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GUELPH RESIDENTIAL GREYWATER FIELD TEST FINAL REPORT

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June 29, 2012

This field test was carried out with assistance from the Green Municipal Fund, a Fund financed by the Government of Canada and administered by the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.

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1.0 Introduction

As Canadian communities continue to grow, further demand and competition for our fresh water resources is anticipated. Further compounding these stresses include the evolving impacts of climate change and the uncertainty of water availability resulting from changes to weather patterns. With this in mind, it is imperative that further attention be dedicated to the development of innovative demand management practices to ensure the efficient use and ongoing sustainability of our water resources.

To date, community water supply master planning has commonly followed a potable water source vs. demand matching approach, with other potential water resources, such as wastewater effluent or storm water reuse not gaining a great level of consideration. This practice has largely been the result of Canada's perceived water abundance, however, as competition increases for available fresh water resources, it is anticipated that future local water supply planning studies will come to integrate these water supply alternatives.

Currently, all municipal water supplied to homes and businesses within the Province of Ontario must be potable, i.e., fit for drinking. Under this servicing model and the typical home plumbing orientation, the water we use to flush our toilets is exactly the same quality as the water we use for personal consumption. In looking to potential future water availability issues, the large scale adoption of home-based water effluent reuse technologies (greywater reuse) possesses the potential to offset current home-based household potable water demands by between 15% and 30%[1], to alleviate stresses on current water resources, and to appropriately match water quality to water use. However, regardless of the many perceived benefits of these technologies, the uptake of home-based greywater reuse systems to date has largely been limited to home-based demonstrations due to a general lack of consumer awareness of the technology, high costs of purchase/installation of greywater systems, and the reluctance of homeowners to assume the maintenance activities required with these systems.

Beyond independent uptake of these technologies by individual homeowners, the support and promotion of these technologies amongst Canadian municipalities has also been limited. With the extent of implementation of demand management initiatives being solely based within local community needs and of the influence of local political will, many municipal water conservation programs remain focused on the implementation of more common and cost-effective program alternatives, i.e., the "low hanging fruit". With great potential still present for many such programs (such as low flush volume toilet retrofits) within many communities, and the absence of public awareness and desire for greywater reuse technologies, promotion of residential greywater systems has been largely viewed as a premature program alternative within many municipal water conservation master plan studies. Further complicating uptake of these technologies on a municipal level is the lack of a municipal management framework for such programs and concerns regarding risk and municipal liability. With this in mind, endorsement of such projects (even on an individual home

[1] Actual volume of water saved is dependent on the efficiency of the fixtures within the home.

basis) has been limited by municipal building officials in some jurisdictions due to concerns of public health, even in spite of provisions within the Ontario Building Code enabling the practice of home greywater reuse.

In the midst of all the current barriers and uncertainty regarding promotion and use of this technology, the potential for water savings are undeniable. Few would argue that, as many municipal water efficiency programs begin to reach saturation levels with their "low hanging fruit" measures, the next frontier of water supply will come from innovative technologies such effluent reuse and other non-potable water systems. However, in absence of current financial drivers and clear local climate change adaptation and mitigation targets, the appetite for such initiatives remains stagnant. Although other areas of the world have determined the necessary policy and service format models to implement these technologies, there continues to be a deficit of knowledge and capacity for such frameworks within the Province of Ontario. With this in mind, it is essential that further research be conducted to assess the feasibility of available technologies, and to promote capacity building in this area to ensure the efficient use and sustainability of our current and future water resources.

City of Guelph Community Water/Wastewater Servicing Planning and Support for Effluent Reuse

The City of Guelph strives to be a leader in water conservation and efficiency. As one of Canada's largest communities reliant solely on a finite groundwater source for its drinking water needs, the City's ability to reclaim precious water and wastewater servicing capacity through conservation initiatives offers numerous benefits. In looking to water supply capacity, community conservation programming offers water resource sustainability and financial competitiveness of the City's water utility while meeting the water resource needs of significant community growth – an anticipated additional 50,000 persons by 2031 (Ontario Places to Grow Plan). Furthermore, when looking to wastewater servicing, as the assimilative capacity of the Speed River (the City's sole location for treated wastewater effluent discharge) to accept increasing amounts of treated wastewater effluent is limited, the ability to reduce the volume of liquid wastewater requiring treatment offers ecological benefits to the Grand River Watershed as well as similar financial benefits to the City's wastewater utility when looking at potential avoided community infrastructure investment through optimization and reduced operational costs for the utility.

In 2006 Guelph City Council endorsed the *Water Supply Master Plan (WSMP).* This detailed Master Plan evaluated the water demand associated with projected growth over a 50 year planning horizon, as well as alternative sources of new water supply. Water conservation was identified as the most cost-effective and immediately available source of new water supply and was ranked as the #1 priority through this plan. The WSMP included three reduction targets based on 2006 daily water production volumes:

- Reduction of 10% (5,300 m3/day) in average day water use by 2010;
- Reduction of 15% (7,950 m3/day) in average day water use by 2017; and
- Reduction of 20% (10,600 m3/day) in average day water use by 2025

Both the *2007 Community Energy Initiative* and the *2007 Council Strategic Plan* set sustainability performance goals of using "*less water and energy per capita than any comparable Canadian city*." These goals continue to guide the City's current water conservation activities and bring greater emphasis to the relationship between water supply, wastewater treatment, and energy demand.

To achieve these targets City staff initiated the *Water Conservation and Efficiency Strategy (WCES) Update* in February of 2008. This award winning 10-year strategy was endorsed by Council in May 2009 and identifies the preferred program, policy, and resource recommendations to achieve a further reduction of 8,773 m^3/day by 2019, as well as to achieve the aggressive reduction targets of the *Water Supply Master Plan, Water and Wastewater Master Servicing Study, Wastewater Treatment Master Plan, Community Energy Initiative,* and *Council's Strategic Plan*.

Through development of the WCES it was noted that many long standing local municipal water conservation programs, such as toilet or clothes washers retrofit rebates, would reach saturation within the existing housing sector by the end of the 10 year planning horizon of this strategy. Therefore, in meeting the long-term targets of the City's Water Supply Master Plan further capacity development was required in the research and evaluation of new demand management alternatives. As part of public consultation completed through development of the WCES strong public and political support for centralized demand substitution approaches, including greywater reuse and rainwater harvesting, was expressed. With this in mind, pilot programs for home-based greywater reuse and rainwater harvesting programs were approved by Guelph City Council as part of the final strategy to further investigate these technology alternatives and build the necessary technical and social capacity for future readiness of these alternatives.

Beyond the evaluation of centralized home-based greywater reuse systems as recommended through the WCESU, the City's 2006 Water Supply Master Plan, 2008 Water and Wastewater Servicing Master Plan, and 2009 Wastewater Treatment Master Plan also began exploring demand substitution from a communal approach. Through these plans the introduction of a communal effluent reuse system is discussed conceptually through the introduction of enhanced wastewater treatment and distribution of treated effluent to customers within the City's urban boundary. Although these Master Plans do anticipate a benefit associated reducing water/wastewater demands and avoiding related capital/operation requirements, key challenges facing implementation of a communal effluent reuse system include the absence of necessary infrastructure design/legislative frameworks for such systems in Ontario, thresholds to the amount of effluent which could be reused in maintaining the necessary assimilative capacity of Speed River (to which treated wastewater is currently discharged), as well as defining the necessary customer base to support significant capital investment and ongoing operation costs of such a utility. With reference to these ongoing challenges, the City's Wastewater Treatment Master Plan recommends completion of an Urban Reuse Study within its initial 10-year forecast to further evaluate the technical feasibility and proposed viability of a communal effluent reuse utility within Guelph.

Guelph Residential Greywater Reuse Field Test

In May of 2009 the City of Guelph initiated the Residential Greywater Reuse Field Test to assess the feasibility of large scale adoption of home-based greywater reuse technologies. The study set a target of installing greywater systems in a total of 30 homes (both existing and new homes)to assess system performance in real world environments. Five core areas of study were chosen by the project team, including:

- System Operation and Performance
- Homeowner Satisfaction
- Household Water Use Monitoring
- Municipal Management Frameworks and Required Support Networks
- Premise Isolation Device Requirements

To solicit participation in the study, City staff completed consultations with interested members of the Guelph and District Home Builders Association in late 2008. As a result of these consultations, three local home builders, Fusion Homes, Reid's Heritage Homes, and Evolve Builders Group, agreed to participate in the field test and to market residential greywater reuse systems to their clientele.

To promote uptake of technology, Guelph offered an incentive of $1500 to the home builders for each greywater system installed in a new home, and $1500 to home owners that installed an approved system in their existing home. The program was initially marketed through a variety of public education and media outlets, including promotion of the greywater brochure at various public outreach events in the City of Guelph, advertisements in the local newspapers, and through the City of Guelph's website—all intended to increase public education, awareness, and promotion of the program.

Program participants were also provided with backflow prevention (premise isolation) devices as well as financial compensation towards the annual testing of these devices over a five-year period. As of completion of this report, the pilot study had a total of 25 participants, including ten new homes and fifteen existing retrofitted homes. In exchange for receiving the incentives identified above, participants had to agree to allow City representatives to monitor the water quality of the greywater produced by their system on a monthly basis for a period of 12 months, with a single final water quality sample to be taken 24 months after system installation. Additionally, participants were requested to provide feedback through social feedback forums, interviews, and surveys to share their experiences and feelings towards the technology.

For reference, additional information regarding Guelph`s Residential Greywater Field Test may be found at www.guelph.ca/greywater.

Greywater Field Test Project Team

A multi-stakeholder project team was established to direct the development, implementation, and evaluation of the study. This project team included local representatives from academia, the home building and home industry, water efficiency engineering consultants, and City staff. The project team is identified below:

Academia:

- Matthew DeLuca, M.Sc., University of Guelph
- Khosrow Farahbakhsh, Ph.D., P. Eng., University of Guelph
- Benjamin Kelly, Ph.D., Nippissing University

City Staff:

- David Auliffe, City of Guelph
- Wayne Galliher, A.Sc.T, City of Guelph
- Jennifer Gilks, M.Sc., City of Guelph

Home Builders:

- Andy Oding, Reid's Heritage Homes
- Ben Polley, Evolve Builders Group
- Ron Thompson, Fusion Homes

Professional Engineering Consultants:

- Bill Gauley, P.Eng., Veritec Consulting Inc.

The City of Guelph would like to thank the members of project team and their respective organizations for their great significant contributions and overall value added to the Guelph Residential Greywater Field Test.

Federation of Canadian Municipalities Green Municipal Fund

In December 2008, Guelph received notice from the Federation of Canadian Municipalities (FCM) that $72,524 in grant funding was to be provided through FCM Green Municipal Fund for the Guelph Residential Greywater Reuse field test. FCM's gracious financial support has provided the necessary resources for the City and project team to effectively evaluate the social, economic, and environmental impacts associated with implementing home-based water reuse technologies as well as the considerations in establishing the appropriate municipal management frameworks for home water reuse technologies. The City of Guelph would like to sincerely thank FCM for their support of this initiative and it is hoped that the findings of this study will help to build further capacity and continue dialogue on water reuse amongst communities across Canada. For more information on the FCM Green Municipal Fund please visit: www.fcm.ca.

2.0 State of Home Greywater Systems

2.1 Water Reuse Classifications

Domestic greywater reuse involves decentralizing wastewater treatment. This practice can reduce water and wastewater treatment demands but increases the involvement of individual home/property owners in the management of their water resources (van Roon, 2007)(Rygaard, Binning, & Albrechtsen, 2010). Through this service model the challenge remains in ensuring public safety, the reliability of greywater reuse systems (GWRS), and managing new responsibilities at the homeowner, regulatory, or governmental levels.

To help manage these challenges, regulatory level codes and standards are commonly used to define the desired construction standards and the approved end uses of greywater to ensure system reliability and protection of public health.

In Canada, regulations have only recently been formed to address greywater reuse practices. For example, the 2006 Ontario Building Code (OBC) specifies that particulate free storm sewage (including household greywater) may be used for toilet or urinal flushing as well as the priming of floor drain traps. However, in other areas of the world where greywater reuse has been more widely practiced, extended end uses of greywater (such as outdoor irrigation) are allowed provided necessary water treatment standards have been met to safeguard public safety when the potential for increased direct personal exposure to greywater is anticipated (such as public sports fields irrigated by treated wastewater effluent). As an example within North America, the US Environmental Protection Agency delineates different categories of wastewater effluent quality and subsequently directs applicable treatment approaches to manage risk associated with public and environmental exposure within each categorization. These effluent quality categorizations are included below for reference:

- **Unrestricted Urban Reuse & Recreational Use** - Unrestricted refers to the contact the general public will have with water treated to this quality. This category would include the irrigation of parks and sports fields, fire protection, decorative fountains, and urban uses such as toilet flushing.

- **Restricted Urban Reuse** - This category restricts use of reclaimed water to activities that result in no contact with the general public or where the areas affected are restricted from the general public. This level of water quality could be used for private landscape irrigation, municipal works uses, such as street cleaning and sewer flushing, and for construction purposes, such as site dust control and concrete making.

- **Industrial Reuse** - Industrial uses of reclaimed water varies based on the requirements of the industry, this could include the use of reclaimed water for equipment washing, cooling towers, stack scrubbing, boiler feed, and process water.

- **Groundwater Recharge** - Groundwater recharge is used to ensure a stable, high quality ground water supply. This process requires reclaimed water of a high quality to be pumped into a holding area, where it is allowed to infiltrate into the water table below, replenishing the ground water supply.

2.2 Technology Approaches

The implementation of greywater reuse systems can occur through both decentralized (site based) and communal approaches. Communal systems have been seen in many areas of the world where issues relating to water scarcity have been experienced, such as within the southern US, Australia, and Israel. In comparing communal and decentralized greywater systems, there are obvious benefits and drawbacks for the implementation of both.

Table 1: Pros and Cons of Decentralized and Communal Greywater Reuse Systems

Decentralized Systems	
Pros	**Cons**
• Low cost • No need to stage timing of other infrastructure removal • Technology exists and is available	• Performance dependant on homeowners' maintenance • Lack of controls for municipality – Can't know the details of each individual home • Technology readiness and uptake • Social acceptance
Communal Systems	
Pros	**Cons**

• High level of automation
• Controls in place
    – Quality and quantity
	• High capital cost initially
	• Does a customer base exist?
	• Lack of standards
	• Feasibility
	    – Portion of treated wastewater which could be utilized

The Guelph Greywater Reuse Field Test selected decentralized home based systems as the preferred servicing approach due to the low cost of implementation (compared to communal models) as well as the local availability of technology and associated expertise. In compliance with local building codes, these systems aimed to reclaim only shower water within the home for later treatment and use in satisfying household toilet flushing demands. As a result, this approach was also preferable as it limited the direct exposure of the public to the treated greywater source, in accordance with the EPA Restricted Urban Use classification noted above.

In concert with the field test, the City also continues to consider other servicing options for effluent reuse in recognition of local resource limitations and anticipated community growth. In October 2011, an environmental assessment was conducted for a large trunk sewer through which feasibility assessment of a communal effluent reuse or a "purple-pipe" system to be installed in parallel with truck sewer was conducted. The technical memorandum to this report evaluating the "Purple Pipe System", entitled "York

Trunk Sewer and Paisley-Clythe Feedermain Municipal Class Environmental Assessment", can be found in the Appendix A of this report.

With reference to decentralized systems, there are currently many examples of technologies being employed for domestic greywater for reuse. Greywater technologies can vary from extremely complex to relatively simple. Some approaches include reed filtration systems, biological treatment, gravity sand filtration, simple mesh screening systems, and UV filtration. These technologies have been used on different scales, from individual homes, to apartment buildings, to small communities, with varying success. Most systems involve a filtration step for pre-treatment and end with some type of disinfection to control microbial growth. Some studies have shown that simple greywater systems using solely coarse filters do not provide an appropriate level of treatment, so systems utilizing additional (and commonly more complex) systems have emerged (Li, Wichmann, & Otterpohl, 2009). These more complex systems can include a filter/sedimentation process, a soil filtration process, and a membrane system.

For purposes of the Field Test, selection of the home based technology was completed by the home owner or home builder, accordingly. In total, 24 of the 25 participating homes installed the Brac Greywater Reuse System. The remaining home in the Field Test installed the iDus Controls' Conserve Pump system. Pictures of these technologies are included within Figure 1 & Figure 2 below. With reference to treatment approach, both systems collect raw greywater discharged from showers and baths in the home, filter the raw greywater through a bag or cartridge filter to remove particulates and soap residue, and then (in the case of the Brac System) disinfect the greywater source by passing it over a chlorine puck. The chlorine puck also ensures that there is free chlorine residual in the greywater which is stored in a tank until required for toilet flushing. If ever a situation occurs where there is insufficient greywater stored in the tank to meet toilet flushing requirements, both system are designed to add potable water to the storage tank until the minimum storage level is achieved. The potable water is added using an air gap to prevent any cross contamination between the greywater and potable water systems.

Figure 1: Brac Greywater Reuse System (left) and IDus Controls' ConservePump Greywater Reuse System (right)

To maintain water quality in periods of prolonged greywater storage, the Brac system also features a recirculation function where treated stored greywater is recycled back over the chlorine puck and then returned to the storage tank. This recirculation function can be set to occur at a given frequency by the homeowner (in earlier Brac models this recirculation feature was controlled manually by the homeowner). Conversely, to manage bacterial growth in the absence of chlorine disinfection the ConservePump system actively purges stored greywater on a 48- or 72-hour basis.

Many other devices and components are available for reuse systems. Devices can be broken down into three tiers, ranked on complexity and price. Tier one ranges from $250-$500 and involves gathering water from the bathroom sink, filtering and disinfecting the water, and then using this water for toilet flushing. Tier two systems, which are represented by technologies such as the Conserve Pump and BRAC system used in the Pilot Program, range in price from $3000-$4500. These models have extensive ranges of use for residential, semi-commercial, and commercial applications. The third tier of systems range from $7000-$20000 and have capabilities for a greater volume of greywater. The treatment functionality for these systems is more comprehensive than tier 1 and tier 2, involving pre-filtration, enhanced disinfection, biological treatment, aeration, sediment disposal, UV sterilization, and a pressure pump. This tier of treatment focuses on full treatment of greywater and has a higher removal of solids and a biological treatment.

Focusing on the second tier of systems, the type of systems used in the Field Test, it is important to note differences in performance, installation, and operation. BRAC units are modular all-in-one systems possessing a filtering device as well as a disinfection component; however, ConservePump units are “smart box’ and component based systems including filtration only as part of its treatment approach. With BRAC systems, homeowners can select a 150L, 250L or 350L storage tank, depending on number of persons in their home and the associated storage needs. Conversely, with the smart box being the only permanent component of the ConservePump system, the selection of other system components (such as tank size or filter type) are easily adaptable to meet premise based installation requirements and limitations (available space, etc).

2.3 Standards

With no current Canadian performance standards or associated labeling programs for certified water reuse technologies, the City of Guelph, through consultation with other City Departments and industry professionals, defined a standard for technology selection for the field test, with reference to existing standards of the Ontario Building Code, Health Canada, and Canadian Standards Association. No specific technologies were selected as "City approved technologies" due to the desire to leave the program open for residents or home builders to choose their preferred technology. This approach to technology selection also kept the standard inclusive of other technologies that may not have been known at the time of field test introduction. Thus, the selection of technology through the Field Test was driven by market forces, product awareness, and perceived consumer value in the technologies.

Further to the above, applicable standard requirements for the systems can be found in a variety of sources. For example, the Ontario Building Code, Canadian Standards Association, *2010 Health Canada Canadian Guidelines for Domestic Water Reuse for Toilet and Urinal Flushing,* and Guelph's Backflow prevention Bylaw all contain relevant information directing auxiliary water system installation, operation, testing, and quality guidelines. These standards are summarized below for reference:

Ontario Building Code

The 2006 Ontario Building Code (OBC) allows treated and particulate free greywater to be used only for only toilet/urinal flushing and the priming of floor drains within the home. Furthermore, the OBC also stipulates that home plumbing lines carrying greywater to be fully marked in English and French as "non-potable." Outdoor uses of greywater are not explicitly specified in the OBC. The code specifies definitions of storm sewage, greywater and non-potable as follows:

- *Storm sewage*: "*Storm Sewage* means water that is discharged from a surface as a result of rainfall, snow melt or snowfall."
- *Greywater*: "*Greywater* means *sanitary sewage* of domestic origin that is derived from *fixtures* other than *sanitary units*."
- *Non-potable* water: not explicitly a defined term, modified version of *potable*, meaning "fit for human consumption"

2010 Health Canada Canadian Guidelines for Domestic Water Reuse for Toilet and Urinal Flushing

Health Canada developed guidelines for the use of greywater as well as defined values for water quality of treated greywater. The Canadian Guidelines for Domestic Reclaimed Water for use in Toilet and Urinal Flushing ensure that the operation of water reclamation systems and exposure to treated greywater in the home ensures the protection of public health. The guidelines were developed as an option to reduce water consumption in Canada and to serve as a guideline to the Canadian public when installing and operating auxiliary water systems. With this in mind, the guidelines outline treated greywater objectives values for biological oxygen demand, total suspended solids, turbidity, *Escherichia coli,* thermotolerant coliforms, and total chlorine residual.

For purposes of assessing system performance, the water quality criteria of the *draft 2007 Health Canada Canadian Guidelines for Domestic Water Reuse for Toilet and Urinal Flushing* (Health Canada standard) were utilized as performance goals for treated greywater quality. These water quality criteria of the draft standard are "intended to enhance treatment reliability and disinfection effectiveness, thus protecting public health". The standard further recommends that these parameters be used as a means of evaluating system treatment effectiveness at the time of start-up or at regular testing intervals during normal system operation. For reference treated greywater quality criteria from the draft Health Canada standard is provided below in Table 2 below:

Table 2: Draft Health Canada Guideline values for reclaimed water used in toilet and urinal flushing

		Water quality parameters	
Parameter	Units	Median	Maximum
BOD_5	mg/L	≤10	≤20
TSS[b]	mg/L	≤10	≤20
Turbidity[b]	NTU	≤2 **(alternative to TSS)**	≤5 **(alternative to TSS)**
Escherichia coli[c]	CFU/100 mL	Not detected	≤200
Thermotolerant coliforms[c]	CFU/100 mL	Not detected	≤200
Total Chlorine residual[d]	mg/L	≥0.5	

[a] Unless otherwise noted, recommended quality limits apply to the reclaimed water at the point of discharge from the treatment facility or treatment unit. BOD_5 = five-day biochemical oxygen demand; TSS = total suspended solids; NTU = nephelometric turbidity unit; CFU = colony-forming unit.
[b] Measured prior to disinfection point.
[c] Only one of either *Escherichia coli* or thermotolerant coliforms needs to be monitored in a given system. Further information is provided in Box 1.
[d] Measured at the point where the treated effluent enters the distribution/plumbing system.

Backflow Prevention Device

Backflow prevention devices are required to protect municipality's drinking water supplies from potential sources of risk. With this in mind, The City's Backflow prevention bylaw defines potential risks by land use (such as the presence of greywater or auxiliary water use system) , stipulates the type of premise isolation device required for installation, and device maintenance requirements to ensure ongoing working order of the device and protection of the municipal water system. For reference Guelph's Backflow Prevention Bylaw and associated resources may be viewed at www.guelph.ca/backflow.

Canadian Standards Association

The Canadian Standards Association (CSA) is a recognized source for safety and performance standards. CSA standard *B64.10, Selection and installation of backflow preventers/Maintenance and field testing of backflow preventers*, is the standard used to test for compliant backflow devices.

More recently, CSA developed B128.1 and B128.2 which provides best practices in the design and installation of non-potable water systems/Maintenance and field testing of non-potable water systems. CSA B128.1/B128.2 are not referenced by the current addition of Ontario's Building Code and as a result are not enforceable through common building inspection processes.

Additionally, CSA B128.3, which is anticipated for release in the Spring of 2013, will define performance standards for non-potable water treatment systems as well as act as a means to certify water reuse systems achieving the set operational parameters of this standard. This draft standard was referenced in the course of this field test with more information available at:
http://www.cwwa.ca/pdf_files/CSA_B128_3_Notice_Feb%2024%2010.pdf

Third-Party Performance Testing Standards

An issue that presents itself in the widespread implementation of reuse water is the lack of third-party performance standards and certifications available for such systems. As stated above performance based standards for such systems are not currently available in Canada. In the United States, the International Association of Plumbing and Mechanical Officials (IAPMO) provides third party standards for the construction, installation, discharge, and use of greywater systems. IAPMO Research and testing inspects and evaluates Reclaimed Water Conservation Systems for flushing toilets to verify compliance to applicable codes and standards. The standard that was applied to the used greywater reuse systems can be referenced as IAPMO IGC 207 – 2009a. This standard was used to confirm that the systems meet the *minimum requirements for protection of public health and safety associated with reclaimed water conservation at the toilet level, the materials in the construction of a reclaimed water conservation system for toilet flushing and to prescribe the minimum testing requirements for the performance of the reclaimed water conservation system for flushing toilets, together with methods of marking and identification.* This standard specifically tests the systems on the operating performance, hydrostatic pressure, mechanical setup, and the chlorine disinfection system to ensure they are within the limit requirements. For more information on IAPMO and their programs, please visit. http://www.iapmo.org/pages/iapmo_green.aspx

3.0 Water & Energy Demands

3.1 Approach

A primary goal of this study was to verify the effectiveness of residential greywater systems to lower household water and energy demands. Veritec Consulting Inc. was retained to monitor the water and energy demands associated with greywater system operation. As part of the water use monitoring, additional water meters were installed on the potable water top-up supply piping and on the treated greywater line of home greywater systems, with water use readings taken by City staff on a monthly basis. In addition, water billing records for all homes were analyzed on an ongoing basis to assess changes in water consumption (amongst homes retrofitted with a greywater system) and average daily household water demands in comparison to control homes (within new construction). A subset of ten of the homes in the study also had data logging water meters installed which allowed for the collection of heightened information on 15 second intervals from all meters as well as the ability to remotely download demand information via radio signals for the duration of the study.

Additionally, kilowatt hour meters were installed on the power supply to the greywater systems to measure energy demands. The energy used by the greywater systems was compared with the energy demands of a municipal water treatment and distribution system providing the same volume of water.

3.2 Home Water Use and Anticipated Water Savings

The 1996 Ontario Build Code permits the use of particulate free Storm Sewage, including greywater, for use in toilet/urinal flushing as well as the priming of floor drain traps within residential dwellings. Beyond building code approval for the use of greywater within the home it is necessary to determine whether sufficient amounts of greywater would be available on a daily basis to meet the water needs for flushing toilets in the home. Toilet flushing remains one of the largest uses of water in the home. The 1999 American Water Works Association Research Foundation's *Residential End Uses of Water Study* identified the average daily water demand required for toilet flushing as about 83 litres per capita per day (Lcd), , followed by clothes washing at 52 Lcd, and showers at 47 Lcd. This AWWA study involved detailed monitoring and data logging of household water demands in many North American jurisdictions, including the Region of Waterloo locally. Figure 1 below illustrates the breakdown of daily household water demands for homes built prior to 1996 as determined in the 1999 AWWARF study:

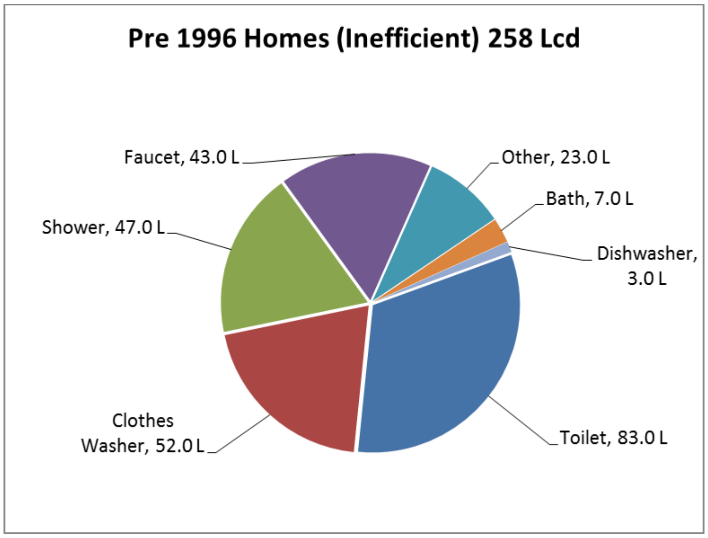

Figure 2: Water End Use Summary for Home Constructed Pre 1996

As can be seen in Figure 1, the volume of greywater produced from shower events (47 Lcd) would not be sufficient to meet the full water demands for toilet flushing (83 Lcd). For homes fitted with inefficient fixtures and appliances it may be necessary to collect greywater from the clothes washer (52 Lcd) as well as the shower to ensure that there is sufficient greywater to meet all toilet flushing needs.

New homes, however, are fitted with much more efficient fixtures and appliances and, therefore, use much less water. The following chart illustrates the water demand breakdown of a typical new home fitted with 6-L toilets and 9.5 Lpm showerheads (both OBC requirements) and a water efficient front-loading clothes washer.

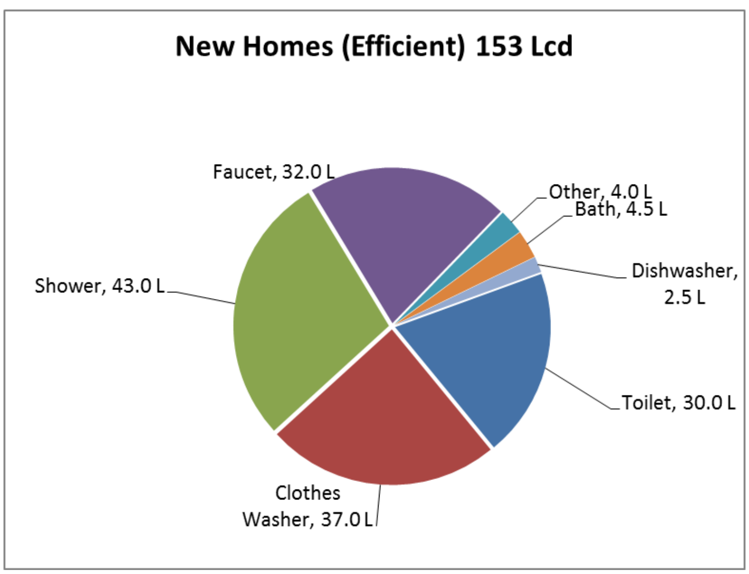

Figure 3: Water End Use Summary for New Homes

Note that in typical new homes the volume of greywater discharged by showering events (43 Lcd) exceeds the volume of greywater required for toilet flushing (30 Lcd or less if home is fitted with high-efficiency toilets). In new homes, therefore, collecting greywater from shower events is sufficient to meet all expected toilet flushing requirements. Since the potential volume of water saved by utilizing greywater for toilet flushing is directly related to the flush volume and frequency of the household toilets (assuming that the average person flushes a toilet in their home 5 times per day as identified in the 1999 AWWA RF REUS), the following table illustrates the different potential water savings for different toilet flush volumes. Note that as the home's toilets become more efficient, the volume of potable water saved on a daily basis become less.

Table 3: Potential Water Savings

Flush volume of Toilets in Home, L	Flushes per Capita per Day	Potential Savings, Lcd
20	5	100
13.2	5	66
6.0	5	30
4.8	5	24
3.0	5	15

The maximum water savings per home is directly related to the volume of greywater used for toilet flushing. Based on Table 3 above the maximum potential savings for a home fitted with efficient 4.8 L toilets would average about 24 Lcd. Because there is a significant natural variation in water demands from day to day for any household, using water billing data or even periodically reading the home's water meter would provide only an indication of the water savings achieved by the City's greywater field test as a whole. The methodology used in this program to verify water savings, i.e., directly metering the greywater demands of the toilets within each home as well as any potable water makeup used, eliminates any extraneous factors and provides a relatively precise quantification of the true water savings.

3.3 Results vs. Anticipated Water Savings

At the time of this report, water savings data from 9 of 10 homes possessing heightened water metering was available. The average daily water savings for each of these homes is identified in the following table. Note that two sites, No. 8 and No. 9, were retrofitted homes that had inefficient 13-litre per flush toilets installed and, therefore, achieved a higher than expected per capita savings (recall that water savings is directly related to the volume of water used to flush toilets within each home).

Table 4: Average Water Savings

Site No.	Average Daily Savings, L	Persons per Household	Lcd Savings
1	68	4	17.0
2	97	6	16.2
3	66	4	16.5
4	74	5	14.8
5	58	3	19.3
6	36	2	18.0
7	29	2	14.5
*8**	*96**	*2*	*48.0**
*9**	*79**	*2*	*39.5**
		Overall Average	**22.6**
		Average of homes with water-efficient toilets installed	**16.6**

*Homes were equipped with inefficient toilet fixtures

As can be seen in the table above, the overall average water savings to date is 22.6 Lcd, or just slightly lower than the maximum calculated rate of 24 Lcd based on 5 flushes per capita per day using 4.8-L toilets. When only those homes with water-efficient 4.8 L toilets are factored in, the average daily water savings is approximately 16.6 Lcd, or about 70% of the expected 24 Lcd savings. One possible reason for lower than expected savings is that the number of toilet flushes in the participating homes was actually less than the assumed 5 flushes per capita per day based on the AWWA REUS data. For example, a small baby would not use the toilet at all and someone that works long hours out of the home or that spends time at the gym or at a friend's home may flush less than 5 times per day at their home. Other possible reasons are presented in the following section.

That being said, the actual average water savings achieved by the homes fitted with efficient showers and toilets is within 8 Lcd of the calculated maximum potential savings, indicating that greywater systems can effectively provide sufficient water to meet household toilet flushing requirements.

3.4 Addition of Potable Water – How Much and Why?

Another reason that water savings were lower than expected was because greywater systems in every participating home received some quantity of potable water during the monitoring period. While an average household should produce enough greywater to more than satisfy its toilet flushing requirements, there may be occasions when toilet flushing needs exceed the volume of water collected from showers (such as during house parties). In these cases, the greywater system adds a minimal volume of potable water to prevent the system's pump from running dry while still leaving sufficient room in the tank to accept additional greywater from the home's showers.

As stated earlier, monitoring equipment was installed to measure the total greywater utilization by each home and the volume of potable water added to each greywater storage tank. While these volumes varied from home to home, the average volume of greywater utilization for homes fitted with 4.8 L toilets (i.e., total greywater production minus any overflow volume) was approximately 80 L/household/day and the average volume of potable water makeup was approximately 20 L/household/day, resulting in a net water savings of

60 L/household/day. Stated another way, on average, about 25% of the greywater supplied for toilet flushing was actually potable water. The volume of potable water added to the greywater systems, however, varied significantly from home to home - from a low of 2.5 L/household/day to a high of 191 L/household/day.

Effects of Greywater Reuse on Municipal Max Day and Peak Hour Demands

All of the homes participating in Guelph's program collected greywater from showers and/or baths. Reducing potable water demands by any means will help reduce peak day demands. The average savings achieved to date in this study (for homes fitted with water-efficient toilets) was 16.6 litres per capita per day (Lcd), though it is anticipated that an ultimate potential savings of approximately 24 Lcd (i.e., 5 flushes/capita/day x 4.8 L/flush) can be achieved should performance of the greywater reuse systems be optimized.

Guelph's current max day to average annual day demand ratio is approximately 1.6 (i.e., the water demand on the highest demand day of the year, typically during the summer, is 60% greater than the average demand throughout the year).

In 2011 Guelph experienced an average annual day demand of about 40 million litres per day with a population of about 122,000 persons. The max day demand in 2011 was approximately 64 million litres. A successful city-wide adoption of residential greywater reuse systems would be expected to ultimately reduce demands by about 24 Lcd (the potential savings associated with inefficient toilets would be greater, however, over time, it is expected that essentially all toilets in the City will be converted to efficient models). With a population of about 122,000 persons, the potential savings would be about 3.0 million litres per day (MLd)[2], thus the max day demand would also be lowered by the same 3.0 MLd or by about 4.7%.

Peak greywater production (collection) in a home tends to occur in the early morning as people shower or bath before they start their day. The greywater collected during the early morning is used slowly throughout the day as homeowners periodically flush toilets. Peak hour water demands tend to occur during the evening when homeowners turn on their lawn sprinklers. Given that the flow rate from a lawn sprinkler is typically about 1,500 litres per hour, eliminating a small number of 4.8-L toilet flushes will have a negligible impact on peak hour demands.

Full Greywater Reuse Program Roll-out in City

As stated above – the potential city-wide adoption of residential greywater reuse systems would be expected to ultimately reduce Guelph's average annual day demands by about 3.0 million litres per day (MLd), a savings that equals about 7.5% of the current average daily demand. This savings estimate assumes that the city's entire toilet stock will eventually be converted to 4.8-L models (HETs). Should the toilet marketplace continue to evolve and flush volumes of only 3.0 litres become the new 'standard' for HETs (WaterSense-approved 3-L fixtures are currently available in the marketplace) the potential water savings would be expected to be slightly less at about 1.9 MLd or 4.85 of the current average daily demand.

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[2] 122,000 persons x 24 L/person/day = 2,928,000 L/day = 2.928 MLd

3.5 System Energy Usage

To measure the energy requirements of the pumps used to convey greywater from the system's storage tank located in home's basement to the various toilets within each home, a small power meter (Kill-A-Watt™ power meter) was installed on the energy source of the greywater supply pump in each participating home. This power meter recorded the total energy in kWh used by each pump. By comparing the total energy demand to the total volume of greywater pumped by each system it is possible to determine the average unit energy use, i.e., the energy demand in kWh per m^3 of grey water used.

The unit energy use values are slightly different for each of these homes but this difference can be explained by difference in the physical attributes of each home – one home may flush toilets on upper floor more often, have a longer run of water supply piping, etc.

At this time, energy demand data is available from only two homes. These values are: - 1.30 kWh for every cubic meter (kWh/m^3) of greywater pumped to 1.85 kWh/m^3, resulting in an average value of 1.58 kWh/m^3. If we assume a typical greywater demand of 24 m^3 per year per home (based on 4.0 persons per home and a grey water usage of 16.6 Lcd) and an energy demand of 1.58 kWh/m^3 the total energy demand would be 38 kWh per year. Based on a cost of about $0.08 per kWh, the associated energy costs would be about $3.00 per household per year.

While the total energy demands and costs associated with operating a greywater system would be minimal to a homeowner, it should be noted that a municipality would be expected to save approximately 0.74 kWh for every m^3 of water and wastewater saved by an efficiency measure – less than half of the additional energy demand of approximately 1.58 kWh/m^3 required to operate this type of residential greywater system[3]. In other words, for every kWh saved by a municipal water/wastewater system through the installation of a residential greywater system, the participating homeowner would be expected to use some amount of energy in *excess* of one kWh. It is expected that the greater unit energy efficiency achieved by the municipal system is because of economies of scale, i.e., the municipal system uses larger pumps, larger diameter pipes with less head loss, etc.

Although the energy demand data collected to date as part of this project is significantly limited (energy demand data from only two homes was collected), it appears that small residential greywater systems are less energy efficient than large municipal systems. As such, while the widespread use of residential grey water systems would be expected to reduce municipal water demands, their use may also increase total energy demands within a municipality.

A net increase in energy demands as a result of the use of residential greywater systems would result in a net increase in GHG emissions. Using an estimated average annual greywater demand of 24 m^3 per home per year and lower of the two monitored energy demand rates of 1.3 kWh per m^3, the total energy demands for a residential greywater system would be approximately 31 kWh per home per year. This energy demand

[3] Greenhouse Gas and Energy Co-Benefits of Water Conservation, March 2009, Carol Maas, Table 1 - systems providing at least 5,000 m^3/day.

equates to a GHG emission of approximately 8 kg of CO2e per year[4]. The energy demand associate with supplying 24 m^3 per year of water for toilet flushing via Guelph's municipal system would be somewhat less at approximately 18 kWh per home per year, a demand that equates to a GHG emission of only about 5 kg of CO2e per year.

[4] Based on Ontario coefficient of 0.27 a kg CO2/kWh as identified in Greenhouse Gas and Energy Co-Benefits of Water Conservation, March 2009, Carol Maas

4.0 Water Quality Monitoring

4.1 Approach

As part of Water Quality Monitoring for the Field Test, the City of Guelph sampled greywater at 20 participant households on a monthly basis for a one-year period. Dip samples of treated greywater were collected from toilets within each home with City staff completing onsite testing for Turbidity and Chlorine Residuals. Beyond onsite sampling and analysis, samples for parameters including biochemical oxygen demand (BOD), chemical oxygen demand (COD), and Escherichia coli (E.coli) were collected by City staff at each home and submitted to Maxxam Analytics Laboratory in Mississauga for testing.

In addition, researchers at the University of Guelph School of Engineering conducted sampling at the 5 remaining homes on a bi-weekly basis. As part of this sampling program, water quality samples were taken of both the shower water entering the greywater reuse system (influent) as well as grey water being supplied to the toilets (effluent). Participants were instructed to collect shower water by plugging their tub and taking a sample of the water following their shower. The raw and treated greywater samples were picked up in the morning for laboratory analysis at the University. Throughout the study duplicate samples were taken by researchers for testing at both Maxxam Analytics and the University to ensure consistency in results attained.

The Health Canada guidelines specify that at least 5 greywater samples should be taken from a system each month to accurately determine the median values, however, neither the City or the University collected samples at this frequently due to challenges in attaining access to private residents under this frequency and financial limitations associated with satisfying this sampling regime. However, to support program participants throughout the duration of the study, homeowners were given the opportunity to request the completion of additional water quality samples at their home should issues or other challenges be experienced with their system.

Figure 4: Treated Greywater Sampling and Analysis

4.2 Household Greywater Characteristics

There are many factors that influence shower water effluent quality, including general household practices and the types of personal hygiene and cleaning products used in the shower. For example, the frequency of shower cleaning, shower duration, and the amount and type of soap/shampoo/conditioner used will affect water quality, as will the hygiene practices of the person showering, the frequency of showering, etc. The volume of water used while showering is also important as it can change the water quality by diluting the amount of soap and dirt present in the water sample. These multiple factors contribute to a raw shower water quality that varied greatly between households in this study. For example, mean BOD values ranged from 78.6 to 317.3 mg/L.

With respect to common indicators for pathogens, such as E.Coli, it is important to note that different persons will naturally have different levels of fecal coliforms in their intestines and on their body based on their biology (age, gender, and weight), personal hygiene practices, and type of work (Ludwig, 2009). Thus, the amount of microbes being passed onto the greywater source via showering can vary significantly between different individuals. To achieve Health Canada treated greywater water guidelines, therefore, treatment methodologies employed by water reuse technologies should be able to manage a wide range of raw water quality.

<u>Treatment Efficiency (Raw vs. Treated) – Subset of Homes</u>

Sampling of raw greywater and treated greywater was conducted at a subset of homes demonstrated improvements in water quality as a result of treatment. However, effluent quality was clearly influenced by the initial quality of the raw shower water. In looking at this in more detail, it can be seen in Figure 3 & Figure 4 below that the ranking of quality does not change following treatment. In other words, the sites with the highest quality of raw greywater produced the highest quality of effluent, and sites with the worst initial quality produced the worst effluent.

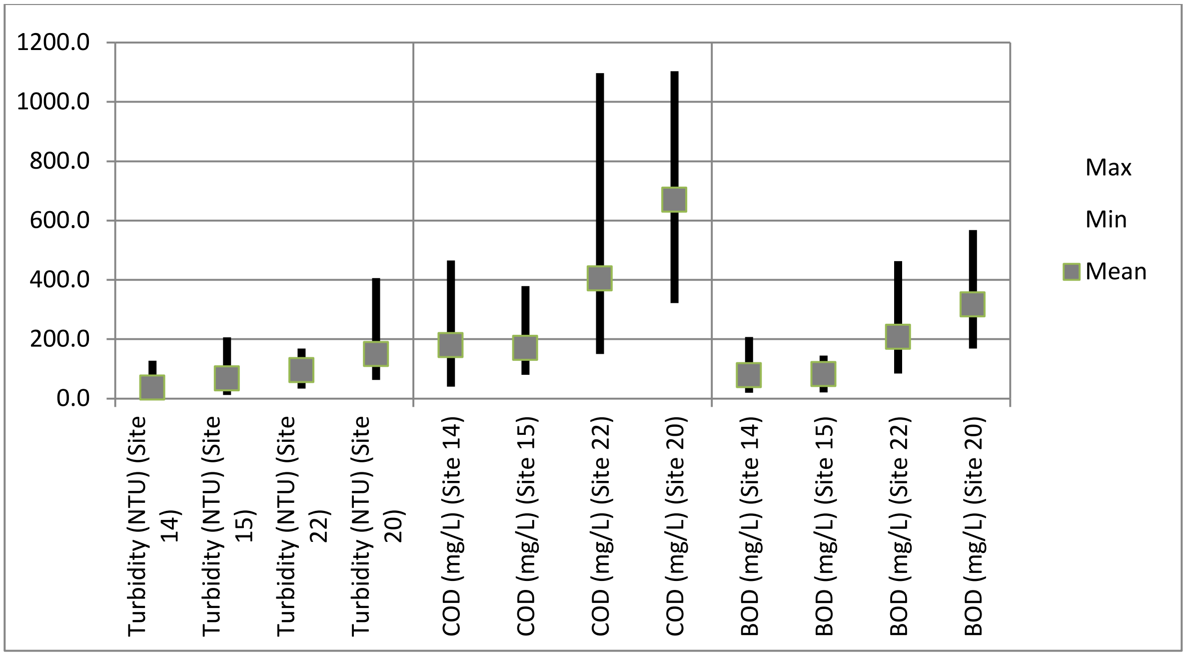

Figure 5: Range and mean values for untreated shower water - All sites (Turbidity, COD, BOD).

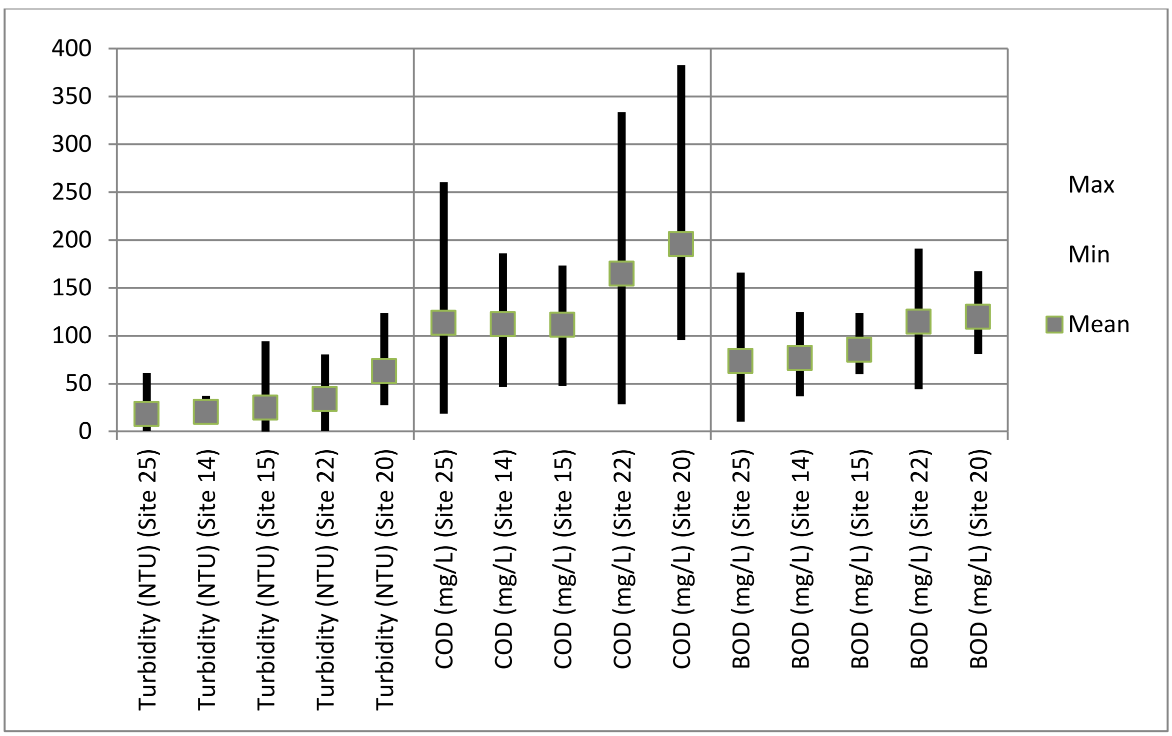

Figure 6: Range, mean, and % reduction values for treated greywater - All sites (Turbidity, COD, BOD).

Overall Compliance and Health Canada Standards

The greywater reuse systems performed poorly in terms of turbidity and BOD, meeting HCG requirements only 15.4% and 28.7% of the time respectively. Despite this, E.coli levels in 80.7% of the samples taken from all sites were below the detection limit of (<1 cfu/100mL). Furthermore, effluent samples from 90.1% (219 of 243) were below the maximum E.coli level (<200cfu/100mL). The remaining 10% of samples that failed to meet E.coli guidelines of HCG were largely localized at a few sites where the greywater systems were not being sufficiently chlorinated (16% or 43 of 264 samples had zero mg/L of free chlorine residual).

It is important to note that the free chlorine residual represents the concentration of chlorine that is still available for disinfection and is not same as the total chlorine level specified by the HCG. This explains why a high degree of disinfection was possible even with many samples having free chlorine concentrations below the 0.5mg/L level (45% or 120 of 264). Although the systems seemingly performed poorly according to several HCG criteria (turbidity and BOD), the most important health-related criterion - E.coli concentrations - was met regularly at most sites.

The results indicate that new homes performed better than retrofitted homes. This result is, however, somewhat deceiving as new homes tended to use a greater volume of municipal water to 'top up' their greywater reuse systems, thus improving greywater quality by diluting it with potable water.

Table 5: Overall compliance with Health Canada Guidelines

Parameter	Guideline Amount	Total Number of Samples	Number of Samples within Guideline Limit	Number of Samples outside Guideline Limit	Percentage of Samples within limit (%)
BOD	20 mg/L	237	167	70	29.5%
COD	20 mg/L	225	205	20	8.9%
E. Coli	200 CFU/mL	247	24	223	90.3%
Turbidity	5 NTU	274	232	42	15.3%
Free Chlorine Residual	0.5 mg/L	265	164	101	38.1%

Potable Water Fed vs. Greywater Fed Toilets

The University of Guelph not only examined raw shower water and treated greywater but also took water samples from the toilet bowls of fixtures supplied by potable water (Table 6). The results suggest that even frequently cleaned potable water-fed toilets (Toilets A and B) can have high average concentrations of fecal coliforms and very few samples that are fecal coliform free. In fact, even potable water taken from toilets can fail to comply with the current HCG requirements. Factors affecting results include chlorine residual, user's hygiene, toilet cleaning practices, and cleaning products used.

Regardless of whether a toilet is supplied by potable water or greywater, not surprisingly, indicator microorganisms can be found in relatively large numbers. Counter intuitively, greywater sampled from toilets at Sites 25, 14, and 15 was actually “cleaner” (from a fecal contamination perspective) than potable water Toilets A and B. This can possibly be attributed to the regular dosing of high concentrations of chlorine within treated greywater that the toilets at these sites received after each flush. As well, each greywater-fed toilet had lower average fecal coliform counts than the irregularly cleaned Toilet A (potable water-fed).

Table 6: Fecal coliform comparison from different toilets

		Potable Water Toilets		**Greywater Fed Toilets**				
		A	**B**	**Site 25**	**Site 14**	**Site 15**	**Site 22**	**Site 20**
Fecal coliforms present in toilet bowl	**% of results <1 cfu/100mL**	0%	50%	77%	80%	60%	25%	0%
	Geometric mean (cfu/100mL)	998	11	2	3	17	69	770
	# of Samples	6	6	9	5	5	16	4
Total Chlorine (mg/L)		0.22	0.33	2.16	2.62	3.53	1.90	0.24
Toilet Cleaning		once/3 months	weekly	Not available	Every few months	cleaned weekly	1-2/week	weekly

Dilution of Greywater Affecting Water Quality Results

The volume of municipal water used to top up a greywater system will impact the effluent quality of treated greywater. At some sites the volume of municipal water supplied to the greywater system actually exceeded the shower water volume. For example, 83% of water used to flush toilets at Home 23 was from municipal sources, which resulted in a low average greywater turbidity of 9.6 NTU (Table 7).

Table 7: Examples of toilet water composition compared with turbidity

	Water Sources Filling Greywater Reuse System			
Site	Shower Water (L/capita/day)	Municipal Top Up (L/capita/day)	Potable water Use for Toilet Flushing (%)	Average Turbidity (NTU)
Home 23	4.7	23.3	83%	9.6
Home 8	9.5	9.3	49.6%	25.8
Home 5	20.8	6.3	23%	33.3

Importance of Regular System Maintenance

To ensure that the greywater reuse systems are performing optimally, regular maintenance must be conducted by the users. This maintenance includes:

- Ensuring that chlorine pucks are always present in the system. Sufficient chlorine residual reduces the presence of E.coli and other microorganisms in the treated greywater; and,
- Regular filter cleaning prevents clogging which ensures that all the shower water is available for reuse. Filter cleaning also helps prevent bio-film growth and fouling of the filter components.

Systems which maintained a sufficiently high concentration of free chlorine (>0.5 mg/L) produced an effluent which had E.coli enumerations below 200 cfu/100mL (graph of results included in the report in Appendix C. However, as explained previously, a high degree of disinfection was possible even with many samples having free chlorine residual concentrations between 0 and 0.5mg/L (45%, 120 of 264).

5.0 Social Feedback Monitoring & Acceptance

5.1 Approach

Understanding social acceptance is of particular importance for fostering desired environmental conservation change. The role of social acceptance is integral to understanding how the field test is perceived by the public and its users. Research of social acceptance sheds light on the need for homeowner support with grey water reuse systems. Of particular importance, is greywater system users willingness and acceptance to complete required maintenance as it is directly linked to the success of system operations and associated water savings.

Project feedback attained through qualitative methods, was used to assist in understanding the social acceptance and opinions of greywater system owners and the general public. Qualitative research methods included ongoing homeowner surveys, focus groups, and homeowner interviews. Quantitative research included a web-based survey available to the general to the public.

5.2 Quantitative Homeowner Surveys

As part of the Field Study, a participant feedback survey was sent out by the City to twenty five participants. Information was collected regarding the users' knowledge of their system, maintenance regime, system performance, and satisfaction level. Survey participants included three homes which were gifted a GRWS with the purchase of their home. The remaining eight systems were involved in a home retrofit. The questions were related to system performance and specific difficulties that were experienced. Some questions allowed the users e to provide more than one response.

The purpose of the ongoing surveys was to assist in showing progression of homeowner understanding and satisfaction. They also served to provide insight on increased understanding of system functionality and gauge homeowner maintenance issues experienced with the system. Distribution of surveys occurred at four, eight, twelve, and twenty-four months after installation and included questions pertaining to knowledge of system, satisfaction level, maintenance regime, type of soap products used, system performance, and bathing schedules and habits.

Some of the difficulties with the GWRS that were raised included: difficulties with motor controls, system operating too often and/or too noisily, overflow and flooding issues, and difficulty with access to the tank and/or filter. The frequency of filter cleaning was mentioned as a problem for some users, while others were able to adapt to this new responsibility. Most users that were interviewed indicated that the system requires a lot of diligence in cleaning. Some went as far to say that when the routine of the cleaning is established, the system functions quite well. Of those interviewed, five users indicated that they clean their filters weekly, and 5 users cleaned their filters monthly.

Survey result indicated that the majority of participants rated the performance of their system as "good" and overall resident satisfaction as determined from resident feedback surveys taken 12 months after ownership is quite high, as evident in Appendix F. At the 24 month survey, overall resident satisfaction was still "good" but there were fewer responses in the "excellent" category than on the 12 month survey. The most common issues cited were mechanical failures, development of biofilm in the toilet tank or bowl, and aesthetics (chlorine or unpleasant smell and water murkiness). The frequency of filter cleaning was also mentioned as a problem for some users. A pie chart of these dissatisfaction reasons collected at the one year survey is outlined in Appendix F (Figure 20).These reasons for lack of satisfaction repeated themselves consistently throughout the other research methods. A summary of these surveys are available in Appendix F (Pilot Program Participant Feedback Surveys) of this report.

5.3 Focus Groups

As per the field test, 3 focus groups were conducted in October 2010 by Metroline Research Group, to seek information from three specific audiences. As per the focus groups, audiences were divided by experience with the system as well as members of the general public. The 3 groups included: new program participants that had the system for 0-6 months, and existing program participants that had the system for longer than six months as well as members of the general public. The purpose of the research was to gather feedback on homeowner experiences with and perceptions of their greywater systems, including their participation in the Field Test, and to identify potential barriers to widespread greywater system use.

General Public

Insights from the Metroline Research Group demonstrated that members of the general public tended to have minimal awareness of greywater technology. This group also found the term "greywater" could prove to be excluding, due to its "ick factor", and were not certain that the technology applied to their specific lifestyles. Return on investment was identified a key decision factor and research demonstrated that they wanted a payback period of less than 10 years if they were to partake in a greywater reuse program.

Program Participants

Results received as part of focus group for those possessing the technologies featured notable differing opinions from that of the general public. The existing participants group suggested that both initial and ongoing engagement and education on the systems are imperative to system success. This suggestion was also backed up by findings from the surveys and the interviews. One interesting indicator was the difference in drivers for uptake of greywater systems between existing participants and the general public. Many existing participants noted their personal conservation ideals/belief as their driver for participation, and seemed less motivated by return on investment. Conversely, members of the general public appreciated the environmental benefits of the system but were primarily driven by the financial benefit introduced by such systems, with a payback on investment period required to be 10 years or less to strongly consider installing such technologies.

Separately, when looking to sub groups of the existing technologies users (i.e. those who retrofitted their home versus those who purchased a home within which the system gifted) some interesting trends emerged. When looking to home retrofit, many participants had identified themselves as environmentally conscious individuals and noted they were attracted to the greywater system based on their "green" attitude. This group as advised that they actively researched technology alternatives and had a high level of awareness of technologies in advance of their participation in the Field Test. By comparison, new homeowners did not generally share this attitude and were most concerned with the financial elements of the program. Furthermore, this group admitted a lesser level of technology awareness prior to installation in their home and as a result shared a higher level of dissatisfaction with the system and related maintenance requirements.

Overall, the focus group results provided detailed qualitative information and demonstrated that there is support for greywater systems. However, due to limited cost effectiveness at this time, there is limited audience uptake. One important finding was that both new and existing program participants indicated that they have limited safety concerns and that health concerns regarding water quality were generally a non-issue. For more information, the full report from Metroline is available in Appendix F of this report.

5.4 Stakeholder Interviews

Qualitative homeowner and homebuilder interviews were conducted by representatives of the University of Guelph. This detailed research provided a deeper understanding of resident satisfaction. This research reaffirmed that the need for direct homeowner support with their systems, and diligence in completing their maintenance program was directly linked to successful system operation and subsequent water savings.

During interviews, participants expressed that their main issues were related to system maintenance, cost, and aesthetics. Member's attempts to balance the technical maintenance generated a great deal of ambivalence toward their participation in the project and auxiliary water systems in general. Some felt that being environmentally responsible outweighs savings while others expressed the need to at least receive a return on their investment. There were also issues surrounding aesthetic appeal relating to bio-film in the toilet, and to the colour and smell of the greywater. These issues were at the forefront of discussions, especially when friends and family were visiting. However, as previously noted, health concerns were not a major deterrent to environmental engagement.

The interviews also confirmed that while the participants installing a greywater system in new homes were initially excited to receive the technology as an "add on" to their home purchase, they later came to perceive some downfalls related to their system and their satisfaction level decreased as a result. The result of these consultations and supporting discussion pertaining to the interviews are included within Appendix F of this report.

5.5 Qualitative Web-based Surveys

Quantitative web-based surveys were available from the City's webpage and responses from residents within the Guelph city limits were encouraged. This survey ran in January 2011 for approximately 4 weeks with a total of 61 responses. While the insight provided by the survey is valuable and adds to the findings of the other research methods established, unfortunately the total number of responses received did not meet the participation threshold to ensure statistical significance on a local level.

Key findings of this research include the following:

- This research found that the term “greywater” was not publically appealing.
- Overall, 94% of people surveyed indicated that they would consider installing a greywater system. However it appears that the initial cost and water savings were the main influencers to installing a greywater system in the home.
- Systems that are not cost effective or that don’t provide a reasonable payback period and return on investment would only appeal to a small percentage of homeowners.
- Financial rebates/incentives were cited as one of the most important things the City can do to encourage participation in the program.

For more information on this survey, a complete summary of survey results are included in Appendix F (Table 19 to Table 22) of this report.

5.6 Social Feedback Recommendations

Program participants who actively signed up for the program are clearly more engaged. These people tend to be more environmentally conscious, “green” homeowners. This group indicated that they were the most satisfied with the system, claimed better success, and were more driven to maintain their system.

Participants through surveys, interviews and focus groups voiced some concerns about the system itself.

Aesthetic Issues

Many struggled with the aesthetic issue of getting the toilet bowl water to an **“**acceptable” appearance level. They wanted a more “hands off” approach and found the system filter to be problematic. Some even had the perception that the system manufacturer was still proving the system and was “working out the bugs” using this program as a trial test. Many found that supplies, such as chlorine pucks, are not readily available and price was an issue. They seem to have a perception that they want clean clear drinking water quality water for the toilet.

Maintenance Issues

Maintenance concerns and mechanical problems were prominent issues for system function. Users indicated that they wanted a more “hands off” approach that was less time consuming. People were generally not interested in cleaning their own filters and replacing chlorine pucks. They often found the filter to be problematic. If it was not cleaned regularly it would clog with hair/debris/soap scum and then the system would bypass the greywater and automatically switch to the municipal system. Some users even had the perception that the manufacturer of the system was still proving the system and working out the “bugs” using this program as a trial test. Many found supplies, such as chlorine pucks, were not readily available and price was consistently an issue.

Communication Improvements

There are avenues for improvement regarding communication and setting appropriate expectations of the greywater system for the homeowner. Program participants wished they had a better sense of their role and responsibility during the installation process. They indicated a need for better training or education when the system is first installed, including some written examples and instructions. They wanted more direction on brands or types of soap/shampoo that will work best in the system. Another recommendation by the homeowners was a more clear indication of who to call when there are questions or problems with the system. They wanted some guidance on whether results from the testing process are acceptable, and how to improve them.

Cost of System

While there is an interest in the program by Guelph residents, there are a number of concerns and barriers to installing a system. The largest barrier is cost of the system and return on investment. Without a good return on investment, potentially interested residents seem to want to wait until either water rates increase or the system payback increases.

Beyond the barriers and concerns is the level of satisfaction with the installation of the system. Overall, however, the participants who received the greywater system through a new home purchase had lower levels of satisfaction but those who chose to install the system are pleased with their participation and their system.

Health Concerns

Both potential and existing program participants expressed that they were not concerned about health and safety issues as being a concern regarding water quality from the system. As represented consistently in all of the social research findings, health concerns were not a major deterrent to environmental engagement.

Incentive Availability

The research indicates that the municipal rebate appears to be a major financial incentive to encouraging potential greywater users to participate in the program and uptake this technology retrofit. The rebate increases the return on investment and payback period for users, making the system more appealing financially as a result.

6.0 Financial Analysis

6.1 Consumer Uptake of Demand Management Programming

The success of demand management programming is dependent on the presence of consumer uptake and participation stemming from a recognized tangible benefit amongst target audiences. With this in mind, primary elements influencing consumer participation in programming include:

- Creation of heightened financial benefit to participants;
- Desired/Improved performance than existing product/process;
- Increased contributions to home/environmental aesthetics;
- Alignment of product with personal ethics/beliefs, and;
- Shifts in social norms and other market pressures.

To explore creation of financial benefits specifically, the introduction of a tangible short-term benefit is a key lever influencing the uptake of technology retrofit based demand management programs. With this in mind, to facilitate the uptake of desired home water efficiency technology retrofits and associated payback on investment to the homeowner many municipalities offer rebate programs through which financial incentives are provided towards the replacement of inefficient home technologies with approved efficient alternatives. These incentive approaches have been very successful for municipalities aiming to increase uptake of demand management programs and have helped to defer or avoid significant community water/wastewater capital investments as a result.

In alignment with benefit to the municipality, the program participant also enjoys reduced utility bills as a result of the efficient technology installation and a shorter payback on investment (POI) for the technology stemming from the incentive received. Although personal financial thresholds for payback on investment may vary based on the level of disposable household income, the general consumer expectation is that resource use efficiencies introduced by water use technology improvements will recoup the cost of the technology investment within 3-5 years and introduce a suitable level of continued financial benefit to the homeowner well in advance of the anticipated life cycle of the given technology. Focus groups with members of the general public completed as part of the Field Test had demonstrated an acceptable POI period of no more than 10 years for these technologies amongst residents surveyed. Furthermore, it was the expectation of residents surveyed that these systems should introduce a continued tangible financial benefit to the homeowners from the point of installation of such systems.

6.2 Payback on Investment

The Payback on investment (POI) period is a common economic measure used to plan and prioritize investments. Specifically, the POI is used to determine the period of time for an investment to recover its initial startup costs. In defining POI it is essential that both initial and ongoing operational and maintenance costs be taken into account to represent the true costs of the technology and return on investment. With this in mind, a series of detailed financial models were developed to analyze greywater reuse system POI to homeowners living in newly constructed and existing housing as part of the Field Test. For reference further explanation of these scenarios is provided below:

- **Scenario 1:** Payback on Investment with 5% annual increase in water/wastewater user rates and annual premise isolation device testing requirement;
- **Scenario 2:** Payback on Investment with 5% annual increase in water/wastewater user rates and no annual premise isolation device testing requirement;
- **Scenario 3:** Payback on Investment with 5% annual increase in water/wastewater user rates and amended premise isolation device testing requirement (5 year frequency);
- **Scenario 4:** Payback on Investment with 10% annual increase in water/wastewater user rates and annual premise isolation device testing requirement;
- **Scenario 5:** Payback on Investment with 10% annual increase in water/wastewater user rates and no annual premise isolation device testing requirement, and;
- **Scenario 6:** Payback on Investment with 10% annual increase in water/wastewater user rates and amended premise isolation device testing requirement (5 year frequency)

As indicated above, key variables in each scenario included proposed annual increases to water/wastewater user rates over time (5 or 10% annually), amendments to the annual premise isolation device testing requirements for homes possessing greywater systems (a cost of approximately $150/year), and toilet technology differences in new and existing homes (stemming from Ontario building code improvements and subsequent retrofits). Furthermore, these scenarios also assumed the presence of one-time City incentive to homeowners installing such systems, annual general operational and maintenance costs (chlorine puck replacements, electricity needs to run the system), and uniform volumetric annual water savings over the anticipated life of the system (20 years). Included below is a summary of these variables and respective POI summaries for reference:

Table 8: New Home POI Scenario Variables:

Item	**Annual Value**		**Units**
	New Homes	Existing Homes	
Total Annual Water Savings from GWR System Installation	18.2	24.7	m3/yr
2012 Combined Water/Wastewater User Rate	$ 2.71	$ 2.71	/m3
Annual Utility Savings per Household	$ 50	$ 67	
System Installation Cost	$ 3,500	$ 3,500	
Annual Backflow Prevention Device Testing Cost	$ 150	$ 150	/yr
Annual O&M Cost for System (Chlorine/Electricity)	$ 55	$ 55	/yr
Incentive from City for System Install	$ 1,500	$ 1,500	

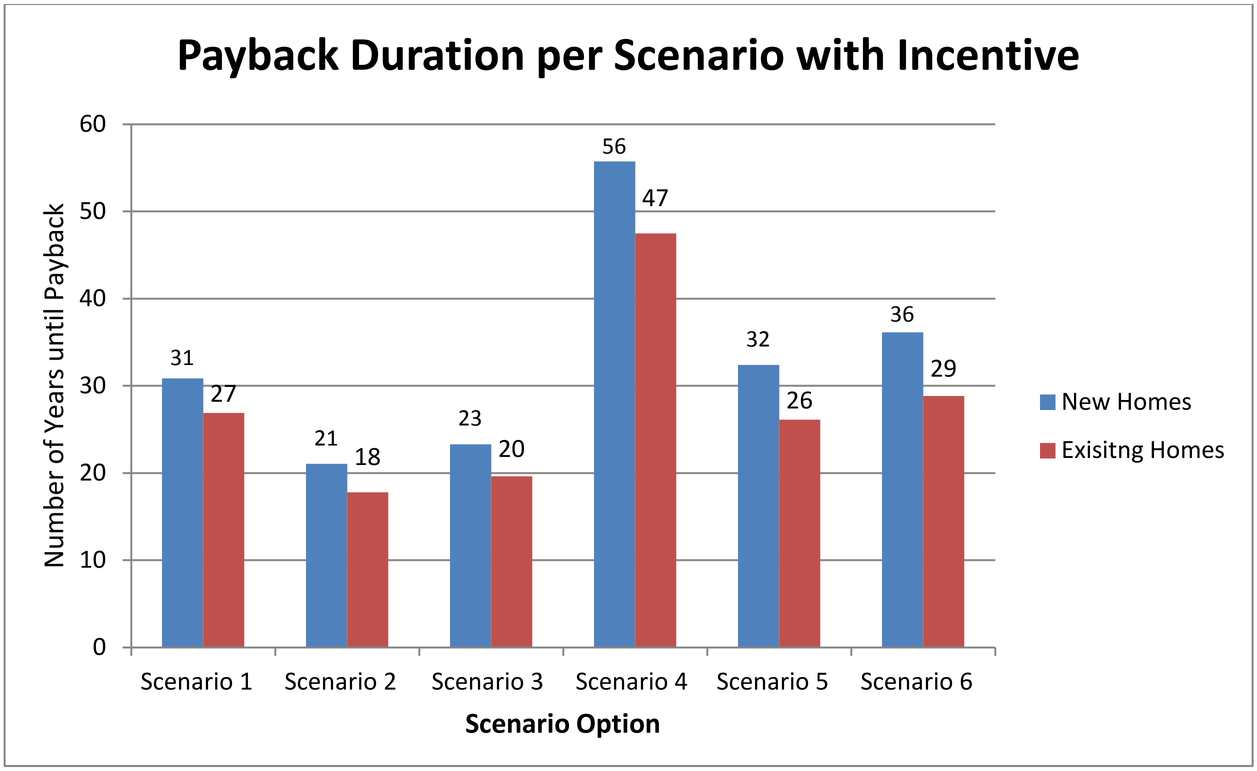

Figure 7: New and Existing Homes Payback and Investment Scenario Summary

Through the modeling of POI for newly constructed homes it is important to note the absence of a payback of investment during the desired payback period (10 years) defined through social research and the intended life cycle of the water reuse system (20 years) within all modeled scenarios. This is largely due to the reduced annual water savings (in comparison to the existing homes) associated with the new construction requirement for efficient toilet fixtures, thus limiting the total use of treated greywater per flush in the home.

In looking to existing home based installations, modeled payback on investment through all scenarios once again failed to achieve the desired payback period resulting from social research through the field test (10 years). However, through the modeling of scenarios # 5 & 6, the payback on investment period for systems installed in existing homes did take place prior to anticipated life cycle of the greywater systems (20 years). Although a positive result, it is important to note that these scenarios are dependent on continued aggressive annual increases in water/wastewater utility rates (10% per year) as well as significant municipal policy changes related to premise isolation testing requirements for homes possessing such systems. In scenario #4 specifically, the requirement for premise isolation testing was removed completely, resulting in a savings of $150/year to the homeowner. However, with acknowledgement to the considerable risk associated with this policy revision and a water utilities obligation to mitigate sources of risk in protecting public health through service delivery, it is not anticipated that such approaches would be supported to promote POI to homeowners. Conversely, when looking to the POI of scenario #6 in existing homes (19.6 years) it is more feasible that a lesser testing frequency for premise devices may be considered by a utility provided that provisions for home greywater system installation are designed to achieve redundancy in premise and/or zone isolation in the home (such as air gaps for potable water system top-up in addition to a premise isolation device) to achieve a desired level of water source protection. Although the evaluation of this risk versus benefit would have to be conducted on a utility by utility basis, this scenario is once again predicated on aggressive annual increases in water/wastewater utility rates (10%) to achieve a payback on investment essentially equal to the useful life of the system.

It should be noted that the modeling of all above scenarios take into account financial savings stemming from incentives offered towards greywater system installation ($1500 per system) in alignment with the approach undertaken during the field test. With this in mind, it is anticipated that significantly longer payback periods would be expected by homeowners privately installing such systems that do not receive any incentives.

6.3 Cost Effectiveness of Municipal Water Demand Management Programming

Servicing capacity reclaimed through water conservation and efficiency is the most cost effective source of new water supply and wastewater treatment capacity. In alignment with this statement, it is common practice that through the development of municipal water efficiency master plans that the current cost of constructing infrastructure to provide one additional litre of water supply and wastewater treatment becomes the financial upset limit under which potential water conservation programs would be deemed as cost effective. For example, through the development of the City of Guelph 2009 Water Conservation and Efficiency Strategy the financial threshold for water conservation programming was deemed to be $4.00 per litre of average day capacity reclaimed, based on review of the current cost to construct 1 litre of average day supply for new water supply and wastewater treatment capacity, as defined through the City's 2006 Water Supply Master Plan and 2009 Wastewater Treatment Master Plan respectively.

To allow for the cost comparison of new servicing capacity construction to reclaimed capacity sources it is necessary that the full cost of offering water demand management programs be defined. These costs may include financial incentives but will also account for other costs associated with services such as staff administration, project management, program marketing, and monitoring. With reference to these costs, the below table provides an overview of the cost per cubic meter of average day servicing capacity reclaimed through common single family residential rebate programming offered by Guelph as taken from Appendix I of the City's Water Conservation and Efficiency Strategy (RMSi 2009):

Table 9: Municipal Rebate Programs – Cost of Reclaimed Capacity

Program	Rebate Provided ($ per participant)	Value of Capacity Reclaimed ($/L*avg day capacity)
HET Toilet Rebate Program – Single Family Res	$75	$2100
Efficient Clothes Washer Rebate Program – Single Family Res	$100	$1900
Efficient Humidifier	$75	$2060
Waterless Floor Drain	$60	$2090

In looking to the cost effectiveness of home greywater reuse system based demand management programming it is necessary that two key variables be considered; daily water savings and incentive amount. Through monitoring of household water demands, reductions in average household water daily savings of 49.8 litres per day and 67.8 litres per day were observed during the Field Test amongst new home and home retrofit installations, respectively. In looking to incentive amount, a one-time incentive of $1500 was selected for purposes of the Field Test through consultation with local stakeholders as an appropriate incentive to facilitate the desired installation of such systems by increasing technology affordability to homeowners. In merging these sources of information, the cost per litre of average day capacity reclaimed as a result of greywater system installations in new and existing homes would be $30.12 per litre and $22.10 per litre, respectively. This is significantly more expensive the City's current conservation program pricing threshold of $4.00/litre as well as that of currently identified construct costs for new infrastructure to create water and wastewater servicing capacity within the City, possessing a total maximum construction cost $8.16 per litre of water/wastewater capacity gained. With this in mind, it is recommended that the current incentive amounts offered as part of subsequent programming be reduced to more accurately reflect the value of water/wastewater capacity reclaimed by the City.

With reference to this analysis, it is important to note that financial thresholds for municipal conservation programming will drastically vary on a jurisdiction by jurisdiction basis and be subject to increases stemming from the overall complexity of establishing new sources of water supply and wastewater treatment as well as the impacts of water scarcity. With this in mind, it is recommended that communities contemplating such programs evaluate affordability and related financial thresholds in the context of their unique water supply and wastewater treatment systems.

6.4 Preliminary Lifecycle Assessment (PLCA)

For purposes of the Field Test a Preliminary Lifecycle Assessment was completed by the University Of Guelph School Of Engineering. The main goal of the PLCA was to determine the environmental performance of greywater reuse systems technologies (GWRS #1) compared to the baseline: treating wastewater solely at the wastewater treatment plant, or business as usual. The environmental performance was analyzed with the following impact categories; water use, climate change (greenhouse gas emissions, GHG), electricity, and resource use (treatment chemical use). A consequential PLCA was conducted on a greywater reuse system. For reference the complete PLCA is available within Appendix D of this report.

Results of the PLCA suggest that GWRS appear to be less sustainable than the conventional centralized treatment approach. However, conserving water does have environmental benefits that were not considered in this calculation. By using a GWRS and through water conservation, water is left in the natural water cycle providing important environmental benefits and services. A more detailed and rigorous life cycle assessment is needed to better understand the environmental impacts of GWRS compared with conventional water and wastewater management approaches.

7.0 Backflow Prevention Device Assessment

7.1 Approach

To ensure the municipal water supply was protected from potential contamination events, backflow prevention devices were installed on participating homes. While the CSA's *Manual for the Selection and Installation of Backflow Preventers* (B64.10) currently allows non-testable backflow preventers to be installed in homes with greywater systems, the City's by-law requires all premise isolation devices to be testable and that these devices be tested on an annual basis (approximate cost of annual testing is $150).

For research purposes, 14 of the participating homes were fitted with a Double Check Valve Assembly (testable device) and 11 were fitted with Dual Check Valves (non-testable device). These devices were installed at no cost to participating homeowners with annual device testing completed by representatives of the City's Building Services Department. Device testing was completed in the field at the point of original system installation and at an annual frequency thereafter. All of the devices were tested in the field through use of a differential pressure gauge, with the same set of differential pressure gauges used for all homes. This differential pressure gauge was also calibrated on an annual basis in order to ensure accuracy.

7.2 Devices in Field

Both Double Check Valve Assemblies (40-100 series) (DCVA) and Dual Checks (40-300 series) (DuC) are designed with two normally closed check valves that open when water flows in the "normal" direction and close when water flows in the opposite direction. These devices will maintain premise isolation even if one of the check valves fail. While the B64.10 classifies a device with only one working check valve as a "failed device", during this pilot project this condition was identified as only a "partial failure".

All piping used to convey non- potable water in this pilot project was clearly marked "Non Potable" using either labels or by the use of purple piping. There were no direct connections of between the potable and non-potable water systems in any home. Make-up water to the greywater tanks was achieved by means of an air gap.

Each backflow prevention device was tested at installation and then annually thereafter. There appears to be little difference between the two types of devices tested as part of this pilot project regarding their effectiveness to deliver an acceptable level of premise isolation. To date, none of the devices completely failed, however, some of the devices did experience failure of a single check valve.

7.3 Recommendations

1. Amend the City's backflow by-law to allow non-testable backflow preventers to be used for properties (residential/non-residential) with a minor hazard classification where no actual cross connections exist. This will eliminate the associated costs for annual device testing while still maintaining public safety.

2. Utilize City's Cross Connection Control Program to ensure that the current level of protection for the public water system remains at an acceptable level.

8.0 Municipal Management Framework

8.1 Background

A key barrier to the uptake of decentralized water reuse systems has been the lack uniform frameworks to manage the installation, maintenance, and ongoing operation of such systems on a jurisdiction by jurisdiction basis. With reference to this challenge, it is essential that communities contemplating wide spread implementation of such technologies individually evaluate their local community circumstances to determine the appropriate management framework through which centralized water reuse may be supported while also reducing potential liability should issues arise.

In breaching this barrier, *the United States Environmental Protection Agency's Handbook for Managing Onsite and Clustered (Decentralized) Wastewater Treatment Systems (EPA No. 832-B-05-001, December 2005),* which provides direction for establishing such frameworks, states that "each community must carefully evaluate its situation and management needs to develop a program that is supported by residents, protects human health and the environment, and allows the community to grow and prosper in a sustainable fashion consistent with land use plans and needs." In best managing these unique elements, the *Handbook* further recommends that each level of government "develop a well thought out strategy that considers a number of factors, including design options, site conditions, operational and maintenance requirements, periodic inspections, monitoring and financial support." Similarly, the *Handbook* also stresses that a central component of such strategies be the introduction of necessary legal authority to implement such requirements. Such Legal authority for centralized water reuse systems may include (but are not limited to):

- Issuing System Operating Permits;
- Requiring System Maintenance Contracts;
- Setting System Maintenance, Repair and Replacement and Maintenance Schedules;
- Mandatory System Inspections, and;
- Monetary Fines for Non-Compliance with above.

8.2 Management Framework Development

In beginning to define a management framework for Guelph, a staff stakeholder workshop was held on February 8, 2012. The workshop served as an initial opportunity for the project team to share results of the Field Test with a wide range of internal City stakeholders and gain stakeholder insights/feedback with respect to key barriers and opportunities related to current technologies.

Stakeholder representation from various groups and divisions within the City were invited with representatives from Building Services, Corporate Communications, Corporate Energy Services, Legal Services, Water Services and Wastewater Services participating in the actual workshop.

Information attained as a result of this workshop was utilized by the Greywater Field Test project team to demonstrate a process to through which creation of potential management framework could be undertaken with hopes that this process may form an example for other Canadian Municipalities considering the application of such technologies in their respective jurisdictions.

For purposes of this workshop Guelph had retained the professional services of staff from a local office of AECOM to assist with facilitation of the workshop, guide City staff and solicit feedback regarding the probability and consequence of potential known issues associated with residential grey water reuse from their individual viewpoints as well as documentation of workshop findings within a final summary report. For reference, this complete report form this session is included in Appendix E.

It is to be noted that based on the original scope of the Guelph Greywater Field Test the Management Framework Workshop included only the participation of Guelph staff stakeholders with discussion informed by information attained via community stakeholder feedback received during through other elements of the Field Test. With this in mind, it is recommended that greater community consultation be conducted by other jurisdictions undertaking such works to best define the opportunities and challenges amongst all stakeholders.

8.3 City of Guelph Greywater Field Test Management Frameworks

With reference to the City of Guelph Greywater Field Test it is important to acknowledge the complement of management frameworks employed by the City as part of implementation and ongoing study as part of the Field Test. These frameworks included the formation of new policy guidelines on a local basis (such as system eligibility standards) but also encompassed the use of existing codes and standards from local, provincial, and federal government entities and respective industry associations. Included below is an overview of these individual frameworks for reference:

- **City of Guelph Backflow Prevention Bylaw** - bylaw defines requirement for the installation of a premise isolation device, and type of respective device, based on the installation and ongoing presence of an auxiliary water system. Bylaw also requires that device be tested on an annual basis by a qualified professional to ensure proper working order and sets value of monetary fines should compliance with such requirements not be met by the owner of the premise.

- **Customer Support** – throughout duration of field test participants had the ability to contact City staff, respective home builders, and product suppliers to assist with questions regarding the system and/or any site based issues experienced. Further to support network, each system was also inspected by a product representative following a prolonged period of operation to assess system performance, repair potential deficiencies, as well as to provide a refresher to homeowners on system maintenance requirements and offer instruction on basic troubleshooting relating to common system field issues.

- **General System Education** – Educational information was provided to all homeowners after system was installed outlining general function of system and required maintenance duties/frequencies. Greywater reuse system product overview workshops were also held with product supplier, local home builder representatives, and plumbing contractors to define system installation, operation, and maintenance requirements.

- **Ongoing System Sampling and Performance Reporting** – sampling of household treated greywater was completed on monthly basis by City staff. Through onsite sampling, homeowners possessed ability to ask ongoing questions of staff regarding system performance and related issues experienced. Furthermore, through ongoing site visits, City staff would alert homeowners to issues detected via onsite water quality sampling (such as insufficient chlorine residuals) and provide advice towards issue remediation.

- **System Eligibility Standards** – system design and installations standards defined through consultation with City departments and research current codes and standards, including Ontario Building Code, CSA Standard B128.1/2 and the Health Canada Guidelines for Domestic Water Reuse (2010).

- **System Installation by Competent Individuals** – to ensure eligibility for incentive, systems had to be installed by professional plumbing contractor.

- **System Installation-based Permitting and Field Plumbing Inspections** – requirement for homeowners installing such systems to attain a building permit and supporting field inspections following contractor installation of system.

8.4 Risk Management

In working to define municipal management, the Staff-stakeholder workshop included a facilitated risk management exercise, based in ISO Standard 31000, to solicit feedback from staff on perceived issues and related opportunities to mitigate such challenges.

The risk assessment conducted during the workshop considered only risks, causes, and impacts from Guelph's perspective, and not from the side of the customer. In general, the assessment also examined greywater reuse on a small scale similar to the Field Test. As such, it is recommended that the risks, causes, and impacts should be re-evaluated if large-scale implementation is being considered.

The following identified risks were reviewed and discussed during the workshop:

1. Operational requirements and capacity planning
2. Potential source contamination of water system
3. Education of homeowners
4. Availability of Contractor / manufacturer to provide continuous support of greywater reuse systems
5. Existence of licensing, permitting, and product performance standards
6. Not implementing greywater re-use in the City
7. Being a leader (there are no established Canadian precedents)

For each of the risks above, the workshop participants discussed causes and impacts as summarized in the tables below. For the high probability / consequence of failure scenarios, mitigating measures were also discussed. The risk rating was established for both the current state and under a scenario of an expanded program (based on hundreds or thousands of installations). Included in the tables below (Table 10 to Table 16) is a summary of staff stakeholder feedback attained through the evaluation of each risk:

Table 10: Risk Associated with Operational Requirements and Capacity Planning

RISK: Operational Requirements and Capacity Planning	
Causes: • Requirement to supply more water due to system failure / homeowner removal of system • Reduction to planned servicing capacity to area knowing systems create demand offset • Reduced wastewater conveyance flows, due to reduction in demands	**Impacts to City:** • Service interruption • Requirement to supply more water • Increased sanitary system flushing • Failure to achieve desired targets for potable water demand reduction
Risk Rating (Pilot): • Low Probability of Failure • Low Consequence of Failure	**Risk Rating (Expanded Program)** • Medium Probability of Failure • Medium Consequence of Failure
Risk Mitigation: • Increase drainage slope design • Line sewers • Look to new communal system or installation in new subdivision so you can control slopes and design standards	

Table 11: Risk Associated with Potential Source Contamination of Water System

RISK: Potential Source Contamination of Water System	
Causes: • Wrongful cross connection (potable / non-potable system) within home • Failure of backflow prevention device (testable) • Failure of backflow prevention device (non-testable) • Reduced wastewater effluent quality (High BOD, COD, Chlorine Residual) • Increased presence of mould foundation (toilet tank / greywater system) • Attempting to install the device by homeowner – improperly • Home changeover / point of sale	**Impacts to City:** • Impact to water quality in home resulting in impacts to the City's reputation • Removal of system in home • Decreased desire for large scale implementation • Concern with health and safety impacts to customer • Loss of City and program reputation
Risk Rating (Pilot): • Low Probability of Failure • High Consequence of Failure	**Risk Rating (Expanded Program):** • Medium Probability of Failure • High Consequence of Failure
Risk Mitigation: • Homeowner Education about internal plumbing and maintenance requirements of the system • Increased testing in system • Development and documentation of proper maintenance procedures (end user training programs) • Continue to meet with homeowners (i.e. re-education through backflow inspection by the City during the five year program, by plumbing inspectors in the future) • Ongoing review and testing of systems that are installed • Improved Standards for installation and system upkeep • Testing of backflow prevention device on regular basis	

Table 12: Risk Associated with Education of Homeowners

RISK: Education of Homeowners	
Causes: • No maintenance of system by homeowner • Wrongful disposal of household hazardous waste • Improper installation / modification of system by homeowners • Extent of information on technologies received by new home buyers from home builders	**Impacts to City:** • Increased water consumption. • System removal, and loss of investment by the City • Impact to greywater re-use effectiveness • Impact to operational costs through pumping potable water • Introduction of hazardous waste to reuse system and loss of reputation to the City as the program is endorsed by City. Although a contact is signed, there is concern for future owners. • General customer dissatisfaction with system (loss of reputation) • Loss of investment by the City • Resulting damage from improper installation or inspections • Homeowner uptake will suffer without the proper education and knowledge
Risk Rating (Pilot): • High Probability of Failure • Low Consequence of Failure	**Risk Rating (Expanded Program):** • High Probability of Failure • High Consequence of Failure
Risk Mitigation: • Homeowner education • More/enhanced education materials • More timely education (i.e. In the case of the new builds) • Education of those supplying the systems (builders) • City (water efficiency) ownership with support from other departments • Development of proper maintenance procedures • Up front capital and operating costs, with tailored educational material from what was learned through pilot project • Continue to meet with homeowners (i.e. re-education through backflow inspection by the City during the five year program, by plumbing inspectors in the future?) • Consider modifying the agreement such that the systems are not removed, or are reclaimed by the City if they are removed • Develop rules governing maintenance, home sales • There could be more regulation of the program by the City. (will come at a financial cost for enforcement at City, and may also deter residents from participating) • Consistent communication from the City • Phased incentive structure, for example if customer complies; the second phase of the grant is issued, when proper operation and maintenance is demonstrated • Create incentive for developers for taking greater ownership for system performance • Require notice of system decommissioning	

Table 13: Risk Associated with Availability of Contractor / Manufacturer to Provide Continuous Support of Greywater Reuse Systems

RISK: Availability of Contractor / Manufacturer to Provide Continuous Support of Greywater Reuse Systems	
Causes: • System repair by homeowner in absence of support • Lack of formal contractor certification program in Canada • Lack of local manufacture representatives to conduct repairs/ education • Warranty Issues	**Impacts to City:** • Impact to City's Reputation • Removal of System
Risk Rating (Pilot): • High Probability of Failure • Low Consequence of Failure	**Risk Rating (Expanded Program):** • High Probability of Failure • High Consequence of Failure
Risk Mitigation: • Lobbying for contractor education programs to create larger support base in Canada (Green Plumbers) • Certification for equipment and installation • Require notice if a backflow device is removed • City look to invest /own companies that supply and install products (trend occurring in Europe). Rent systems out to people like a water heater program – establish terms of rental	

Table 14: Risk Associated with Lack of Licensing, Permitting and Product Performance Standards

RISK: Existence of Licensing, Permitting and Product Performance Standards	
Causes: • Illegal system installation • Inability for building officials to enforce CSA standards • Lack of system owner licensing process • Lack of experience in installation • Lack of experience in Inspector training • Lack of experience in regulation side	**Impacts to City:** • Contamination within home • System decommission, or failure • Customer dissatisfaction with program
Risk Rating (Pilot): • High Probability of Failure • High Consequence of Failure	**Risk Rating (Expanded Program):** • High Probability of Failure • High Consequence of Failure
Risk Mitigation: • Control through installation through grant program • CSA Standard Development (wait until implementation of CSA B128.3 testing program/available certified technology). • City could lobby ministry of housing to include CSA B128 standards as part of base building code – currently no reference standard or tools for enforcement for initial installation although OBC contains direction on backflow requirements (i.e. no certification for installation).	

Table 15: Risk Associated with Not Implementing Greywater Re-use in the City

RISK: Not Implementing Greywater Re-use in the City	
Causes: • Risk of not implementing achieving water conservation program targets. Inability to reach such targets may impacts to existing/future permit to take water for water supply sources.	**Impacts to City:** • Loss of Reputation • Failure to meet long-term water conservation targets • Future regulatory compliance issues (Water Opportunities and Conservation Act)
Risk Rating (Pilot): • High Consequence • Low Probability	**Risk Rating (Expanded Program):** • High Consequence • Medium Probability

Table 16: Risk Associated with Being a Leader in Relation to No Established Canadian Precedents

RISK: Being a Leader in Relation to No Established Canadian Precedents	
Causes: • No widespread uptake in City/Country	**Impacts to City:** • Lack of manufacture supplier support, increase costs • Impeding market • Loss of reputation by promoting technology • Higher implementation and management costs – market conditions drive costs • If no manufacture supplier support, increased liability, decreased reputation to City.
Risk Rating: • High Probability • High Consequence	**Risk Rating (Expanded Program):** • High Probability • High Consequence
Risk Mitigation: • Continue to research and review industry practices including international programs and technologies • Solicit input from Canadian practitioners • Engage manufacturers, plumbing contractors and other agencies (consider WEAO, WEF, OWWA etc.)	

8.5 Impact on Overall Risk Level of Expanded System Implementation

In general, the level of risk based on the consequences and probability of failure will increase as the program and acceptance of greywater systems expands beyond the current 25 pilot installations.

For example, while City staff was able to interact on a “one on one” basis with the relatively few participants in the pilot project, this same level of interaction would not be possible for an expanded program including hundreds or thousands of greywater systems.

This in turn will put additional requirements to ensure that the recommended mitigation factors, tools and resources are in place within the City to allow for increased levels of inspection, communication, testing, education, and enforcement. Ultimately, as systems are implemented in wider areas of the City, the possible geographic areas and individual sources of contamination will also increase.

Some of this increased risk level will be mitigated as general consumer/household knowledge of the systems functionality and use increases and as greywater reuse systems become more commonly accepted.

In addition, one key issue is the lack of CSA Standards and Certification for the equipment and installation of systems. Similar to more widespread understanding of the systems by end users, as the manufacturing community expands development and distribution of greywater systems to the user community, research and development will also assist in developing technologies that are more user-friendly and less costly.

In general, it was suggested that currently certification and training and public education are thought be the biggest risks for the City moving forward with broader implementation of programs.

8.6 Management Framework Recommendations

Through information attained through staff stakeholder consultation, the following actions are recommended to further enhance municipal management frameworks at the current scale of greywater reuse technology implementation:

1. **Need for Increased Communication & Public Education:** With system operation/performance contingent on the homeowner's ability and willingness to complete ongoing system maintenance, it is recommended that introductory educational and promotional elements of water reuse programming accurately reflect all duties/requirements of system ownership. Although this approach may work to effectively limit some audiences from participating, the added transparency provided through introduction of these requirements would be expected to promote a more robust and prepared participant base. Beyond introductory program marketing, it is also recommended that early educational opportunities be introduced to familiarize participating homeowners with their water reuse system as well as system maintenance and common troubleshooting requirements. Furthermore, in sustaining benefits to all parties via system use, it is recommended that vehicles for continued communication with program participants be implemented to offer reminders to homeowners about regular maintenance, to share lessons learned from participant peers, and to increase awareness of support resources available amongst participant groups.

2. **Participant Support Networks:** In concert with homeowner educational requirements, it is also recommended that educational opportunities for local trades and contractors be developed to further the knowledge base and support network for program participants. An example of such educational opportunities would include the Green Plumbers Program, available in Australia and the United States of America, through which plumbing contractors may gain certification in water reuse system installation and servicing, amongst other environmental disciplines.

   Separately, through defining technology eligibility standards for water reuse programming, it is recommended that consideration be given to the presence of necessary educational and customer support requirements through eligible technology selection. This may be limited to the presence of operational manuals and local-based customer service support representatives, but could be further defined to increase educational requirements to include instructional videos or other resources seen to best support the needs of program participants.

3. **Operational Permitting/Contracts:** In looking to legacy challenges around technology installation (such as home resale and technology management amongst new homeowners), staff/stakeholder consultation completed as part of this study offered some valuable suggestions with reference to system-based operational permitting which were not considered through initial implementation of the pilot. With this in mind, it is recommended that further evaluation of water reuse system operational permits be assessed in hope that the introduction of such controls would increase the level of information received regarding active systems on an ongoing basis as well as define the duty to disclose necessary operational requirements of system during events such as home resale and system decommissioning.

4. **Technology Performance Testing and Certification:** the Canadian Standards Association endorsed Standard B128.3 - *Performance of Non-Potable Water Treatment Systems* within the closing period of the Field Test. This Standard aims to evaluate and certify water reuse technologies (packaged plants) versus a series of common stresses/operational challenges confronted by such system in real world environments. With this standard recently approved, and certified testing facilities for such technologies still to be established, the presence of CSA B128.3 certified technologies is not anticipated in the short-term. However, in looking to the timing of the introduction of certified technologies, it is recommended that technology eligibility criteria for water reuse programming integrate this certification in the future to reinforce the use of robust technologies in the field.

9.0 Executive Summary & Recommendations

Background

As one of Canada's largest communities reliant solely on a finite groundwater source for its drinking water needs, the City of Guelph's ability to achieve water and wastewater servicing capacity through conservation offers numerous benefits. In looking to water supply capacity, community conservation programming offers water resource sustainability and financial competitiveness of the City's water utility while meeting the water resource needs associated with significant community growth – an anticipated additional 50,000 persons by 2031 (Ontario Places to Grow Plan). When looking to wastewater servicing, as the assimilative capacity of the Speed River (the City's sole location for treated wastewater effluent discharge) to accept increasing volumes of treated wastewater effluent is limited, the ability to reduce the volume of liquid wastewater requiring treatment offers ecological benefits to the Grand River Watershed as well as capital and operation financial benefits to the City.

In 2006 Guelph City Council endorsed the *Water Supply Master Plan (WSMP).* This detailed Master Plan evaluates the water demand associated with projected growth over a 50-year planning horizon as well as new water supply alternatives necessary to facilitate future community growth. This Master Plan identified water conservation and efficiency as the most cost-effective and immediately available source of new water supply and, as such, ranked water conservation and efficiency as the #1 water supply priority action. In support of this direction, the WSMP identified three time-based water reduction targets based on 2006 average daily water production volumes:

- Reduction of 10% (5,300 m3/day) in average day water use by 2010;
- Reduction of 15% (7,950 m3/day) in average day water use by 2017; and
- Reduction of 20% (10,600 m3/day) in average day water use by 2025

Further to the WSMP, both the *2007 Community Energy Initiative* and the *2007 Guelph Strategic Plan* set sustainability performance goals of using "*less water and energy per capita than any comparable Canadian city*." These goals continue to guide the City's current water conservation activities and bring greater emphasis to the relationship between water supply, wastewater treatment, and energy demand.

To achieve these targets, an update to the City's *Water Conservation and Efficiency Strategy (WCES) was initiated* in February of 2008. This award winning 10-year strategy was endorsed by Council in May 2009 and identifies the preferred program, policy, and resource recommendations to achieve a further reduction of 8,773 m^3/day by 2019, as well as to achieve the aggressive reduction targets of the *Water Supply Master Plan, Water and Wastewater Master Servicing Study, Wastewater Treatment Master Plan, Community Energy Initiative,* and *Council's Strategic Plan*.

Through development of the WCES it was noted that many long standing local municipal water conservation programs, such as toilet or clothes washers retrofit rebates, would reach saturation by the end of the 10-year planning horizon of this strategy. Therefore, in meeting the long-term reduction targets of the WSMP, further capacity development was required in the area of research and evaluation of new demand management alternatives. As part of public consultation completed through development of the WCES, strong public and political support for decentralized demand substitution approaches, including greywater reuse and rainwater harvesting, was expressed. With this in mind, pilot programs for home-based greywater reuse and rainwater harvesting programs were approved by Guelph City Council as part of the final WCES to further investigate these technology alternatives and build the necessary technical and social capacity to ensure future readiness of these alternatives.

Residential Greywater Reuse Field Test

In May of 2009 the City of Guelph initiated the Residential Greywater Reuse Field Test to assess the feasibility of large scale adoption of home-based greywater reuse technologies. The study set a target of installing greywater systems in a total of 30 homes (both existing and new homes) to assess system performance in real world environments. Five core areas of study were chosen by the project team, including:

- System Operation and Performance
- Public Perception and Homeowner Satisfaction
- Household Water Use and Related Energy Monitoring
- Municipal Management Frameworks and Required Support Networks
- Premise Isolation Device Requirements

To solicit participation in the study, City staff completed consultations with interested members of the Guelph and District Home Builders Association in late 2008. As a result of these consultations, three local home builders, Fusion Homes, Reid's Heritage Homes, and Evolve Builders Group, agreed to participate in the Field Test and to market residential greywater reuse systems to their clientele.

To promote uptake of greywater reuse technology, Guelph offered an incentive of $1500 to home owners installing an approved greywater system in either new or existing homes. Program participants were also provided at no charge with backflow prevention (premise isolation) devices as well as financial compensation towards the required annual testing of these devices over a five-year period. In exchange for receiving the incentives identified above, participants agreed to allow City representatives to monitor the water quality of the greywater produced by their system on a monthly basis for a period of 12 months, with a single final water quality sample to be taken 24 months after system installation. Additionally, participants were requested to provide feedback through social feedback forums, interviews, and surveys to share their experiences and attitudes towards the technology.

As of completion of this report, a total of 25 participants have installed home greywater reuse systems, including ten in new homes and fifteen in existing homes. Further findings of the Field Test are detailed in the following sections for reference. For additional information on the Guelph Residential Greywater Field Test please visit www.guelph.ca/greywater.

Greywater Field Test Project Team

A multi-stakeholder project team was established to direct the development, implementation, and evaluation of the Field Test. This project team included representatives from academia, the local home building and home renovation industry, water efficiency engineering consultants, and City staff. The project team is identified below:

Academia

- Matthew DeLuca, M.Sc., University of Guelph
- Khosrow Farahbakhsh, Ph.D., P. Eng., University of Guelph
- Benjamin Kelly, Ph.D., Nippissing University

City Staff:

- David Auliffe, City of Guelph
- Wayne Galliher, A.Sc.T, City of Guelph
- Jennifer Gilks, M.Sc., City of Guelph

Home Builders:

- Andy Oding, Reid's Heritage Homes
- Ben Polley, Evolve Builders Group
- Ron Thompson, Fusion Homes

Professional Engineering Consultants:

- Bill Gauley, P.Eng., Veritec Consulting Inc.

The City of Guelph would like to thank the members of project team and their respective organizations for their great significant contributions and overall value added to the Guelph Residential Greywater Field Test.

Federation of Canadian Municipalities Green Municipal Fund

In December 2008, Guelph received notice from the Federation of Canadian Municipalities (FCM) that $72,524 in grant funding was to be provided through the FCM Green Municipal Fund for the Guelph Residential Greywater Reuse Field Test. FCM's gracious financial support has provided the necessary resources for the City and project team to effectively evaluate the social, economic, and environmental impacts associated with implementing home-based water reuse technologies as well as the considerations in establishing the appropriate municipal management frameworks for home water reuse technologies. The City of Guelph would like to sincerely thank FCM for their support of this initiative and it is hoped that the findings of this study will help to build further capacity and continue dialogue on water reuse amongst communities across Canada. For more information on the FCM Green Municipal Fund please visit: www.fcm.ca.

Field Test Observations

Key findings of the Residential Field Test included the following:

- **Water Demand Reductions:** Home greywater systems were successful in reducing household water demand over the period of study with average water demands decreasing by 22.6 litres per capita per day. However, the volume of water saved (and therefore the financial savings) is directly related to the flush volume of the toilets in the home (at this time greywater can only be used for toilet or urinal flushing in the home). In other words, as toilets become more efficient and less greywater is used per flush, the potential for water savings in the home decreases. Conversely, water savings would be greater in homes fitted with inefficient toilets that would flush with more greywater.

- **Public Health and Safety:** The social research completed as part of this project concluded that both systems owners and members of the general public had minimal concerns regarding personal health and safety associated with general greywater exposure via system upkeep and general operation. Interestingly, aesthetic concerns (odour and colour of treated greywater, for example) were the dominant quality concerns.

- **Audience for Technology:** With limited public awareness of residential water reuse technologies, the audience for such systems is greatly limited at this time. With this in mind, the future marketing and promotion of such technologies may be best suited to partnerships with green renovators and/or showcase opportunities through “Green Building” demonstration projects. Separately, social research identified that the term “greywater reuse” may limit acceptance of such technologies/practices amongst members of the general public. With this in mind, it is anticipated that future marketing/promotion approaches seek opportunities for more suitable terminologies, such as “recycled water”, to increase the perceived accessibility/applicability of these technologies to broader audiences.

- **Cost Effectiveness**: At the current municipal water and wastewater user rates, and with the use of residential greywater limited to toilet or urinal flushing, residential greywater reuse systems had significant payback periods (+30 years) when taking into account all operational costs of the systems. While this payback period will decrease as rates increase and system costs diminish, it is difficult to make a business case for the installation of greywater reuse systems in single-family homes at this time. Perhaps the business case associated with installing large-scale or communal greywater reuse systems would be more attractive.

- **Maintenance Program Challenges:** Residential greywater systems require ongoing maintenance, e.g., homeowners are required to remove soap and debris from system filters and to add chlorine pucks for disinfection when required.. Although this maintenance program was achievable for most participating homeowners, many of the homeowners grew tired of the maintenance requirements over time and expressed their desire for more system automation to alleviate the manual maintenance requirements for the homeowner.

- **Treatment Approach vs. Water Quality Guidelines**: Overall, the quality of treated greywater produced by the systems included in this pilot project had only a limited overall compliance with the water quality objectives of the *2010 Health Canada Guidelines for Domestic Water Reuse*. Although greywater quality is largely dependent on homeowner diligence regarding maintenance, quality is also related to the type of treatment employed by the greywater system (filtration and/or chlorination) and the high variability in inlet greywater quality, which is influenced by differences in soap/product use, duration of showers, and person hygiene habits amongst those studied. Most systems installed frequently met the guidelines for E.coli or fecal coliforms but failed to meet guidelines for turbidity and BOD.

Field Test Recommendations

Based on findings of Guelph's Field Test, the following recommendations have been developed for the implementation and enhancement of home water reuse system-based programming:

5. **Need for Increased Communication & Public Education:** With system operation/performance contingent on the homeowner's ability and willingness to complete ongoing system maintenance, it is recommended that introductory educational and promotional elements of water reuse programming accurately reflect all duties/requirements of system ownership. Although this approach may work to effectively limit some audiences from participating, the added transparency provided through introduction of these requirements would be expected to promote a more robust and prepared participant base. Beyond introductory program marketing, it is also recommended that early educational opportunities be introduced to familiarize participating homeowners with their water reuse system as well as system maintenance and common troubleshooting requirements. Furthermore, in sustaining benefits to all parties via system use, it is recommended that vehicles for continued communication with program participants be implemented to offer reminders to homeowners about regular maintenance, to share lessons learned from participant peers, and to increase awareness of support resources available amongst participant groups.

6. **Participant Support Networks:** In concert with homeowner educational requirements, it is also recommended that educational opportunities for local trades and contractors be developed to further the knowledge base and support network for program participants. An example of such educational opportunities would include the Green Plumbers Program, available in Australia and the United States of America, through which plumbing contractors may gain certification in water reuse system installation and servicing, amongst other environmental disciplines.

   Separately, through defining technology eligibility standards for water reuse programming, it is recommended that consideration be given to the presence of necessary educational and customer support requirements through eligible technology selection. This may be limited to the presence of operational manuals and local-based customer service support representatives, but could be further defined to increase educational requirements to include instructional videos or other resources seen to best support the needs of program participants.

7. **Affordability, Scale and Evaluation of Format:** With residential water reuse currently limited to end uses such as toilet flushing and the priming of traps, the business case for individual home-based water reuse systems will continue to be a challenge unless there is a significant increase in water/wastewater user rates. However, when looking to environments within which water reuse has gained significant uptake, such as in industry, the business case for such endeavors has been greatly aided by the overall scale of implementation and ability to offset significant

water/wastewater demands. In learning from these models, it is recommended that further evaluation of opportunities for increased scale and alternate service formats be investigated within residential environments. These format alternatives may range from a shared decentralized system within multi-residential type settings to more complex and large scale communal wastewater effluent systems, that are anticipated to enjoy the economies of scale realized within industry and provide the business case necessary for qualified personnel to manage ongoing operational and maintenance requirements of such systems. In working to define these preferred models, it is recommended that a community water reuse feasibility study be completed to assess opportunity by sector, through detailed stakeholder consultation and field process audits, to assess potable vs. non-potable water demands as well as the community appetite for subsequent programming and utility servicing models to best match local need.

8. **Backflow Prevention Policy Amendments:** A key challenge to making a business case for water reuse is the requirement for backflow prevention devices to be installed in homes with greywater systems and the associated cost of device testing on an annual basis. Although protection of public health is of paramount importance, there may be opportunities to manage the risk associated with the operation of greywater systems through alternate premise isolation service models and building practice requirements. In Guelph's Field Test, both testable and non-testable premise isolation devices were installed with field testing of all devices completed on annual basis. Both types of devices achieved the desired level of performance and no complete device failures were observed. In reference to these encouraging field results, and in having implemented system construction requirements prohibiting direct connection of potable and non-potable water systems in the home, it is recommended that City of Guelph Backflow Prevention requirements for such systems be revised to extend the duration at which such devices must be tested provided that redundancies are present within the home to limit cross-connections of the potable and non-potable systems (such as a premise isolation device and air gap for potable water addition to system). Furthermore, it is recommended that non-testable backflow prevention devices (such as Dual Check Valves) be considered for use with such systems with devices to be replaced (if needed) upon the revised inspection frequency to ensure ongoing working order. These recommendations are anticipated to significantly increase financial benefit to homeowners installing greywater systems by significantly reducing annual backflow device testing costs and reducing the costs associated with device replacement. However, with the public interest of mitigating potential risk, it is further recommended that greywater system and related plumbing system inspections be implemented on a annual basis in concert with this backflow policy revision to ensure proper working order of the systems and to manage the occurrence of private changes to household plumbing which may introduce potential threats following initial home plumbing inspections.

9. **Rebates and Incentives:** Based on the relatively high cost of system installation and the limited return on investment at this time, rebates and incentives continue to be an essential tool in promoting system uptake. However, in looking to municipal affordability, it is recommended that the financial value of municipal incentives be amended to reflect the value of water/wastewater serving capacity saved via system use on a municipality by municipality basis. Beyond the incentive amount, it is also recommended that the use of incentive programs create a linkage to desired community capacity building and knowledge development. For example, water reuse based programming noted in Southern Australia require that systems be installed by a certified Green Plumber to ensure proper system installation/program eligibility. Such program models are seen to create an incentive for local

contractors to attain associated certifications as a matter of business development. They may also enhance a community's knowledge base for water reuse and associated support networks.

10. **Management Frameworks:** With reference to the limited of scale of the Field Test (25 homes) and associated management controls in place, the risk of system malfunction or failure was largely limited to the occurrence of individual private household servicing challenges (inability to flush household toilets) and/or premise based contamination events (wrongful connection of potable and greywater home plumbing systems). Although these risks do require ongoing attention and response strategies, the format and scale at which these technologies were implemented during the Field Test provided a manageable level of risk in comparison to a more extensive roll-out of greywater reuse technologies. However, in looking to legacy challenges around such technologies (such as home resale and technology management amongst new homeowners), staff/stakeholder consultation completed as part of this study offered some valuable suggestions with reference to system-based operational permitting which were not considered through initial implementation of the pilot. With this in mind, it is recommended that further evaluation of water reuse system operational permits be assessed in hope that the introduction of such controls would increase the level of information received regarding active systems on an ongoing basis as well as define the duty to disclose necessary operational requirements of system during events such as home resale and system decommissioning. Furthermore, in building upon consultation completed at a staff stakeholder level, it is recommended that greater dialogue with community stakeholders be completed to assess the full spectrum of service models alternatives, risk by model as well as related mitigation and service response strategies to best address community desire and need.

11. **Technology Performance Testing and Certification:** With homeowner feedback attained through the Field Test showing great support for more automated/passive greywater reuse technologies, it is essential that further technology enhancement be undertaken at this time to meet greater consumer appeal. Fundamental to such improvements is the introduction of a representative performance testing protocols and associated technology certification programs to make greater performance information available to consumers and reinforce credible technologies in the marketplace. In this regard, the Canadian Standards Association endorsed Standard B128.3 - *Performance of Non-Potable Water Treatment Systems* within the closing period of the Field Test. This Standard aims to evaluate and certify water reuse technologies (packaged plants) versus a series of common stresses/operational challenges confronted by such system in real world environments. With this standard recently approved, and certified testing facilities for such technologies still to be established, the presence of CSA B128.3 certified technologies is not anticipated in the short-term. However, in looking to the timing of the introduction of certified technologies, it is recommended that technology eligibility criteria for water reuse programming integrate this certification in the future to reinforce the use of robust technologies in the field.

Next Steps

The Greywater Field Testing project provided significant insight into the challenges and opportunities associated with residential water reuse practices, including greywater reuse. This insight provided impetus to undertake further research and development to develop appropriate technologies and public acceptance strategies to enable progressive implementation of residential water reuse and recycling practices. For example, more attention must be placed on technologies that can produce effluent of higher aesthetic quality. Additionally appropriate technologies must minimize maintenance requirements and offer more cost-effective alternatives to homeowners. The process of technology development must also include shared and community-based systems. The University of Guelph in partnership with the City of Guelph, Viqua, Veritec Consulting, Guelph Chamber of Commerce and three builders, was recently awarded research funding for a two-year project to develop appropriate technology for residential water reuse in Ontario. This project will build on the outcome of the Greywater Field Testing project and will contribute to building capacity in developing and implementing sustainable water and wastewater management practices.

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