. *Innovative Residential Water and Wastewater Management*. Ottawa: Canada Mortgage and Housing Corporation.

Water Strategy Expert Panel (WSEP). 2005. *Watertight: The case for change in Ontario's water and Wastewater secto*r, Ontario: Publications Ontario.

Weger, I. 2008. Personal communication, developer in Anguilla. January 8, 2008.

Winkler, R. C. (1982). "Behavioral economics and water conservation". *Preserving the environment: New strategies for behavior change*. Eds. E. S. Geller, R. A. Winett and P. B. Everett. New York: Pergamon Press.

Wolfe, S. 2009. A social Innovation Framework for Water Demand Management Policy: Practitioners' capabilities, capacity, collaboration and commitment. *Society and Natural Resources*, 22(5), 474-483.

Wolfe, S., and Hendriks, E. (Under review). Building Toward Water Efficiency: Canadian Policy Innovation and Education in New and Existing Homes. *The International Journal of Housing and the Built Environment*.

Wolff, G., and Gleick, P. (2002). "The Soft Path for Water". *The world's water, 2002-2003: the biennial report on freshwater resources*. United States: Island Press, 1-32.

XCG. 2007. Region of Waterloo: Water Supply Strategy Report. Volume 1, final report. Retrieved November 2007 from "Downloads":
http://www.region.waterloo.on.ca/web/region.nsf/8ef02c0fded0c82a85256e590071a3ce/385b816b979413bb852573520057cea6!OpenDocument

Yin, R. K. (1994). *Case study research: Design and methods* (2 ed.). Thousand Oaks, CA: Sage.

**Appendix A: Residential Cistern Use Survey**

This survey seeks to gather information regarding attitudes towards the use of cisterns in an urban residential setting. Cisterns are storage containers for rainwater fed by a house's eves troughs. Cisterns are often found underground and typically hold more than a rain barrel. Stored rainwater can be used for indoor and outdoor residential activities. It would be greatly appreciated if the adult(s) responsible for household decisions would please fill out this survey.

**Basic information about you and household:**

1. Total number of occupants in the dwelling: ___________
    i. Number of adults (age 19 and over): ________
    ii. Number of children or youths (age 18 and under): _______

2. Are you the owner of the house you currently live in? Please circle one:

    i. YES    ii. NO

**Characteristics of the house:**

3. Would you describe your house as a single detached home? Please circle one:

    i. YES    ii. NO

4. Does your house have a basement? Please circle one:

    i. YES    ii. NO

5. How many floors does your house have? Please count the basement as one floor. If your house is a split level house please count the number of levels: _____________

6. Approximate size of the house (square feet): _____________

7. Approximately how old do you think the house is? _____________

8. Approximately how long have you lived in the house? _____________

9. Are you the first owner of this house? Please circle one:

    i. YES    ii. NO    iii. NOT APPLICABLE

10. To the best of your knowledge, does your house have a cistern? Please circle one:

    i. YES    ii. NO    iii. DON'T KNOW

If you answered "**NO**" or **"DON'T KNOW"** please jump to question #28 and continue to answer the survey. If "**YES**" please continue with the following question (#11).

*"YES my house has a cistern" (question #10):*

11. Did the builder install the cistern? Please circle one:

    i. YES ii. NO iii. DON'T KNOW

12. Did you install the cistern yourself? Please circle one:

    i. YES ii. NO

13. Have you ever used your cistern? Please circle one:

    i. YES, in the past and presently
    ii. YES, in the past but NOT now
    iii. NO, I have never used my cistern

If you answered **YES** (either i or ii), please briefly describe what the collected water is used for:
____________________________________________________________________________

If you answered, "**YES,** I have used my cistern in the past and presently" (i) please continue with question #14. If you answered "**YES,** I have used my cistern in the past but NOT now" (ii) please jump to question # 26. If you answered, "**NO** I have never used my cistern" (iii), please jump to question # 27.

-----------------------------------------------------------------------------------------------------------

*"YES I have used cistern in the past and presently" (question #13):*

14. On average in the summer how often have you used water from your cistern each week? Please circle one:

    i. 0-1 ii. 2-4 iii. 4+

15. On average in the winter how often have you used water from your cistern per week? Please circle one:

    i. 0-1 ii. 2-4 iii. 4+

16. On a scale of 1 to 6, did the presence of a cistern influence your decision to move into this house?

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| No, the cistern had no influence on my (our) decision to move into the house. | | | | | | | Yes, the cistern was an appealing feature that positively influenced my (our) decision to move into the house. |

17. On a scale of 1 to 6, how useful a feature did you expect the cistern to be when you moved into the house? Please circle the most appropriate response:

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Expected it to be not at all useful. | | | | | | | Expected it to be extremely useful. |

18. On a scale of 1 to 6, how useful have you found your cistern to be? Please circle the most appropriate response:

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Not at all useful | | | | | | | Extremely useful |

19. On a scale of 1 to 6, how satisfied are you with your cistern use? Please circle the most appropriate response:

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Very unsatisfied | | | | | | | Very satisfied |

20. On a scale of 1 to 6, how likely would it be for you to move into another home with a cistern? Please circle the most appropriate response:

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| No, I would not move into a house with a cistern | | | | | | | Yes, I would move into a house with a cistern |

21. On a scale of 1 to 6, how easy is it to **operate** your cistern? Please circle the most appropriate response:

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Very difficult | | | | | | | Very easy |

22. On a scale of 1 to 6 how easy, is it to **maintain** your cistern? Please circle the most appropriate response:

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Very difficult | | | | | | | Very easy |

23. On a scale of 1 to 6, how would you rate the **capacity** of your cistern? Please circle the most appropriate response:

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Cistern capacity is too small | | | | | | | Cistern capacity is too big |

24. On a scale of 1 to 6, what is the variety of uses for the water from your cistern? Please circle the most appropriate response:

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Too few uses | | | | | | | Too many uses |

25. If you could, how would you like to improve your current cistern system?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
_______________________________________________________

Please continue with question # 32.

---------------------------------------------------------------------------------------------------------------

*"YES I have used my cistern in the past but NOT now" (question #13):*

26. Why is your cistern not in use? Please circle all that apply:

i. The cistern wasn't functioning when I moved into the house
ii. Too much work to maintain
iii. Water quality a concern
iv. Easier to just use municipal water
v. Municipal water is cheap
vi. We have plenty of water there is no need to use the cistern
vii. Cistern capacity is too small
viii. Other

_____________________________________________________________________
_____________________________________________________________________
__________________________________________________________

Please continue with question # 32.

*"NO I have never used my cistern" (question # 13)*

27. Why have you never used your cistern? Please circle all that apply:

i. Never thought of it
ii. System was broken
iii. Too much money
iv. Too much work to maintain
v. Water quality a concern
vi. Easier to just use municipal water
vii. Municipal water is cheap
viii. We have plenty of water, there is no need to use the cistern
ix. Other

______________________________________________________________________________
______________________________________________________________________________
________________________________________________________________

Please continue to question #32.

---------------------------------------------------------------------------------------------------------------

*"NO" or I "DON'T KNOW if my home has a cistern (question # 10)*

28. Before this survey had you ever, heard of using rainwater collected in cisterns for home use? Please choose one:

i. YES ii. NO iii. NOT SURE

29. On a scale of 1 to 6, please rate how willing you would be to install a cistern for outdoor use (e.g. watering landscapes, washing cars etc)?

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Very unwilling to install a cistern | | | | | | | Very willing to install a cistern |

30. In your opinion what acts as a deterrent to installing cisterns? Please circle all that apply:

i. Too much money
ii. Too much work to maintain
iii. Water quality a concern
iv. Easier to just use municipal water
v. Municipal water is cheap
vi. We have plenty of water, there is no need to use the cistern
viii. Other ______________________________________________________________
______________________________________________________________
______________________________________________________

31. In your opinion what acts as an incentive to install a cistern? Please circle all that apply:

i. Puts less stress on the water source supplying us
ii. Threatens fewer ecosystems
iii. More independent supply
iv. Use of rainwater on property more accurately mimics natural processes
v. Can be used to recharge underground water supplies
vi. Help reduce demand on existing infrastructure (water supply and stormwater)

Please continue to answer question # 32.

**Water conservation**

32. On the scale below please indicate how important you think that water conservation is:

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Unimportant | | | | | | | Very important |

33. Please briefly explain why you think water conservation is important or unimportant.
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________

34. What (if any) water efficiency and conservation features does your house have? Please select all that apply:

i. Low flow toilet
ii. Low flow shower head
iii. Low flow faucets
iv. Rain barrel
v. Front loading washing machine
vi. Others (list as many as relevant)

___________________________________________________________________________
___________________________________________________________________
___________________________________________________________________________
___________________________________________________________________

**Uses of rainwater:**

35. Would you consider using rainwater in and around the home? Please circle all activities you would be willing to use rainwater for:

i. Landscaping
ii. Outdoor cleaning (e.g. car)
iii. Flushing toilets
iv. Laundry
v. Dishwasher
vi. Showering
vii. Indoor cleaning
vii. Other ____________________

36. For those options above that you indicated you would NOT feel comfortable using rainwater for, please circle all the reasons why you would not be comfortable using rainwater:

i. Too expensive to renovate home to use rainwater indoors
ii. I would not install a cistern just for outdoor use
iii. I already have a rain barrel
iv. Health reasons (afraid water will get myself or my family sick) from disease
v. Health reasons from contamination
vi. Too much work to install
vii. Too much work to maintain
viii. Why bother? We have plenty of water
ix. Not enough information promoting the practice
x. Never really seen it done before
xi. Other
______________________________________________________________________
______________________________________________________________________
__________________________________________________________

**Water and Population Growth**

37. On a scale of 1 to 6, how concerned are you that the Region of Waterloo will be unable to provide for the water needs of the predicted population growth? The growth is estimated to be approximately 40% of the current population by 2031.

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Not concerned at all- the growing water needs can be accommodated | | | | | | | Very concerned the growing water needs will not be able to be accommodated |

38. How should the Region plan to meet the water needs of the increased population in the future (assuming growth is inevitable)? Please circle all that you feel apply:

    i. Encourage greater conservation and efficiency measures
    ii. Ban outdoor watering with municipal water
    iii. Build a pipeline to Lake Erie to take water
    iv. Change building practices to ensure maximum efficiencies
    v. Fix leaky underground infrastructure (pipes, etc.) that result in significant water losses
    vi. Increase public awareness campaigns that educate residents on how to be more water efficient
    vii. Make water more expensive so that it is used more wisely
    viii. Other ideas ______________________________________________

39. On a scale of 1 to 6, how much does climate change threatened the security of our water supply?

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Security of our water supply is NOT threatened by climate change | | | | | | | Security of our water supply is threatened by climate change |

40. On a scale of 1 to 6, do you think building a pipeline to Lake Erie to supply water to the Region is a good idea?

| | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|
| Relying on a pipeline to Lake Erie to supply water is a good idea | | | | | | | Relying on a pipeline to Lake Erie to supply water is a NOT a good idea |

41. On a scale of 1 to 6, how concerned are you that your taxes will increase significantly to build new infrastructure to supply water, dispose of wastewater and manage stormwater?

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Not concerned | | | | | Very concerned | |

Please feel free to add any comments or suggestions you have:

**Additional Demographic Information**

Participants, please circle the most appropriate age range for yourself:

Participant 1:

i. Age 20 to 24
ii. Age 25 to 44
iii. Age 45 to 54
iv. Age 55 to 64
v. Age 65 to 74
vi. Age 75 to 84
vii. Age 85 and over

Participant 2:

i. Age 20 to 24
ii. Age 25 to 44
iii. Age 45 to 54
iv. Age 55 to 64
v. Age 65 to 74
vi. Age 75 to 84
vii. Age 85 and over

This completes the survey. Thank you for your time!

**Appendix B1: Interview Questions for Municipal Officials**

Name:
Date of Interview:

1. **Basic information about the interviewee and their position**
    - Please state the current organization you are employed by and your current position.
    - Approximately how long have you been in your current position?
    - Could you please tell me about your education and how you got to where you are today (brief work history).

2. **Government structure and the interviewee**
    - (*If a municipal official*) Please briefly describe the municipal structure you work within (i.e. upper tier or lower tier)
    - What are the duties and responsibilities of your department?
    - What other regulatory bodies do you interact with? (I.e. other departments, higher levels of government etc).
    - Do you have any experience with rainwater harvesting (in your professional and personal experiences)?
        - If so, please explain.
        - Did you consider this a positive experience? Negative? Why?

3. **Growth and the City/Region**
    - The Region is expected to experience significant growth in the coming years. What in your view will be the greatest challenge for the City/Region in accommodating the expected growth?
        - What do you think the City/Region should focus on (in terms of water supply and stormwater management) to accommodate the expected increasing population?
        - Do you think supplying water with pipes and other "hard methods" is the best/most reliable way to provide for growth? Alternatively, do you think a greater promotion of efficiency and conservation methods ("soft methods") are the best way to meet the demands of growth?

4. **Attitudes towards the use of cisterns**
    - How viable do you think the storage of rainwater in cisterns is for residential indoor and outdoor use?
    - (*If interviewee is involved with approving building permits*). Hypothetically, if you were to come across a building permit to install a cistern system (to be used for outdoor landscaping, cleaning and indoor toilet flushing) how would you respond? I.e.
        - What concerns or other questions would you consider?
        - What types (if any) of special permitting, site visits or additional steps and precautions would have to be done for an application to be successful?
        - Personally, would you be more or less inclined to approve the application?
        - What is your department and government's (municipal/provincial) view on such applications?
        - Would your reaction to the permit to install the cistern system be different if it was a retrofit?
        - What (if anything) could be done to make you more comfortable with the use rainwater stored in cisterns for domestic use?

5. **Other**

- What type of sources (journals, bulletins, networks, associations) do you rely on to stay updated on surrounding communities reactions/plans for expected growth, innovative ideas etc?

**Appendix B2: Interview Questions for experts**

Name:
Date of Interview:

1. **Basic information about the expert and their expertise**
   - Please state the current organization you are employed by and your current position.
   - Approximately how long have you been in your current position?
   - Could you please tell me about your education and how you got to where you are today?
   - What are the duties of your current position?

2. **Experience/knowledge with cisterns**
   - Could you please tell me about how you first became involved in (installing/testing/using etc) cisterns for residential home use?
   - What have your experiences with cisterns in residential use been since?

3. **Cistern feasibility**
   - Do you think harvesting rainwater is a viable means to supplement or reduce reliance on municipal water supply? Why or why not?
   - In your opinion, what activities should or could rainwater be safely used for in the residential setting? And why do you think these uses of rainwater are appropriate?

   **New home construction and cistern feasibility**
   - What is the financial feasibility of installing a cistern system for indoor and outdoor use in a new home that is being constructed? (i.e. approximately how much extra is it going to cost, roughly what is the payback time)?
   - What are the benefits/drawbacks of installing a cistern system (environmentally, financially, are there more requirements and regulatory hoops to jump through when setting up cistern systems? Etc). Please explain
   - What type of (if any) "experts" do you need to install engage when installing the system?
   - How difficult is it to <u>maintain</u> a cistern system?
     - (i.e. what needs to be done and how often)?
     - Can "lay person" do so? Alternatively, will the experts needed to install the cisterns be needed to maintain it as well? If so, approximately what would be the average cost per year for maintenance?
     - Is there any regulatory frameworks/certification one must follow to maintain a cistern system?
   - How difficult is it to <u>operate</u> a cistern system?
     - What type of learning curve is there for "lay" home occupants?

   **Existing home modification (retro fit) for cisterns and feasibility**
   - What is the financial feasibility of installing a cistern system for indoor and outdoor use in an existing home? (i.e. how much extra is it going to cost)?
     - Are these less/more common than installation of rainwater harvesting systems in new homes?

4. **Barriers to cistern use**

- In your opinion what are the significant barriers to widespread adoption of cistern use (rainwater harvesting) in the urban residential setting?
- Do you think these barriers can be over come? If so, how? (What needs to change, what do people (home owners/residents, government regulators) need to be aware of etc).
- I have heard of concern over pollutants in rainwater (e.g. acid rain) how would you responded to this?

**5. Drivers that might promote cistern use**

- In your opinion what are the current drivers/incentives to cistern use?
- How would you "sell" the use and benefit of rainwater harvesting systems to homeowners?
- What could be done to create more drivers for cistern use in the urban residential setting?

**6. Miscellaneous questions**

- How do you see the future in regards to water conservation and efficiency (i.e. new innovations, practices etc) of new residential home building unfolds?
- Do you see other technologies as a more viable means for water conservation? If so why?

**Appendix C: Additional Guelph focused analysis**

C.1. Guelph's progressive efforts

The City of Guelph is quickly becoming a progressive area that is encouraging residents' experimentation and participation with unconventional water supply systems. Participants with experience in RWH in Guelph indicated that the area was fortunate to have "progressive building inspectors" (Despins 2009, Galliher 2009, Leidl 2009). It was emphasized that for progressiveness to occur, it was necessary to have a champion and buy in. "[B]uy-in from a higher level, someone needs to step up to the plate in terms of the liability factor; whether that be the municipality allowing the practice and promoting it or the province changing the building code that allows for some of that" (Despins 2009).

Guelph is certainly "stepping up to the plate" by offering incentives through their long term water strategy. The strategy offers innovative incentives in the form of rebates for greywater recycling and RWH systems over the next ten years (RMSi 2009). The suggested greywater rebate is a "…one time $1000 rebate…" (RMSi 2009: A12). The RWH rebate is to be $2000 (RMSi 2009: A13). Each year, for the next ten years Guelph expects to offer 20 greywater rebates a year (10 for retro fits and 10 for new builds) and 20 RWH rebates a year (10 for retro fits and 10 for new builds) (RMSi 2009: A48, A49). The RWH program will begin 2010, the greywater system rollout started earlier since there is already an accepted and standardized system on the market, while the RWH systems tend to be custom-built and is less familiar or "tangible"(WG). "RWH systems have not been out in the public eye as long (at least as a standardized system). … "Its delivery is not as clean; although there are some RWH projects that have done a lot locally" (Galliher 2009).

Guelph's strategy update listed RWH and greywater systems as uncommon strategies in North America. It cited regulatory and cost barriers as disincentives to their widespread use (RMSi 2009). When asked what encouraged this type of innovations' acceptance, Galliher, Guelph's water conservation manager, highlighted the innovative officials (e.g. the chief plumbing official) and the opportunity for hands-on learning with the University of Guelph's test RWH sites. Allowing the officials to become more accustomed to and thus more comfortable with the systems (Galliher 2009). "The great work at the University is also an important group or 'key partner' for the City of Guelph" (Galliher 2009). This sentiment was supported by Despins and Leidl's positive experiences with the local officials. Galliher (2009) suggested that the existing experiences through the City's back-flow prevention programs have given officials relevant experience. Galliher (2009) noted that "RWH is an old technology, but is taboo in a lot of municipalities today". When asked what has enabled Guelph to move past the taboo factors, Galliher surmised it was Council, city staff, engaged building officials and the community that act as important motivating influences.

The openness of Guelph to innovative accommodate "taboo" systems like RWH and greywater recycling seem to overcome many of the barriers discussed in this research. Naturally, questions of liability and user capability surfaced in the interview with Galliher. Who acknowledged that the systems were not "hands-off technologies". The systems "…need accountability and ownership by the owner of the system. ... The process is not a black box, so its success requires an engaged community or people willing to commit" (Galliher 2009).

C.2. Guelph's market demand

Galliher (2009) believes that once people become more familiar with innovative systems adoption will increase. Early in the program, the greywater rebate surpassed initial expectations. Initially, the rebates were only for new builds and builders had to put people on waiting lists to have greywater systems installed in their new houses. Polley's latest effort in downtown Guelph (to outfit an existing gutted house with greywater and RWH) received media attention. This led to an increase in demand for greywater systems (Galliher 2009, Polley 2009). The media coverage encouraged the public living in existing housing stock, to inquire with Galliher about how they could participate. The demand was evident, so the program's parameters extended to include retrofits (Galliher 2009). Perhaps the City's support aided the systems' popularity as they gave builders "marketing prompts" for buyers.

Galliher (2009) mentioned that unconventional systems creates potential for greater related markets. For example, by providing an "opportunity for business specialization" it acts as an incentive for the industry to create RWH "prefab systems" like the common greywater systems.

C.3. Liability and process

When this researcher asked how the City of Guelph would handle liability concerns regarding the rebates, Galliher (2009) stated that there would be full disclosure to the participants. They will have to sign an indemnity statement, which clearly acknowledges the user's understanding that the system requires maintenance and the systems' water is not potable. "Legalize is still involved" (Galliher 2009). The conditions of the rebate also clearly state the various relationships. "Deficiency responsibilities lie with the producer and/or supplier. For peace of mind, the City will come in (for some period of time) and test the water quality to ensure they are off to a good start so that the City can then step away. The

City will act as a resource providing high level guidance" (Galliher 2009). In addition to contributing guidance, education and best practices, the municipality involved the health department (a common barrier cited by participants). Key to the program's initial success was the education and early involvement of concerned parties.

The onus will be on participants to choose the system and have it properly installed by a qualified plumber. "So the relationship is between the buyer and the manufacturer" (Galliher 2009). Conditions for receiving the rebate from the municipality include: the participation of a qualified plumber, required City components (e.g. air gap) and inspection of the installation by building officials to ensure it is appropriately set up (Galliher 2009). Finally, the presence of the RWH or greywater systems and the need for back-flow prevention will be included on property titles. Ideally, if properties that received the rebates are resold, the new owners will maintain the system, otherwise it would represent a loss (monetarily and in producing water savings) (Galliher 2009).