August 19, 2014

Sustainable Neighbourhood Retrofit Action Plan (SNAP) County Court - 71 Turtlecreek Blvd. Green Home Makeover

Energy and Water Use and Stormwater Monitoring Final Report

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1. Introduction

The County Court Sustainable Neighbourhood Retrofit Action Plan (SNAP) project focuses on promoting the adoption of more sustainable practices in an existing community in the City of Brampton. The neighbourhood is bounded by Hurontario Street to the west, Kennedy Road to the east, Highway 407 to the south and Etobicoke Creek to the north. As a strategic means of encouraging community members to renovate their 1980's era homes to take advantage of more energy and water efficient products available today, a single family detached home in the neighbourhood was selected to receive a "green home makeover". This makeover demonstration also supported new private sector partnerships and educational opportunities for the renovation industry.

The four bedroom house located at 71 Turtlecreek Boulevard in Brampton was selected in part because very few renovations had been undertaken since it was built in 1984. This offered the greatest opportunity to showcase the impact of green renovation. The green home makeover involved renovations to improve energy efficiency including replacement of heating (furnace, hot water, dryer), ventilation and air conditioning system components with high efficiency models, improved insulation in the walls and attic, replacement of all windows and air leak sealing. It also included renovations to improve water efficiency including replacement of the clothes washer, dishwasher, toilets and fixtures with low flow models. The front yard was also renovated to showcase landscaping that is less water-demanding than conventional turfgrass to help conserve municipal water and lot level stormwater management practices that reduce the amount of runoff that enters the storm sewers during rain and snowmelt events, to help restore more natural patterns of flow and aquatic habitat in Etobicoke Creek. A rain garden and permeable pavement driveway and walkway were installed and rain barrels were added to harvest roof runoff for use in landscape irrigation to offset use of municipal water. The renovations took place between September 14, 2011 and February 9, 2012. Appendix A describes all of the renovations that were implemented.

One of the objectives of the green home makeover is to demonstrate to the community the energy and water use savings and lot runoff volume reductions that are possible to inspire others to undertake similar types of renovations. Energy and water use in the home prior to the renovations were evaluated in the report entitled *Sustainable Neighbourhood Retrofit Action Plan (SNAP) County Court - 71 Turtlecreek Blvd. Green Home Makeover Pre-renovation Energy and Water Use* (TRCA, 2012a). In this report, pre-renovation energy and water use are compared to post-renovation consumption to quantify the savings achieved. In order to more accurately characterize usage in the home, the pre-renovation evaluation period used in this report is extended to four years for energy consumption and five years for water consumption from the two year period examined in the 2012 report. Post-renovation energy and water use and the effectiveness of the lot level stormwater practices to reduce runoff are assessed over a two year period. Efforts have been made to characterize energy and water usage both on an annual and seasonal basis where suitable information is available.

2. Information Sources

Energy Use

Pre-renovation energy use was evaluated over the four year period between mid-September 2007 and mid-September 2011. Post-renovation energy use was evaluated over the two year period between mid-March 2012 and mid-March 2014. Information regarding energy use and cost was drawn from electricity and natural gas bills. Electricity bills provide usage information on a monthly basis in units of kilowatt hours (kWh) as measured by the electricity meter installed on the home. Electricity bills also provide information on cost of electricity, which varies depending on the time of day the energy is consumed. Natural gas bills are also monthly and provide usage in units of cubic metres (m^3). Actual gas meter readings are provided bimonthly and every other bill is based on estimated usage. Both actual and estimated meter readings were used to determine natural gas use.[1] To calculate the cost of natural gas, the “total new gas charges” were extracted from each bill. Service charges such as the hot water tank rental fee were excluded from the cost analysis. Natural gas and electricity costs are reported exclusive of taxes in order to eliminate the effect of the introduction of the Harmonized Sales Tax (HST) midway through the evaluation period.

Seasonal use of natural gas and electricity was calculated by totaling monthly use each season.[2] Winter was assumed to be represented by the billing period beginning mid-December and ending mid-March. Spring was assumed to be represented by the billing period beginning mid-March and ending mid-June. Summer was assumed to be represented by the billing period beginning mid-June and ending mid-September. Fall was assumed to be represented by the billing period beginning mid-September and ending mid-December. For comparison, electricity and natural gas usage data were converted to common units of gigajoules (GJ)[3].

Water Use

Pre-renovation water use was assessed over the five year period beginning in late-September 2006 and ending in late-September 2011. Post-renovation water use was assessed over the two year period from mid-March 2012 to mid-March 2014. Information regarding water use was drawn from quarterly water bills which provide usage information in units of cubic metres (m^3), truncated to the nearest 10 cubic metres, as measured by the water meter installed on the home. To help quantify the savings achieved by yard renovations, pre-renovation outdoor water use was estimated through a seasonal analysis of water bill information. Since water use measurements were only available on a quarterly period, to characterize it on a seasonal basis billing information was summed according to a non-growing season

[1] Over the majority of the evaluation period, actual and estimated gas meter readings were provided for a one month billing period. Total usage was determined by taking the sum of both types of readings. From January to September of 2012, actual gas meter readings were provided for a two month rather than a one month billing period. .

[2] Each monthly billing period for natural gas began approximately one week later than the billing period for electricity. This was not considered to have a significant effect on the seasonal or annual analysis.

[3] One cubic metre of natural gas is equivalent to 0.0370804 gigajoules (GJ) of energy. One kilowatt hour of electricity is equivalent to 0.0036 GJ of energy.

and a growing season. The non-growing season was assumed to be represented by the billing period beginning in late-September and ending in late-March, during which outdoor water use is typically minimal or none at all. The growing season was assumed to be represented by the billing period beginning in late-March and ending in late-September, during which irrigation of lawns and gardens as well as other outdoor water uses typically occur. It is assumed that outdoor water use accounts for the difference in water usage between these two periods. Because the number of days between each billing period varies, water use is reported in units of litres per day (L/d). To understand how water use in the home compares to average residential water use in the Region of Peel, Ontario and Canada, annual water use in litres per capita day (L/cd) have also been calculated based on occupancy information provided by the homeowners.

Stormwater Runoff

Information sources used to evaluate the runoff reduction effectiveness of the Low Impact Development (LID) stormwater management practices implemented as part of the green home makeover were historical measurements of rainfall depth in the region, field monitoring of rainfall depth in the neighbourhood and water levels in the permeable driveway and rain garden. Post-renovation field monitoring was conducted between April to November 2012 and June to September 2013 , representing a monitoring period of 12 months.

Historical rainfall data from Environment Canada's Lester B. Pearson Airport climate station was used to characterize local rainfall depth, based on 30 year climate normal values that represent the average of 1981 to 2010 data. Environment Canada's climate normal monthly rainfall depth values and derived seasonal totals were compared to measured rainfall depth in the neighbourhood to determine whether or not rainfall during the post-renovation monitoring period deviated substantially from normal values (see Section 8, Table 3 for results of this comparison). Rainfall depth in the neighbourhood was continuously measured every 5 minutes by a tipping bucket rain gauge installed at City of Brampton Fire Station #206 (7880 Hurontario St.), located approximately 0.5 kilometres (km) from the property. The relationship between rainfall event depth and the portion of average annual rainfall depth that occurs as events less than or equal to that depth, based on 55 years of historical data (1950 to 2005) from the Lester B. Pearson Airport climate station (TRCA, 2013a) was also used to predict runoff capture performance of the rain garden and permeable driveway in an average precipitation year.

Water levels in the rain garden and permeable driveway were continuously measured every 5 minutes with pressure transducers installed in monitoring wells that extend to the base of each practice. Water level data was used to identify when each practice overflowed due to the water storage capacity being exceeded. By examining the relationship between rainfall event depth and the frequency of overflow, the size of rainfall event that each practice is capable of fully capturing runoff from on a consistent basis was determined. Using the relationship established by TRCA from the 55 year historical rainfall dataset from Lester B. Pearson Airport climate station, predictions were made regarding what portion of annual rainfall depth and runoff volume this represents in an average year. Continuous water level data was also used to evaluate the rate at which each practice drained, the length of time required to fully drain and how drainage rates varied over the monitoring period. This provides insight into the performance of stormwater infiltration practices on fine-textured soil like the silty clay glacial till subsoil present in this neighbourhood and provides a basis for examining how their drainage performance changes over time as the practices age.

Rainwater Use

The volume of rainwater used by the homeowners over the post-renovation monitoring period was evaluated by collecting continuous water level data in the front and rear yard rain barrels. Pressure transducers were installed in each rain barrel that collected water level data every 5 minutes over an April to November 2012 and June to September 2013 post-renovation monitoring period (12 months).

The volume of rainwater used during each usage event was calculated assuming the rain barrels are cylindrical and using the formula for the volume of a cylinder (i.e. $V = \pi r^2 h$) with the radius dimension being the average measured value and the height dimension being the decline in water level measured by the pressure transducer. Annual volumes of rainwater used were calculated by summing the usage event volumes for each year of the monitoring period.

3. Energy Use

Total pre-renovation household energy use is assessed against post-renovation use in Figure 1. Considering both natural gas and electricity, household energy consumption decreased from an average of 174 to 98 GJ per year, a reduction of 44%. Prior to the renovations, household energy use was 28% higher than the Ontario average of 136 GJ per year and 30% higher than the Canadian average of 134 GJ per year for single family detached homes (Statistics Canada, 2011). Post-renovation, household energy consumption is well below both provincial and national averages for this type of dwelling, decreasing to 28% below the provincial average and 27% below the national average for single family detached homes.

The energy consumption of a household also depends in part on its occupancy rate (Statistics Canada, 2011). As the occupancy of a household increases, more energy may be consumed for water heating, cooking, and home entertainment. Average household occupancy was reduced from five in the pre-renovation assessment period to four following the renovations. Therefore, a small portion of the observed reductions in energy consumption may be attributed to a decrease in average household occupancy in the post-renovation period.[4]

Household consumption of natural gas decreased by 49%, from 135 to 69 GJ per year (Figure 2). Post-renovation household consumption of natural gas is considerably lower than both the provincial (93 GJ per year) and national (92 GJ per year) average (Statistics Canada, 2011). Household electricity consumption was reduced by 26%, from 39 to 29 GJ per year (Figure 3). This is slightly less than the Ontario average of 30 GJ per year and well below the Canadian average of 40 GJ per year (Statistics Canada, 2011). It should be noted that the provincial and national averages for natural gas and electricity consumption are based on all dwelling types and household occupancies. Statistics regarding the consumption of different fuel types by dwelling type or household occupancy were not available.

[4] In Ontario, five person dwellings consume 13% more energy than four person dwellings. As such, approximately this proportion of the observed reduction in energy consumption may be attributed to the reduction in occupancy rate from 5 to 4 between the pre- and post-renovation assessment periods and not to the green home makeover.

Figure 1: Comparison of Pre- and Post-renovation Annual Household Energy Consumption

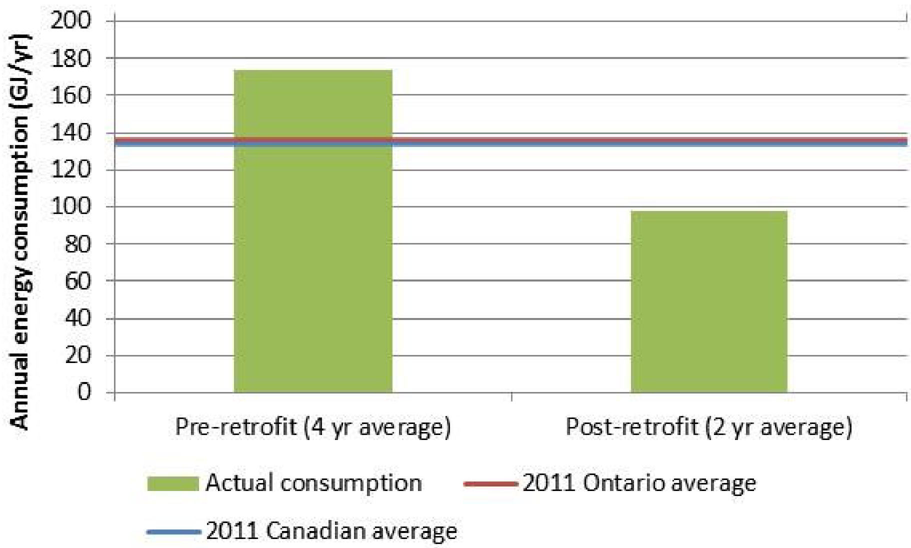


Figure 2: Comparison of Pre- and Post-renovation Annual Household Natural Gas Consumption

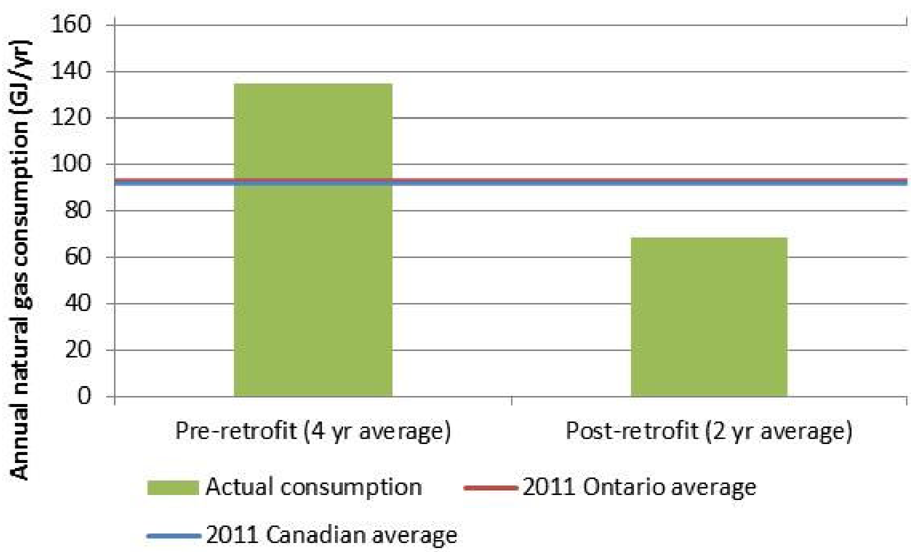
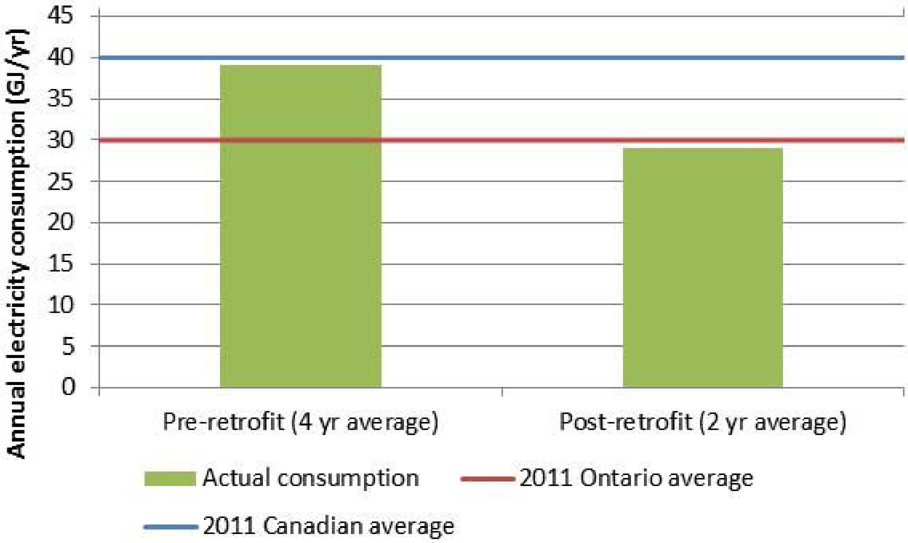


Figure 3: Comparison of Pre- and Post-renovation Annual Household Electricity Consumption



Seasonal household consumption of natural gas during the pre- and post-renovation period is presented in Figure 4. Considerable reductions in usage were achieved in all four seasons. Natural gas consumption decreased by 41% in winter, 56% in spring, 79% in summer, and 51% in the fall. The substantial reduction during the summer months can be largely attributed to the more energy efficient hot water tank and drain water heat recovery system as water heating would have been the only natural gas use during this period. The proportion of natural gas consumed each season was similar in the pre- and post-renovation periods, with the majority of natural gas being consumed in the fall and winter (Figure 5). This is expected, since natural gas is primarily used in the home for space and water heating.

Figure 4: Comparison of Pre- and Post-renovation Seasonal Household Natural Gas Consumption

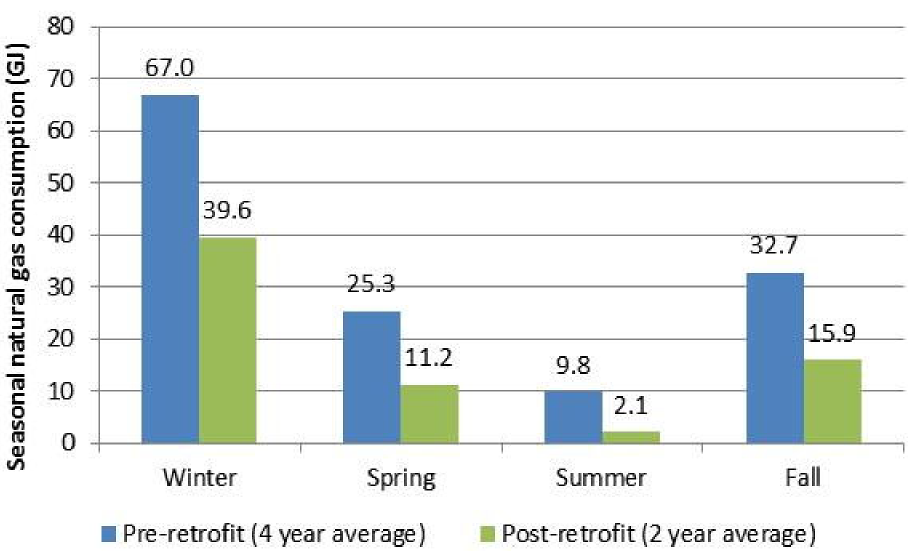
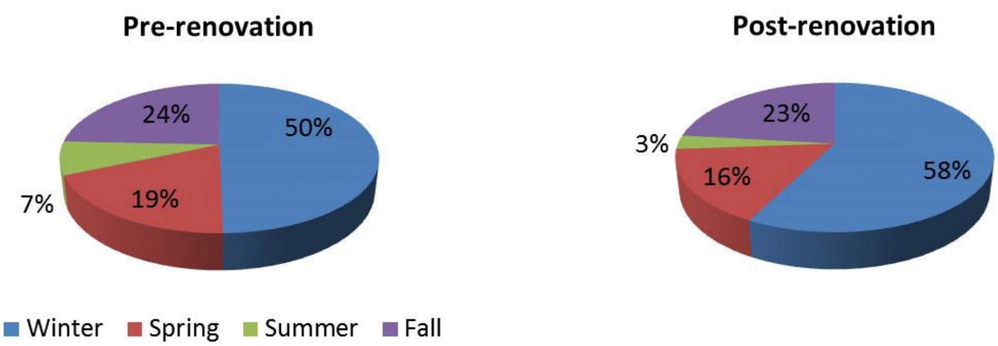


Figure 5: Seasonal Distribution of Household Natural Gas Consumption



NB: Values are seasonal averages over the four year pre-renovation and two year post-renovation assessment periods.

Seasonal household consumption of electricity also decreased considerably after the renovations (Figure 6). Consumption was reduced by 25% in winter, 19% in spring, 30% in summer, and 28% in fall. Again, the proportion of electricity used each season was relatively unchanged between the pre- and post-renovation assessment periods (Figure 7). Increased electricity savings observed during summer months can be attributed to the more efficient air conditioner that was installed as well as improvements to the building envelope (i.e. insulation, leak sealing) which would have helped prevent heat gain inside the home during hot summer days. Electricity use was nearly constant throughout the fall, winter, and spring, and increased slightly during the summer. The principal uses of electricity in the home are for air conditioning, lighting, appliances, and electronics.

Figure 6: Comparison of Pre- and Post-renovation Seasonal Household Electricity Consumption

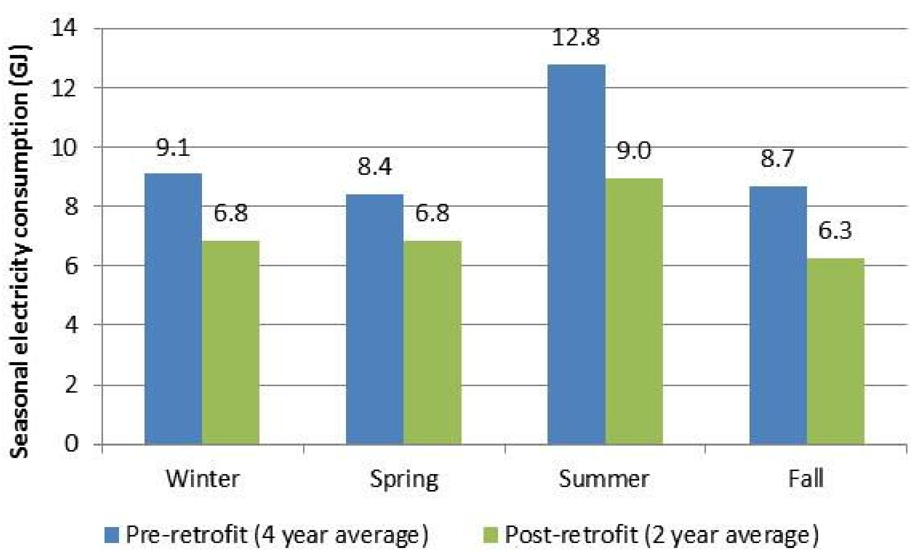
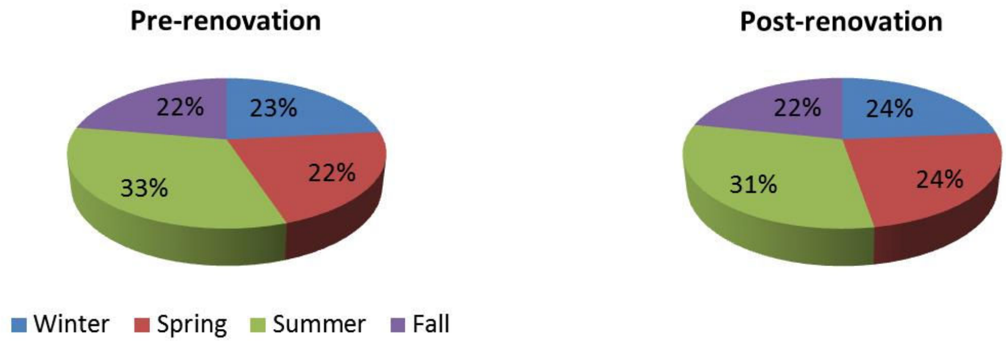


Figure 7: Seasonal Distribution of Household Electricity Consumption



NB: Values are seasonal averages over the four year pre-renovation and two year post-renovation assessment periods.

4. Energy Costs

Total household energy costs including both natural gas and electricity decreased by 36%, from an average of $2,597 to an average of $1,665 per year. Annual expenditures for natural gas were reduced by 52% following the renovations (Figure 8). The cost of natural gas[5] remained at approximately $10 per GJ between the pre- and post-renovation periods, so cost savings align closely with the observed reduction in consumption (49%). Seasonal cost savings ranged from 48% during summer to 56% during fall (Figure 9). As noted in the introduction, service charges such as the hot water tank rental fee were excluded from the cost analysis.

Post-renovation annual electricity costs were 17% less than pre-renovation costs. Electricity supply cost during the post-renovation period increased by 13%, from $30 to $34 per GJ, which explains why the savings in electricity costs were less than the savings in consumption. Seasonal costs savings ranged from 11% during spring to 22% during summer (Figure 10).

[5] The cost per GJ of natural gas and electricity was calculated by dividing the total cost of fuel in a given year by the total amount of fuel used. Annual cost per GJ was averaged over each assessment period to compare pre- and post-renovation supply costs. For natural gas, the "total effective gas supply rate" was not considered in the analysis because it was highly variable and did not account for changes in other auxiliary charges such as customer, delivery, and transportation to Enbridge fees. Actual supply rates for electricity were not available.

Figure 8: Annual Household Energy Costs (in $CDN)

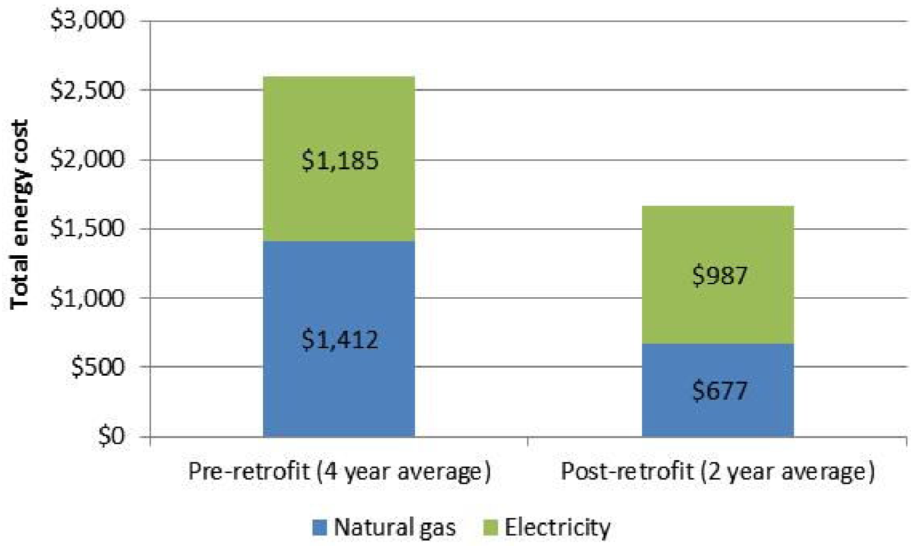


Figure 9: Seasonal Household Natural Gas Costs (in $CDN)

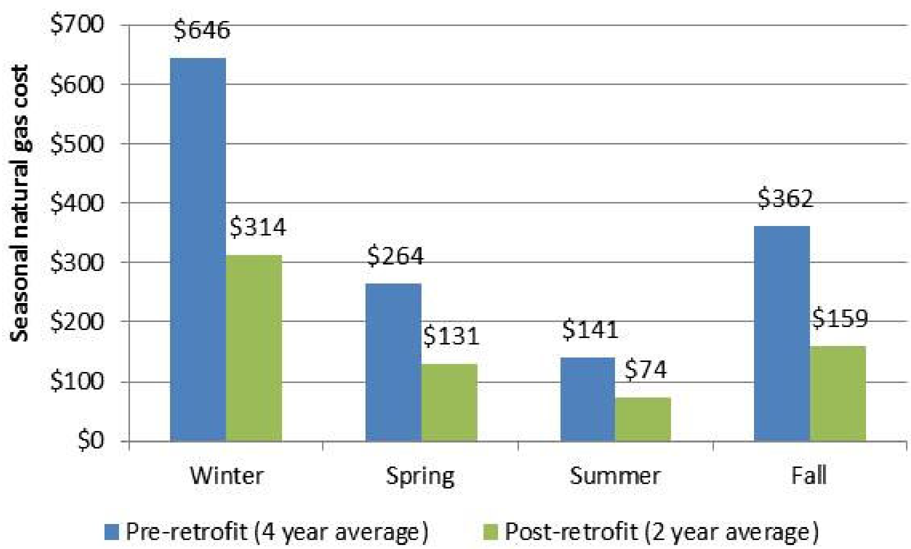
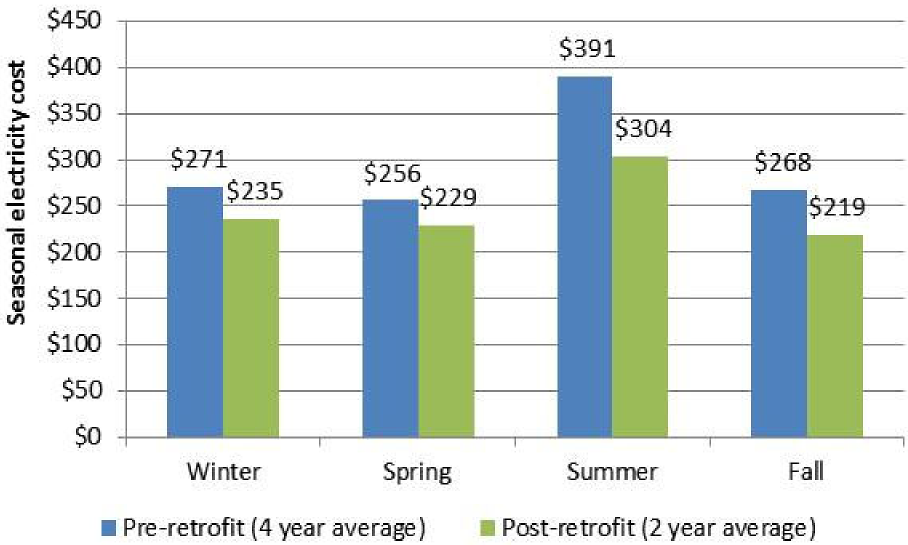


Figure 10: Seasonal Household Electricity Costs (in $CDN)



5. Water Use

Pre- and post-renovation household water usage for 71 Turtlecreek Boulevard is compared in Table 1 and Figure 11. The approach to comparing pre- and post-renovation household water usage was to base the calculations on a 5 year pre-renovation period that ended just prior to the initiation of renovation work and a 2 year post-renovation period that began after renovations were completed. This excludes the time period when renovations were taking place (October to December 2011), during which occupancy and water use may have deviated substantially from normal patterns. Five years of data were used to characterize pre-renovation water use in an effort to better encompass the range of variability that can occur in outdoor water use from year to year due to weather variability.

In the five year period just prior to the renovations, average household water use (both indoor and outdoor uses combined) was 196 L/cd, which is well below average use in the Region of Peel (244 L/cd), Ontario (225 L/cd), and Canada (274 L/cd) (Environment Canada, 2011 and Region of Peel, 2014) but 31% above the Region of Peel Water Efficiency Strategy target of an average of 150 L/cd by 2025 (Region of Peel, 2012). Post-renovation water use declined 41% to an average of 116 L/cd which is 23% below the Region of Peel 2025 target. Water consumption decreased by 65% in the non-growing season and by 43% in the growing season.

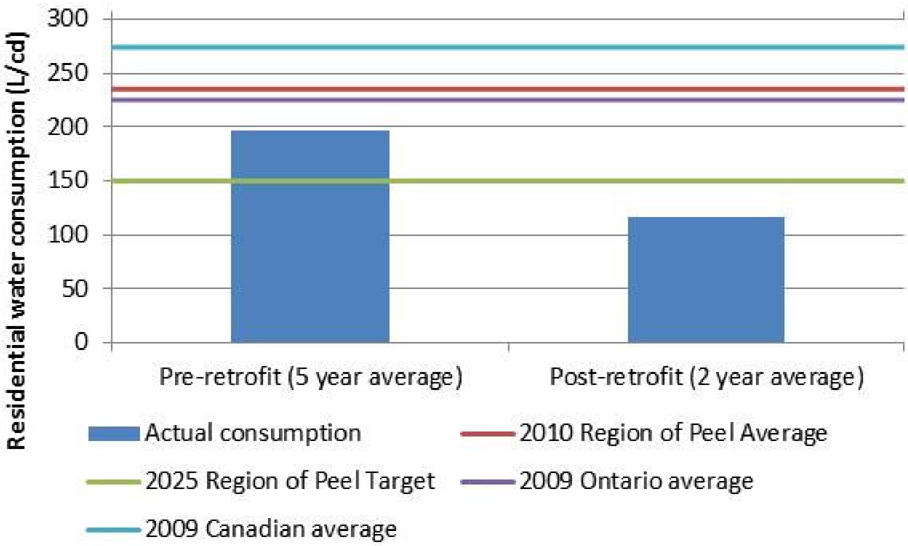
Table 1: Pre- and Post-renovation Household Water Use Statistic, 71 Turtlecreek Boulevard

Water Use Parameter	**Pre-renovation Use** Sept. 27, 2006 to Sept. 27, 2011 (Five Year Average)	**Post-renovation Use** Dec. 24, 2011 to Dec. 24, 2013 (Two Year Average)	**Change**
Annual water use (m^3) [1]	334	155	-54%
Daily water use (L/d) [1]	914	426	-53%
Average per capita daily water use (L/cd) [1]	196 [2]	116 [3]	-41%
Daily water use, non-growing season (L/d) [1]	896	312	-65%
Daily water use, growing season (L/d) [1]	932	533	-43%
Daily outdoor water use, growing season (L/d)	36	222	521%
Annual outdoor water use, estimated (m^3)	6.5	40.5	521%

Notes:

1. Values represent total household water use (i.e. indoor and outdoor uses combined).
2. The value for average household water use, 5 years post-renovation for 71 Turtlecreek Blvd. is based on the total volume of water used between September 27, 2006 to September 27, 2011, taken from quarterly water bill statements, divided by the total number of days included in this period and divided by the average occupancy over this period, using occupancy information provided by the homeowner.
3. The value for average household water use, 2 years post-renovation for 71 Turtlecreek Blvd. is based on the total volume of water used between December 24, 2011 to December 24, 2013, taken from quarterly water bill statements, divided by the total number of days included in this period and divided by the average occupancy over this period, using occupancy information provided by the homeowner.

Figure 11: Pre- and Post-renovation Per Capita Water Usage



To compare recent trends in water usage at 71 Turtlecreek Blvd. to those for all of Peel Region, annual household water use values were calculated (Table 2) using information from quarterly water bills for each year between 2006 and 2013 and occupancy information provided by the homeowners. It is was found that annual household water usage for 71 Turtlecreek Blvd. was increasing over the 5 years prior to renovation, counter to the decreasing trend observed for all households in Peel Region (Table 2, Figure 12). From these results it is clear that prior to renovation the homeowners at 71 Turtlecreek Blvd. were already very conservative users of water with annual household water use being consistently well below average values for the Region of Peel. It is also notable that the values for pre- and post-renovation household water use for 71 Turtlecreek Blvd. calculated as the mean of annual values (i.e. Table 2) are very similar to those calculated using the pre- and post-renovation time periods described previously (i.e. Table 1).

Although overall household water consumption decreased considerably, there was an increase seen in outdoor water use post-renovation. Post-renovation water consumption during the growing season increased from 4% to 71% above non-growing season usage. This is much higher than average in the Region of Peel, where usage during the summer months has been found to increase by approximately 20% (Veritec Consulting Inc., 2004). This is likely due to the fact that prior to the renovations, the occupants watered their lawns and gardens very little. In the Homeowner's Survey conducted by Toronto and Region Conservation (TRCA) in 2011, the family reported that they watered their lawns less than once per week, and only when there had been a lengthy dry spell and there was no rain in the forecast. As part of the renovations, a large portion of the lawn was replaced with a Fusion Landscape® design featuring garden beds with less water-demanding plants and Low Impact Development (LID) stormwater management practices (i.e. rain barrels, rain garden, permeable driveway and walkways and downspout disconnection to front lawn).[6] Outdoor watering was likely intensified in order to promote establishment of the new landscape features. With time, outdoor water use is expected to decrease beyond pre-renovation values. In spring 2012, when the new plantings were still getting established,

[6] For more information about Fusion Landscaping®, visit: http://www.peelregion.ca/watersmartpeel/residents/fusion-landscaping/.

the climate was drier than normal, with 22% less rainfall in April to June than 30 year climate normals (Environment Canada, 2014). High consumption of potable water for outdoor watering suggests that the installed rain barrels were not frequently used for outdoor watering, which was confirmed through monitoring of rainwater usage (Section 6).

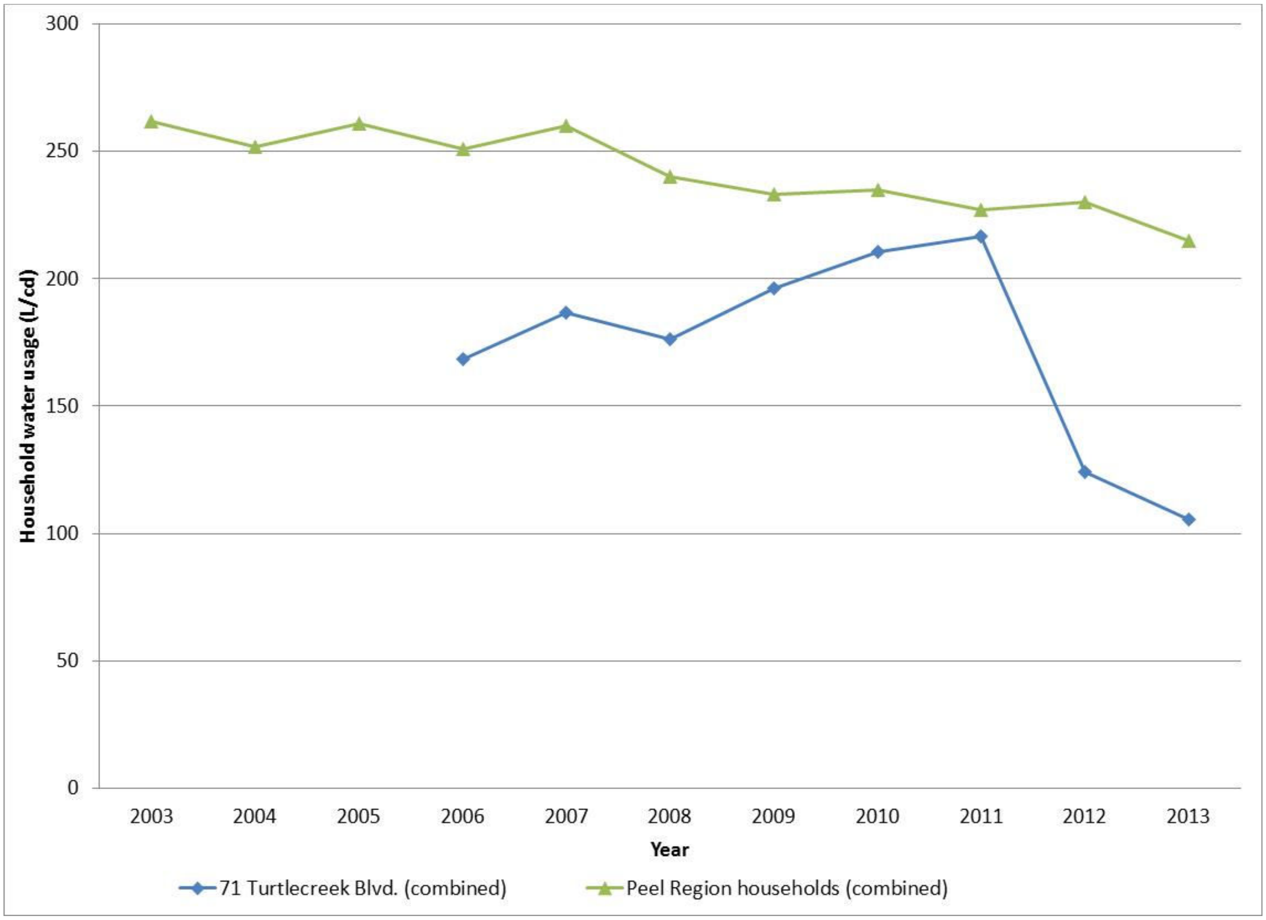
Table 2: Comparison of Household Water Use Statistics, Region of Peel and 71 Turtlecreek Blvd.

Time Period	Region of Peel, household water use, combined (L/cd)	71 Turtlecreek Blvd. household water use, combined (L/cd)
2006	251 [1]	168 [4]
2007	260 [1]	187 [4]
2008	240 [1]	176 [4]
2009	233 [1]	196 [4]
2010	235 [1]	211 [4]
2011	227 [1]	217 [4]
2012	230 [1]	124 [4]
2013	215 [1]	105 [4]
Average, 5 years pre-renovation	244 [2]	188 [5]
Average, 2 years post-renovation	223 [3]	115 [6]

Notes:

1. Data provided by the Region of Peel (2014).
2. Values for average household water use, 5 years pre-renovation for the Region of Peel are based on the mean of annual values from 2006 to 2010 provided by Region of Peel (2014).
3. Values for average household water use, 2 years post-renovation for the Region of Peel are based on the mean of annual values from 2012 to 2013 provided by Region of Peel (2014).
4. Values for annual household water use for 71 Turtlecreek Blvd. are based on the total volume of water used that year taken from quarterly water bill statement, divided by the total number of days included in the four billing periods and divided by the time-weighted average occupancy for the year, using occupancy information provided by the homeowner.
5. The value for average household water use, 5 years pre-renovation for 71 Turtlecreek Blvd. in this table is based on the mean of annual values from 2006 to 2010.
6. The value for average household water use, 2 years post-renovation for 71 Turtlecreek Blvd. in this table is based on the total volume of water used between December 24, 2011 to December 24, 2013, taken from quarterly water bill statements, divided by the total number of days included in this period and divided by the time-weighted average occupancy over this period, using occupancy information provided by the homeowner.

Figure 12: Comparison of Annual Household Water Use, Region of Peel and 71 Turtlecreek Blvd.



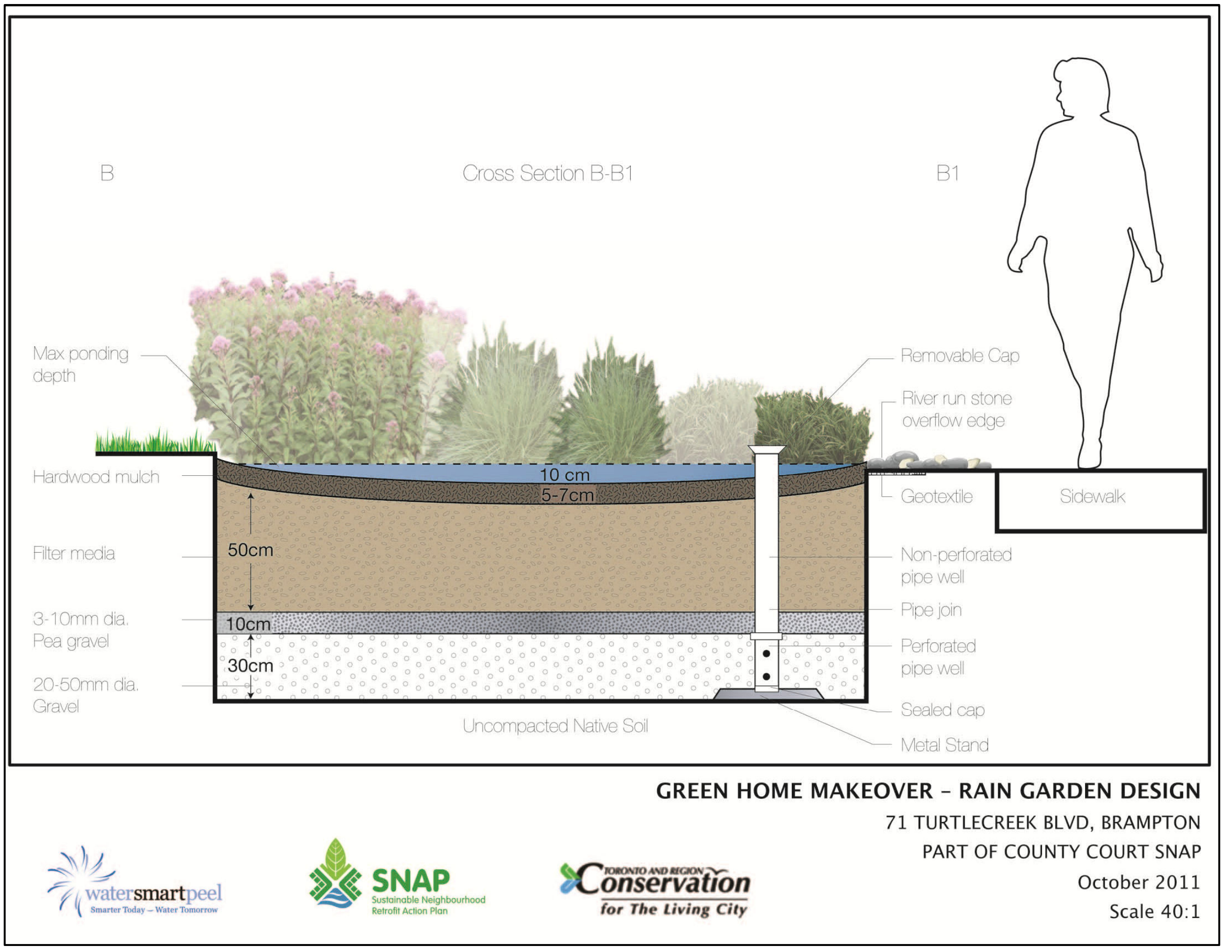
6. Stormwater Runoff

Prior to the green home makeover renovations, downspouts that conveyed stormwater runoff from the roofs of 69 and 71Turtlecreek Blvd. were directly connected to the building foundation sub-drains which flow to the municipal storm sewer system. The conventional asphalt driveway at 71 Turtlecreek Blvd. drained directly to a street catchbasin. Since they drained directly to storm sewers it can be estimated that 80 to 90% of precipitation falling on these impervious areas would have become runoff.

Rain Garden

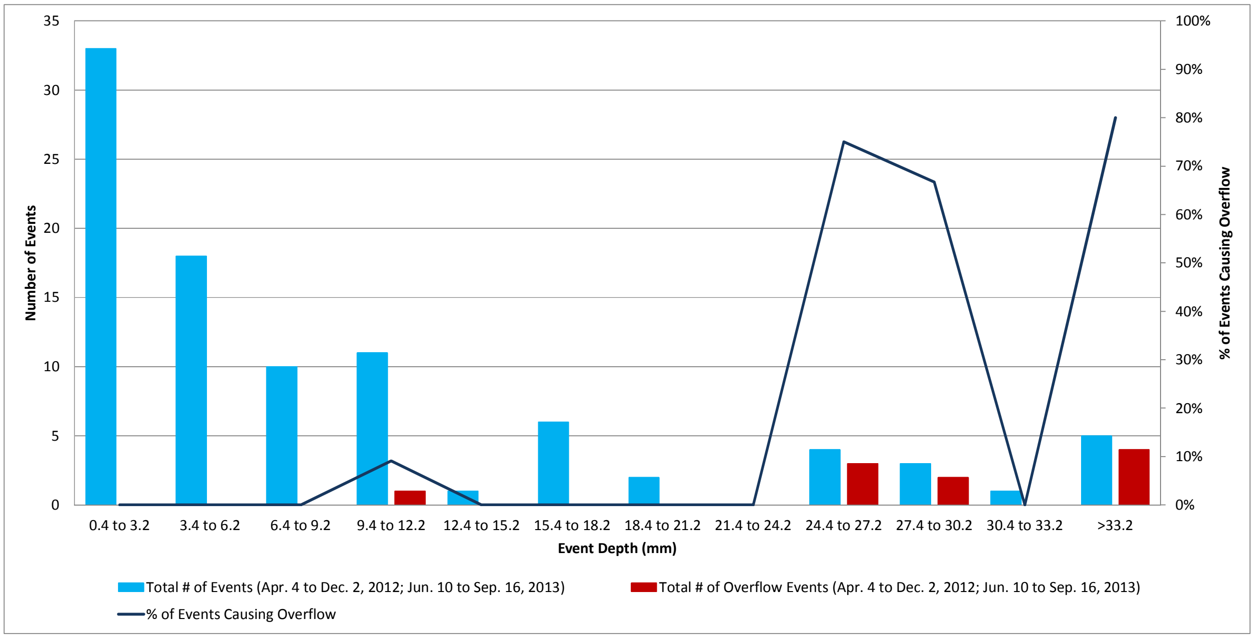
Renovations related to stormwater management that were part of the green home makeover included installation of a rain garden in the shared front yard area between 69 and 71 Turtlecreek Blvd. with an 8.5 square metre (m^2) surface footprint and excavation depth of 1.07 metres (Figure 13) to which drainage from a total roof area of 127.5 m^2 was directed (71.5 m^2 of the roof of 71 Turtlecreek Blvd. and 56 m^2 of the roof of 69 Turtlecreek Blvd.). The design objective for this rain garden was to be capable of fully capturing runoff from the roof drainage area that would result from a 25 mm rainfall event, assuming 10% loss of rainfall to evaporation and that the rain garden is fully drained at the onset of the storm. In this region, approximately 80% of average annual rainfall depth occurs as storm events 25 mm in depth or less (TRCA, 2013).

Figure 13: Design drawing of the rain garden



Runoff capture performance of the rain garden over the post-renovation monitoring period is illustrated in Figure 14 which describes the frequency of rainfall events that caused the rain garden to overflow by event depth ranges. Through continuous field monitoring of water level it was observed that the rain garden was capable of fully capturing runoff from rain events up to 21.2 mm depth on a very consistent basis. As shown in Figure 14, the rain garden was observed to overflow during only one rainfall event that was less than 21.2 mm in depth. Since no rainfall events in the range of 21.4 to 24.2 mm depth occurred during the monitoring period, no evidence is available about the runoff capture performance of the rain garden in such conditions. During most rainfall events of 24.4 mm depth or greater, the rain garden was observed to fill to capacity and produce some overflow. In this region approximately 70% of total annual rainfall occurs as storm events 20 mm in depth or less (TRCA, 2013). Assuming that 90% of rain falling on the roof area generates runoff (i.e. 10% loss to evaporation), it can be estimated that in an average year, the rain garden reduces roof runoff by a minimum of 44 cubic metres (m^3), which is equivalent to 44,000 litres or about 275 bath tubs full of water. This is a very conservative estimate considering that the rain garden captures and infiltrates a portion of rain events greater than 20 mm in depth as well. The main reason for not achieving the design objective of fully capturing runoff from storm events up to 25 mm in depth is because the rain garden was not fully drained at the onset of most storm events greater than 21.2 mm in depth that occurred over the monitoring period.

Figure 14: Rain garden frequency of overflow events by rainfall event depth range



Over the monitoring period the rate at which the rain garden drained varied considerably but on average it could drain from completely full to empty within 120 hours (5 days) and from completely full to half full within 48 hours (2 days). Table 2 provides summary statistics that help to describe the observed drainage rates. The peak 48 hour infiltration rates characterize the highest drainage rate the practice was capable of achieving over the monitoring period. With the rain garden filled to capacity and therefore, the greatest amount of hydraulic head helping to force water into the underlying native soil, the rain garden drained at an average rate of 3.3 mm per hour (mm/h) which is very similar to the rates observed for three 2 metre deep rectangular infiltration trenches installed on clayey silt glacial till subsoil in the Mayfield Industrial Park in Bolton (TRCA, 2013b). Observed peak 48 hour infiltration rates varied considerably (standard deviation of 1.5) with rates showing a decreasing trend during lengthy periods of wet weather. Drainage rate of the rain garden slowed considerably over the very wet fall of 2012 when rainfall depth was 27% greater than the 30 year climate normal value (Figure 15). Drainage rates during this period likely represent saturated or nearly saturated groundwater flow conditions whereas the higher rates observed during drier periods represent unsaturated flow conditions. With the return of more normal rainfall patterns during summer of 2013 it was observed that the rain garden drained at rates very similar to those observed over the June to August 2012 period.

During the post-renovation monitoring period, an extremely wet period occurred between July 7 and 9, 2013, when 101.4 mm of rainfall occurred over five events, with rainfall intensity on July 8 exceeding the 2 year return period 12 hour storm event for the region. As shown in Figure 16 the rain garden and permeable driveway both overflowed on two occasions. Peak 48 hour infiltration rates for both practices over this very wet period (Figure 16) were similar to mean values calculated over the whole monitoring period (Table 2).

Table 2: Rain garden and permeable driveway peak 48 hour infiltration rates

Peak 48 Hour Infiltration Rate (mm/h) [1]	Rain Garden	Permeable Driveway
Mean	3.3	1.4
Minimum	0.9	0.9
Maximum	5.3	1.7
Standard Deviation	1.5	0.2
Number of observations	9	13

Notes:

1. Peak 48 hour infiltration rate is the rate observed over a 48 hour drainage period beginning when the practice is filled to capacity with water and rainfall has stopped, which characterizes the highest drainage rate the practice is capable of achieving over the monitoring period.

Figure 15: Hydrograph of water levels and rainfall over the month of September 2012

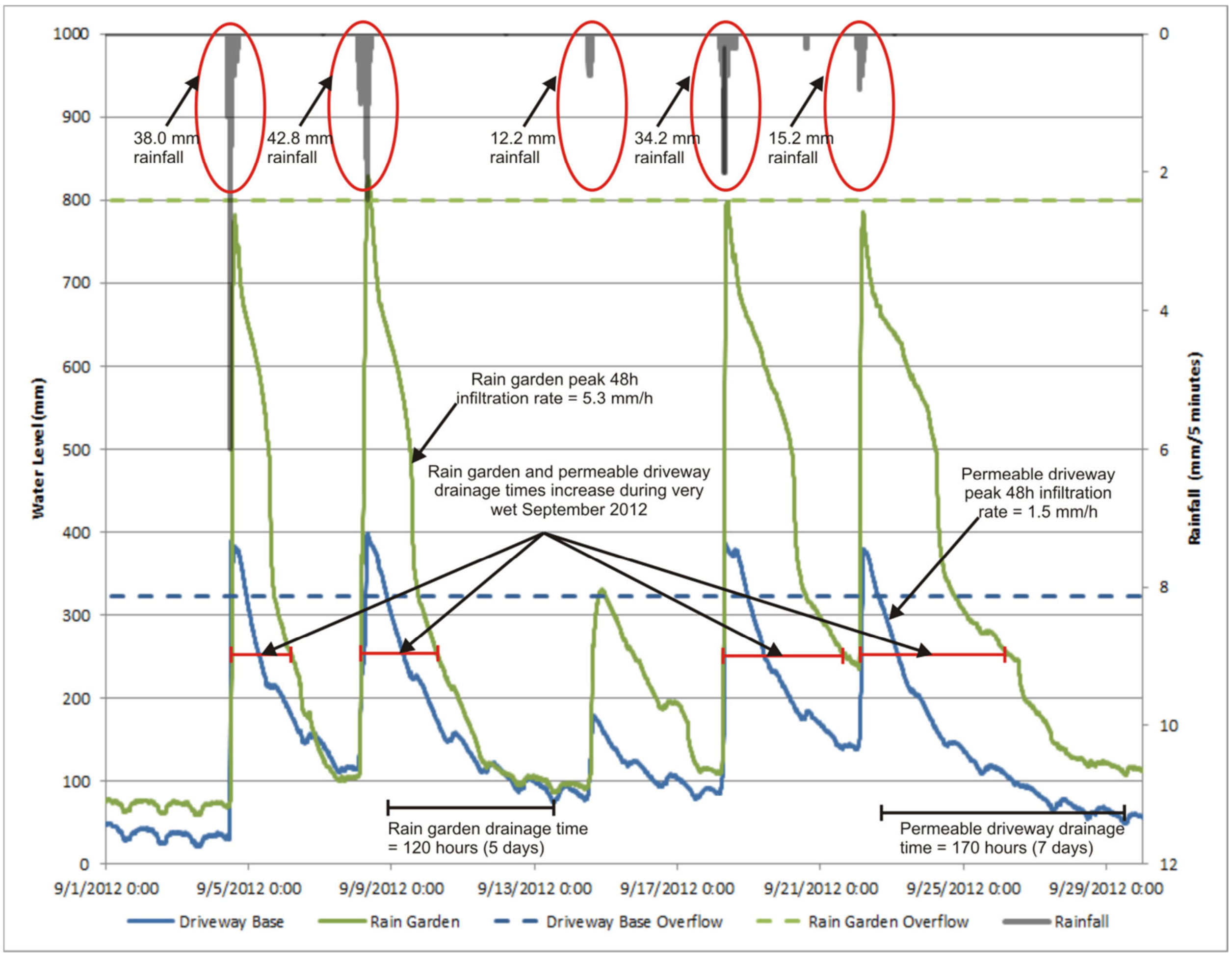
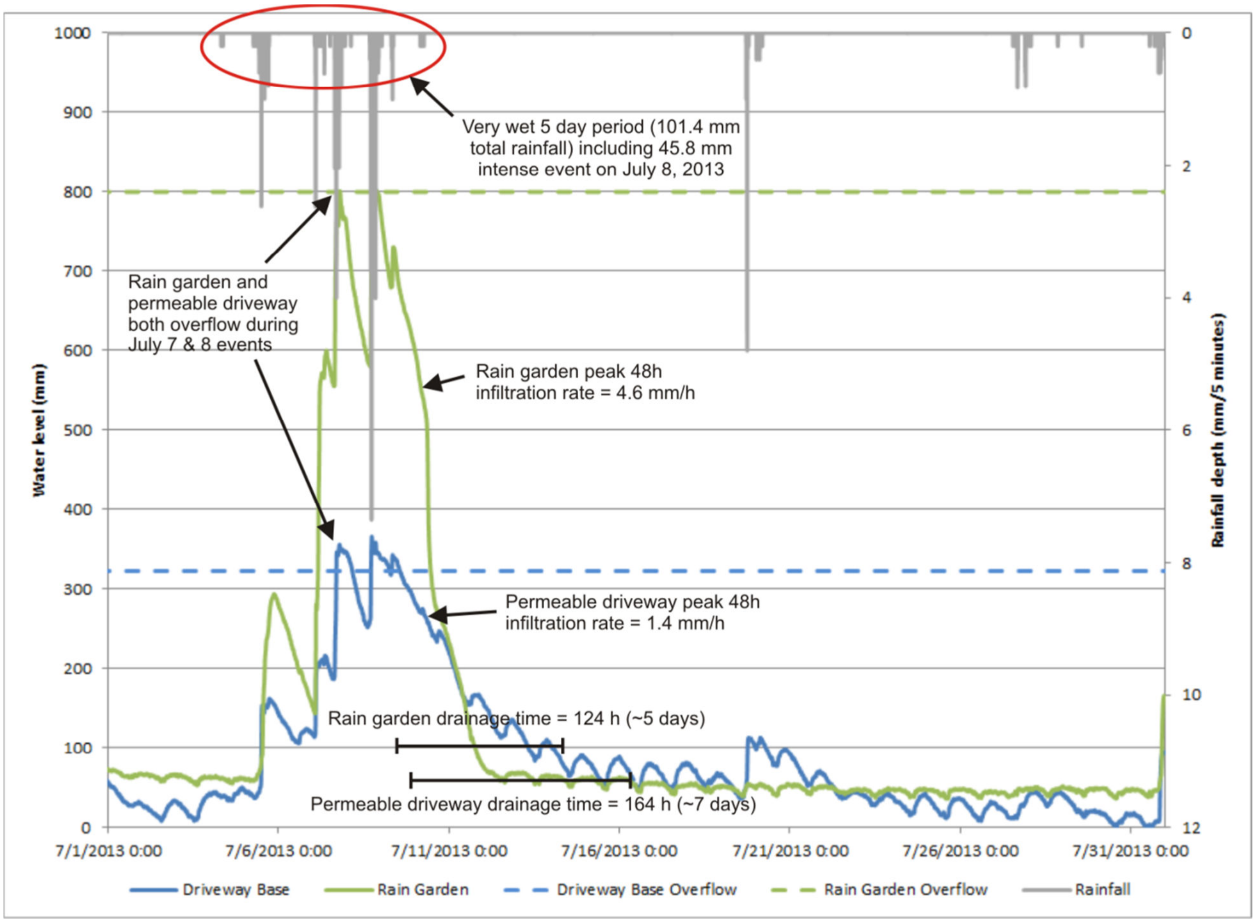


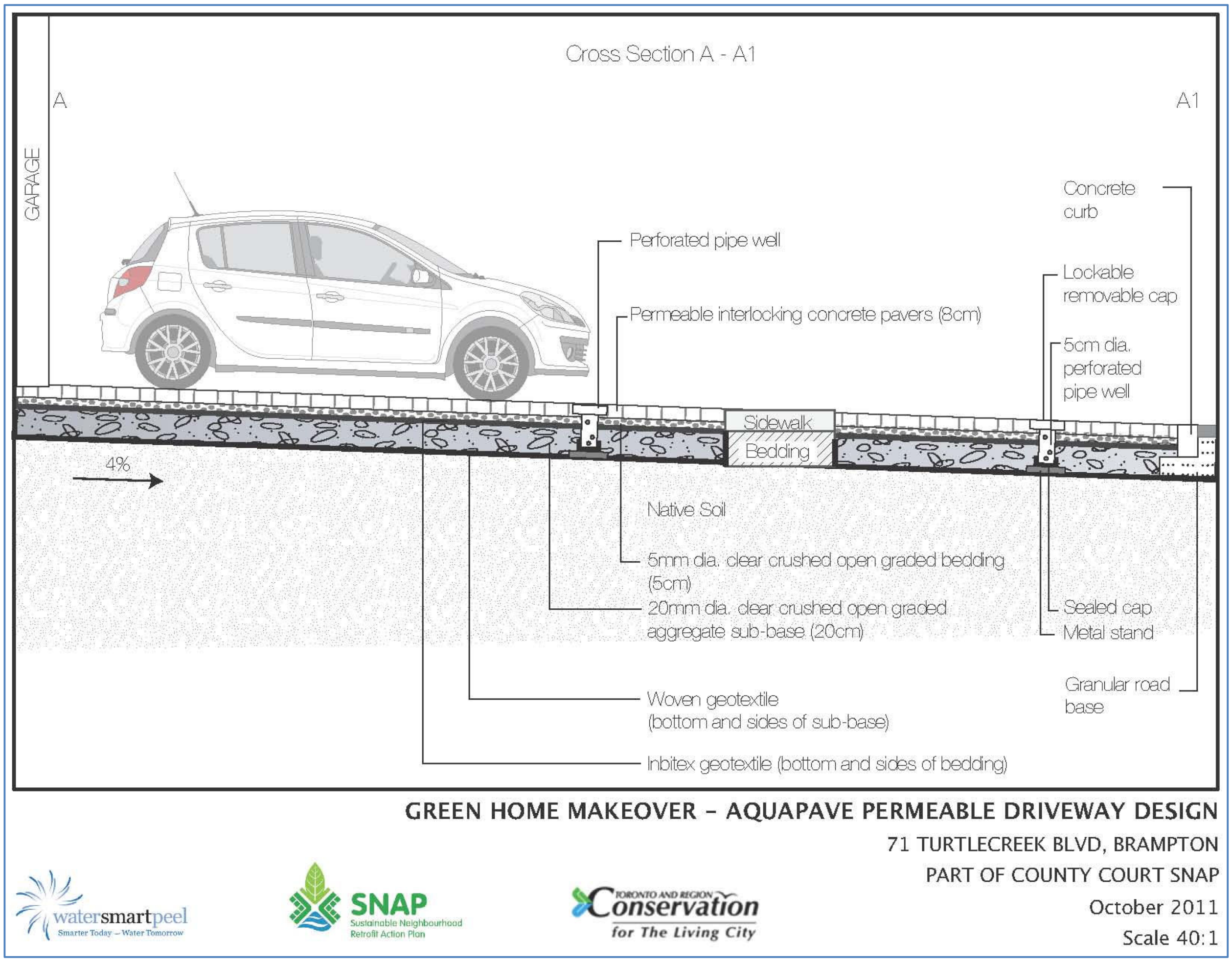
Figure 16: Hydrograph of water levels and rainfall over the month of July 2013



Permeable Driveway

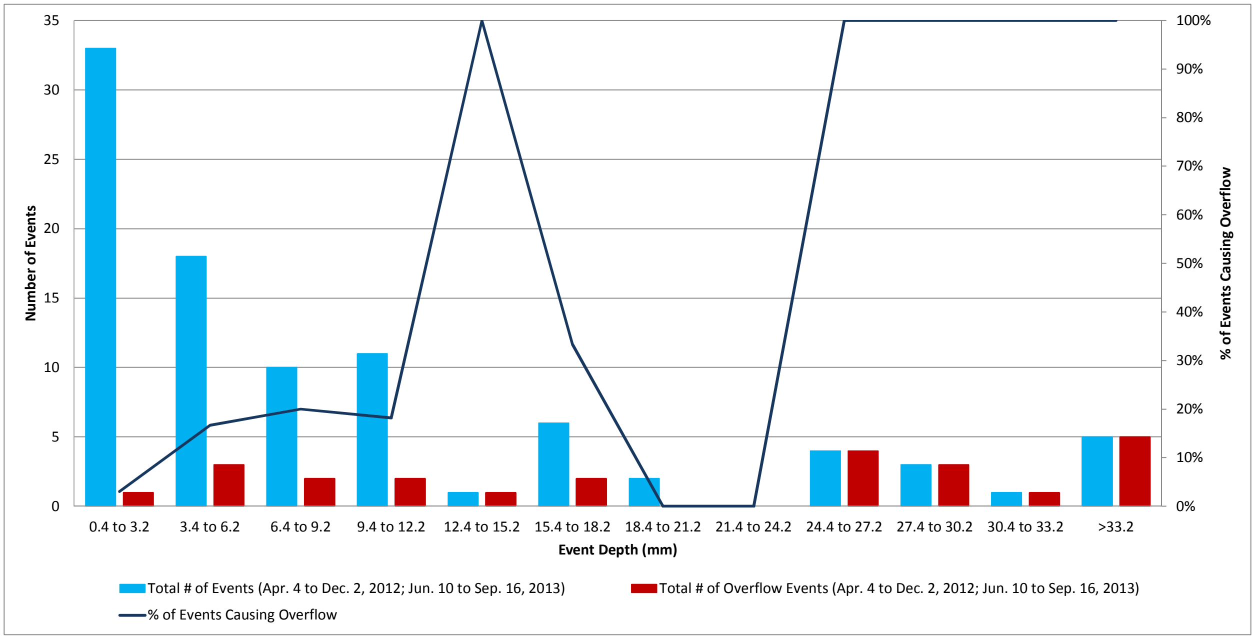
Another stormwater management related renovation that was part of the green home makeover was replacement of a 50.7 square metre (m^2) conventional asphalt driveway (4% slope) with one featuring a permeable interlocking concrete paver surface and a 0.25 metre deep clear stone base, including bedding (Figure 17). The depth of the permeable driveway base was designed to meet load bearing requirements rather than water storage capacity. However, considering the geometry, dimensions and slope of the driveway and assuming the clear stone base provides 30% void space for water storage and 10% loss of rainfall to evaporation, it can be estimated that it should be capable of capturing all runoff from a 25 mm rainfall event when fully drained at the onset of the storm. The permeable driveway was designed to allow infiltrated runoff from the upper section to flow through the gravel base of the sidewalk and be temporarily stored in the base of the lower section. This was confirmed to occur through field monitoring of water levels in the bases of both the upper and lower driveway sections. Monitoring showed that water levels in the upper section recede rapidly after a rain event and much more slowly in the lower section.

Figure 17: Design of the permeable driveway



Runoff capture performance of the permeable driveway over the post-renovation monitoring period is illustrated in Figure 18. By continuous field monitoring of water level in the lower portion of the permeable driveway it was observed that it is also capable of capturing runoff from rain events up to 21.2 mm depth on a fairly consistent basis, but less consistently than the rain garden. As shown in Figure 15, the permeable driveway was observed to overflow occasionally during rain events up to 12.2 mm in depth (2 to 20% of events). Frequency of overflow jumped to 100% for rain events in the range of 12.4 to 15.2 mm depth but only one event of this size occurred during the monitoring period so it does not provide strong evidence about runoff capture performance. During rain events between 15.4 and 21.2 mm depth, frequency of overflow remained low (25% or 2 of 8 events). However, during all rainfall events of 24.4 mm depth or greater, the permeable driveway was observed to fill to capacity and produce some overflow. As noted previously, in this region approximately 70% of total annual rainfall occurs as storm events 20 mm in depth or less (TRCA, 2013). Assuming that 10% of rain falling on the permeable driveway is lost to evaporation, it can be estimated that in an average year, in comparison to a conventional asphalt driveway, it reduces runoff by a minimum of 17.6 cubic metres (m^3), which is equivalent to 17,600 litres or about 110 bath tubs full of water. This is a very conservative estimate considering that the permeable driveway captures and infiltrates a portion of rain events greater than 20 mm in depth as well. Similar to the rain garden, the main reason that the permeable driveway was not capable of fully capturing runoff from storm events up to 25 mm in depth is because it was not fully drained at the onset of most storm events greater than 21.2 mm in depth that occurred over the monitoring period.

Figure 18: Permeable driveway frequency of overflow events by rainfall event depth range



Over the monitoring period the rate at which the permeable driveway drained varied but on average it could drain from completely full to empty within 170 hours (7 days) and from completely full to half full within 48 hours (2 days). Table 2 provides summary statistics that help to describe the observed drainage rates. With the gravel base filled to capacity the permeable driveway drained at an average rate of 1.4 mm per hour (mm/h). Observed peak 48 hour infiltration rates were very consistent (standard deviation of 0.2), much more so than the rain garden, with rates showing a decreasing trend during lengthy periods of wet weather as was observed in the rain garden. With the return of more normal rainfall patterns during summer of 2013 it was observed that the rain garden drained at rates very similar to those observed over the June to August 2012 period. It is likely that the permeable driveway drained more slowly than the rain garden due in part to differences in hydraulic head (i.e. water depth when full) and the degree to which the underlying subsoil is compacted. No steps were taken to decompact subsoil below the asphalt driveway after it was removed to help avoid rutting of the permeable interlocking paver surface that replaced it and after many years of vehicle traffic, it is likely much more compacted than the subsoil below the rain garden which would cause it to drain more slowly.

7. Rainwater Use

A total of only 2.3 m^3 of rainwater was used over the monitoring period, indicating that the rain barrels were rarely drained between storm events and mainly used to occasionally fill watering cans. Assuming a water utility rate of $9.6724 per 10 m^3 (Region of Peel, 2013), a total of $2.22 in water utility bill saving was achieved over the monitoring period. Comparisons of water use during growing and non-growing seasons over the post-renovation period indicate that the homeowners used a considerable amount of water for outdoor uses. This high water usage can be associated with the initial need to water their newly established Fusion Landscape® garden. However, from these results it is clear that they most often chose to use municipal water for outdoor purposes rather than rainwater, likely out of convenience and the time required to fill watering cans. In a post-renovation interview with the homeowners, they noted that they watered the newly planted garden beds more to ensure it became well established and that the rain barrels did not provide adequate water pressure nor quantity to do a deep soaking of the beds. It is postulated that if a means of using rainwater from the barrels that was more convenient than use of a hose with gravity fed flow or filling watering cans had been put in place (e.g. soaker hose draining to the garden or lawn, submersible pump and pressure sprayer) more rainwater may have been used, resulting in greater water utility bill savings.

8. Discussion

Climate

Household energy and water consumption are affected by climate, and therefore must be understood within the context of factors such as air temperature and precipitation. Natural gas is primarily consumed during the fall and winter for space and water heating. In both the pre- and post-renovation periods, mean temperature during the fall and winter remained within 1°C of the 30 year climate normal values based on historical climate data collected at the Lester B. Pearson International Airport by Environment Canada (Table 3). This suggests that the reduction in natural gas usage observed here provides a reasonable estimation of long term savings.

During the post-renovation period, mean temperature was 1.9°C warmer in the spring than the 30 year climate normal. This likely caused electricity consumption to increase in order to meet space cooling needs. Higher than average electricity use during the post-renovation period would reduce calculated electricity savings. In the long term, slightly greater savings in electricity use may be achieved than were observed through this evaluation.

Outdoor water consumption can be affected by the amount of rainfall received during the growing season (mid-March to mid-September) because homeowners usually refrain from watering during periods of wet weather. In the pre-renovation period, total rain was 18% greater than normal during the spring and 16% greater than normal during the summer. During the post-renovation period, total rainfall was 29% greater than the climate normal during the summer season. It follows that increases in outdoor water use during spring were likely overestimated due to the atypically wet spring in the pre-renovation period. Conversely, increases in outdoor water use during summer were likely underestimated as the average summer rainfall during the post-renovation period was much greater than during the pre-renovation period. Without detailed analysis, it is difficult to determine the cumulative effect of these conditions on overall outdoor water use. Rainfall during the non-growing season was 18% greater than normal during the winter of the post-renovation period. This was not considered to have a significant effect on outdoor watering.

It should be noted that average post-renovation summer rainfall was 29% greater than normal and included some particularly wet months and extreme storm events. This was amenable to the evaluation of the performance of the rain garden and permeable driveway as it provides insight into the effectiveness of these practices during wetter than normal and extreme storm event conditions.

Table 3: Pre- and Post-renovation Climate

	Mean Air Temp. (°C)			**Total Rain (mm)**		
	Pre-renovation (Sep 2007-Sep 2011)	**Post-renovation** (Mar 2012-Mar 2014)	**30 Year Climate Normal** (1981 to 2010)	**Pre-renovation** (Sep 2006-Sep 2011)	**Post-renovation** (Mar 2012-Mar 2014)	**30 Year Climate Normal** (1981 to 2010)
Winter	-4.4	-4.5	-4.1	84.4	98.6	83.4
Spring	7.7	8.7	6.8	200.6	146.8	169.9
Summer	20.7	21.4	20.2	262.0	290.2	225.3
Fall	10.6	9.8	9.8	192.2	206.7	203.1
Annual	**8.7**	**8.8**	**8.2**	**739.1**	**742.3**	**681.7**

NB: Pre-renovation air temperature was calculated to align with the assessment period for energy use (the four year period from September 2007 to September 2011). Pre-renovation rainfall was calculated to align with the assessment period for water use (the five year period from September 2006 to September 2011). The post-renovation assessment periods for both energy and water use were identical (the two year period from March 2012 to March 2014).

Source: Environment Canada, 2014.

Data collection

A seasonal analysis of the water use data was challenging due to the coarse nature of the water use data (truncated to the nearest 10 cubic metres) and quarterly billing period. As recommended in the previous report, pre-renovation water use was characterized over a 5 year period of billing data to better encompass the range of variability that can occur in outdoor water use from year to year due to weather variability. To more accurately characterize household water use in future projects, sub-metering should be considered that captures actual meter readings on a daily basis during pre- and post-renovation periods, which would provide data at a finer resolution, both volumetrically and temporally. Consideration should also be given to metering individual outdoor water taps to provide the information needed to assess outdoor water use more accurately. Consideration should also be given to evaluating water conservation benefits of landscaping and rain barrel renovation components based on data from a longer post-renovation period, or excluding data from the first two years when the newly planted gardens are becoming established and they are being watered more than normal.

Demonstration value

A key objective of this Green Home Makeover was to act as demonstration for other homeowners interested in undertaking green renovation, and encourage uptake of sustainable action across the neighbourhood and beyond. The monitoring results indicate that the rain garden and permeable driveway are both performing well, which suggests that it would be beneficial from a stormwater management perspective to promote similar renovations across the neighbourhood. However, the cost to construct these best management practices (see Appendix A) is likely a factor that may be limiting the number of homeowners willing to implement them. To help lower the construction cost and effort involved, rain gardens shallower than the 1 metre deep one implemented at 71 Turtlecreek Blvd. could be promoted, albeit with lower rainfall capture performance and more frequent occurrence of overflow.

Based on the results from monitoring rainwater use, the likelihood of achieving substantial water conservation benefits from just providing homeowners with a rain barrel alone, without highly convenient means of using the harvested rainwater (e.g. submersible pump and pressure sprayer; soaker hose attachment) or automated means of draining them during dry periods between storms, is low. Consideration should be given to including soaker hose attachments as part of rain barrel giveaways and combining with rebates on submersible pumps or smart irrigation system controls that link to internet-based weather forecasts and can trigger a rain barrel to drain prior to onset of the next storm (e.g. RainGrid).

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Appendix A: Renovations Implemented as Part of the Green Home Makeover

ITEM	QUANTITY	PRODUCT INFORMATION	UNIT VALUE	TOTAL VALUE	SPONSORING SUPPLIER
ENERGY EFFICIENCY					
Insulation and Draftproofing					
Insulation - attic	1	a. Climatizer Plus - Loose Fill Cellulose Insulation b. IPF Green Integrated Polyurethane Foam c. Moore Vents d. Rigid Insulation Board e. Roxul Batt insulation f. Peel and Stick Weather Strip	\$2,450	\$2,450	GreenSaver
Insulation - basement walls and headers	1	Icynene Light Density Spray Foam	\$6,200	\$6,200	GreenSaver
Draft proofing	1	a. IPF Green Integrated Polyurethane Foam b. 321 Acrylic Latex with Silicone Caulk	\$350	\$350	GreenSaver
Windows and Doors					
Cellular blinds	1	Levolor Accordia blinds	\$5,000	\$5,000	Sears Canada
Wood blinds	1	FSC certified wood blinds	\$1,200	\$1,200	Sears Canada
Energy star windows and doors	1	Triple glazed windows (x23), Wood frame doors (x3)	\$37,000	\$37,000	Sears Canada
Plug-load					
Plug-load/lighting retrofits	1	a. CFL Bulbs – 60W, 100W b. Plug In Digital Timer c. Power Bar with Digital Timer d. In Home Energy Monitor	\$150	\$150	GreenSaver/ HydroOneBrampton
Dishwasher	1	Kenmore Elite Integrated Console Tall Tub Built-in Dishwasher - Stainless Steel (Sears #13973)	\$1,500	\$1,500	Sears Canada
Refrigerator	1	Kenmore Elite Counter-Depth French Door Bottom Mount (Sears #70703)	\$2,850	\$2,850	Sears Canada
Freezer	1	Kenmore®/MD 21 cu. ft. Frost Free Upright Freezer (Sears #18002)	\$800	\$800	Sears Canada

ITEM	QUANTITY	PRODUCT INFORMATION	UNIT VALUE	TOTAL VALUE	SPONSORING SUPPLIER
Stove	1	Kenmore®/MD All-Touch Electric Self Clean Dual Fan Convection Smooth Top Range-Stainless (Sears# 68953)	$1,400	$1,400	Sears Canada
Washer	1	Kenmore®/MD 4.1 cu. ft. High- Efficiency Top Load Washer - White (Sears # 28012)	$650	$650	Sears Canada
Dryer	1	Kenmore®/MD 7.5 cu. ft. Electric Dryer - White (Sears# 68012)	$550	$550	Sears Canada
Range Hood	1	Kenmore Elite 30'' Vent Hood - Stainless Steel (Sears # 31614)	$450	$450	Sears Canada
Microwave	1	Kenmore®/MD 1.4 cuft. Countertop Microwave - Stainless Steel (Sears # 86173)	$170	$170	Sears Canada
Dishwasher and washer installation	1	N/A	$199	$199	Sears Canada
Heating and Cooling					
High Efficiency Furnace	1	SmartAir Plus RGRG 96 AFUE, Modulating, Variable Speed Motor Furnace & Serial Communicating Thermostat	$5,000	$5,000	Reliance
Water Heater	1	GSW Envirosense 6G50100NVC-02 condensing storage water heater	$2,500	$2,500	Reliance
Hi SEER A/C	1	SmartAir Plus RARL16 16 SEER Air Conditioner R410A & Evaporator Coil	$4,800	$4,800	Reliance
HRV	1	Vanee 60H Heat Recovery Ventilator	$2,999	$2,999	Reliance
Air Filtration System	1	SmartAir Purity	$999	$999	Reliance
Humidifier	1	SmartAir Pulse Humidifier	$419	$419	Reliance
Drain water heat recovery	1	Power Pipe	$1,000	$1,000	Enbridge/RenewAbility
INDOOR WATER EFFICIENCY					
Toilets	2	H&H Proficiency UHET (3L)	$197	$394	Water Matrix
	1	Water Matrix Meridian Dual-Flush	$149	$149	Water Matrix
Showerheads	2	Oxygenics Body Spa hand-held	$80	$160	Water Matrix
Bathroom aerators	3	Niagara Conservation	$3	$9	Water Matrix

ITEM	QUANTITY	PRODUCT INFORMATION	UNIT VALUE	TOTAL VALUE	SPONSORING SUPPLIER
Kitchen aerator	1	Niagara Conservation Swivel Head	$3	$3	Water Matrix
Installation of Water Matrix gifts	1	N/A	$225	$225	Water Matrix
OUTDOOR LANDSCAPE					
Front Yard Landscaping					
Design	1	Fusion landscape design incorporating LID features	$2,250	$2,250	Region of Peel
Plant material	1	See Plant List	$2,500	$2,500	Sheridan Nurseries
Sod	1	1 skid (810 sq. ft.) bluegrass sod	$308	$308	Zander Sod
Soil and mulch	1	Gro-Max® soil (7yards) andCPM® mulch for front yard (3 yards)	$575	$575	Gro-Bark
	1	6.5 yards custom soil mix for rain garden	$450	$450	Gro-Bark
	1	Hardwood mulch for rain garden (1.3 yards3)	$125	$125	Gro-Bark
	1	Custom soil for the rain garden (5 yards3)	$85	$85	Purchased
Gravel and stone	1	Pea gravel (1.0 m3, 3-10mm dia. or 3/8"), Clear Gravel (3.0 m3, 20-50mm dia. or 3/4"), River run stone (0.3 m3, 1-3" dia.)	$381	$381	Purchased
Downspout submersion materials	1	N/A	$95	$95	Purchased
Rain barrels	1	50 gallon rain barrel	$150	$150	Region of Peel
	1	60 gallon rain barrel	$132	$132	Flexible Rain Barrels
Monitoring wells	2	Well for driveway	$100	$201	Purchased
	1	Well for rain garden	$109	$250	Purchased

ITEM	QUANTITY	PRODUCT INFORMATION	UNIT VALUE	TOTAL VALUE	SPONSORING SUPPLIER
Driveway and Walkways					
Driveway and malkway materials	1	AquaPave Interlocking Stone, Joint Stabilizer, Inbetex, AP-SC1000 Woven GTX, Bedding Sand, Upper Sub Base	$5,000	$5,000	Hanson Hardscapes
Driveway and walkway installation	1	Driveway and two walkways	$8,500	$8,500	Tassone Landscape Construction
Poured concrete curb installation	1	N/A	$3,000	$3,000	Purchased
Waste Management					
Waste removal, recycling and disposal	1	Landscape waste removal, recycling and/or disposal	$10,000	$10,000	1-800-GOT-JUNK
CONSTRUCTION PROJECT MANAGEMENT					
General contracting and project management	1	Basement wall framing, home inspection, window coverings installation, rain barrel installation (front and back), building reno permit, regrading permit, rain garden materials, 3 downspout disconnection (garden and neighbour), painting, fill around trim.	$16,157	$16,157	Purchased
TOTAL COST				**$129,735**	