Rainwater Harvesting in the Niagara Region

for the Niagara Region

4/7/2014
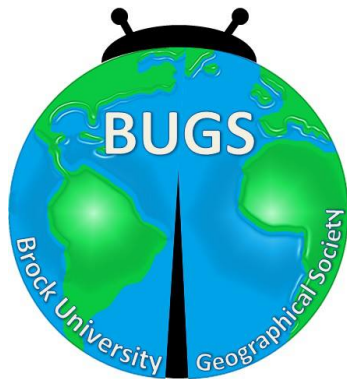
April 7, 2014

Dr. Jayson Childs

Niagara Region

2201 St. David's Road

P.O. Box 1042

Thorold, ON, L2V 4T7

Dear Jayson Childs:

Re: Rooftop Rainfall Catchment

B.U.G.S. Consulting Ltd. (BUGS) is pleased to present this rainfall harvesting report for Dr. Jayson Childs and the Niagara Region. The purpose of this project was to conduct a preliminary assessment on the potential for rooftop rainwater harvest within the region, and to explore potential benefits.

This report represents the best estimations of BUGS, using published sources and ARCGIS 10.1. Estimations on rainwater collection potential have been given for a sample neighborhood in Thorold, Brock University, and all the Niagara Region residences. The work was completed with several assumptions, discussed in the document, and therefore, BUGS has provided recommendations for further research.

Please do not hesitate to contact BUGS, if you have any questions or concerns. We look forward to hearing from you.

Sincerely,

Nicholas Riddick, GIS-GM   Josh Valenti

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N.R./

Enclosures: 1.) Rooftop Rainfall Catchment Report

Executive Summary

B.U.G.S. Consulting Ltd. (BUGS) was retained by Dr. Jayson Childs at the Niagara Region (Client), in January of 2014 to conduct a preliminary assessment on the potential for rooftop rainwater harvest within the region. Furthermore, BUGS is to explore the potential benefits, relating to rainwater harvest.

BUGS completed preliminary rainwater harvesting estimates for four areas:
1.   Section of a neighborhood in north Thorold, Ontario
2.   Brock University, Glenridge Campus buildings
3.   All residences in the Niagara Region
4.   Average dwelling

The results of this analysis were promising and are summarized in the table below.

Catchment Area	Rainwater Collection Potential		
	100% Efficiency	75% Efficiency	50% Efficiency
Niagara Region	44,614.08 ML	33,460.56 ML	22,307.04 ML
Brock University	129.03 ML	96.93 ML	64.62 ML
Thorold neighborhood	38.87 ML	29.15 ML	19.43 ML
Average Individual Dwelling	275,637 L	206,728 L	137,819 L

It is estimated that rainwater can be harvested at a quantity equal to 33.75% - 67.49% of domestic water consumption in the Niagara Region. Furthermore, on a household level, it is estimated that rainwater can be harvested at a quantity equal to 28.69% - 57.38% of water consumption.

This document does not go into detail regarding the use, installation, and implementation of rainwater harvesting systems. For more information, see the Canada Mortgage and Housing Corporation's (CMHC) document titled 'Guidelines for Residential Rainwater Harvesting Systems Handbook'.

Due to the number of assumptions and statistics used in this preliminary investigation, further study is recommended. Recommendations are primarily made with the intention of completing a cost-benefit analysis to determine if the region should go ahead with the implementation or promotion of such systems.

BUGS believes that implementing rainwater harvesting systems will yield benefits economically and environmentally. These systems will reduce storm water flow in high precipitation events, protect source waters and reduce the demand on infrastructure.

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1.0 Introduction

B.U.G.S. Consulting Ltd. (BUGS) was retained by Dr. Jayson Childs at the Niagara Region (Client), in January of 2014 to conduct a preliminary assessment on the potential for rooftop rainwater harvest within the region. Furthermore, BUGS is to explore the potential benefits, relating to rainwater harvest. It is believed that collecting rainwater from rooftops will provide environmental and economic benefits, all of which will be explored in this assessment.

BUGS is a dedicated, professional, and locally based consulting firm, specializing in GIS and related Geomatics technologies. The BUGS team is comprised of Mr. Nicholas Riddick and Mr. Josh Valenti. Both are trained environmental technicians and geomatics specialists.

1.1 Goal

The goal of this project was to analyze the potential for rainwater harvesting from rooftops, using three unique catchment areas (area of rooftop), and explore potential benefits. Furthermore, some of the costs and considerations regarding the implementation of rainwater collection systems (primarily in residential settings) will be evaluated. Please note, there are requirements and recommendations regarding rainwater harvesting, which this document does not explore in great detail, as the purpose of this document is to assess preliminary potential and benefits. For further information on said requirements and recommendations, please see Section 1.2.

1.2 Rainwater Harvesting Handbook

The Canada Mortgage and Housing Corporation (CMHC) has published the 'Guidelines for Residential Rainwater Harvesting Systems Handbook', which provides a wealth of information regarding the use, installation, and implementation of rainwater harvesting systems. The following URL will lead to the CMHC page on rainwater harvesting.

CMHC - Rainwater Harvesting: http://www.cmhc-schl.gc.ca/en/inpr/su/waho/waho_002.cfm

1.3 Catchment Areas

The three catchment areas analyzed in this project include:

Catchment Area 1: The first catchment area includes a section of a neighborhood in north Thorold, Ontario. The catchment area occupies a 500m × 500m area, located south of the Sullivan Ave. and Collier Rd. intersection (near Brock University).

Catchment Area 2: The second catchment area includes all buildings at the Brock University, Glenridge Campus.

Catchment Area 3: The final catchment area includes all residential dwellings within the Niagara Region. This is based on estimates on number of residences supplied by Statistics Canada and the average residential dwelling size calculated in Catchment 1.

1.4 Study Area

The study area includes the entire Niagara Region, and two subset regions; Brock University Glenridge Campus, and a 500m × 500m neighborhood in north Thorold (Figure 1).
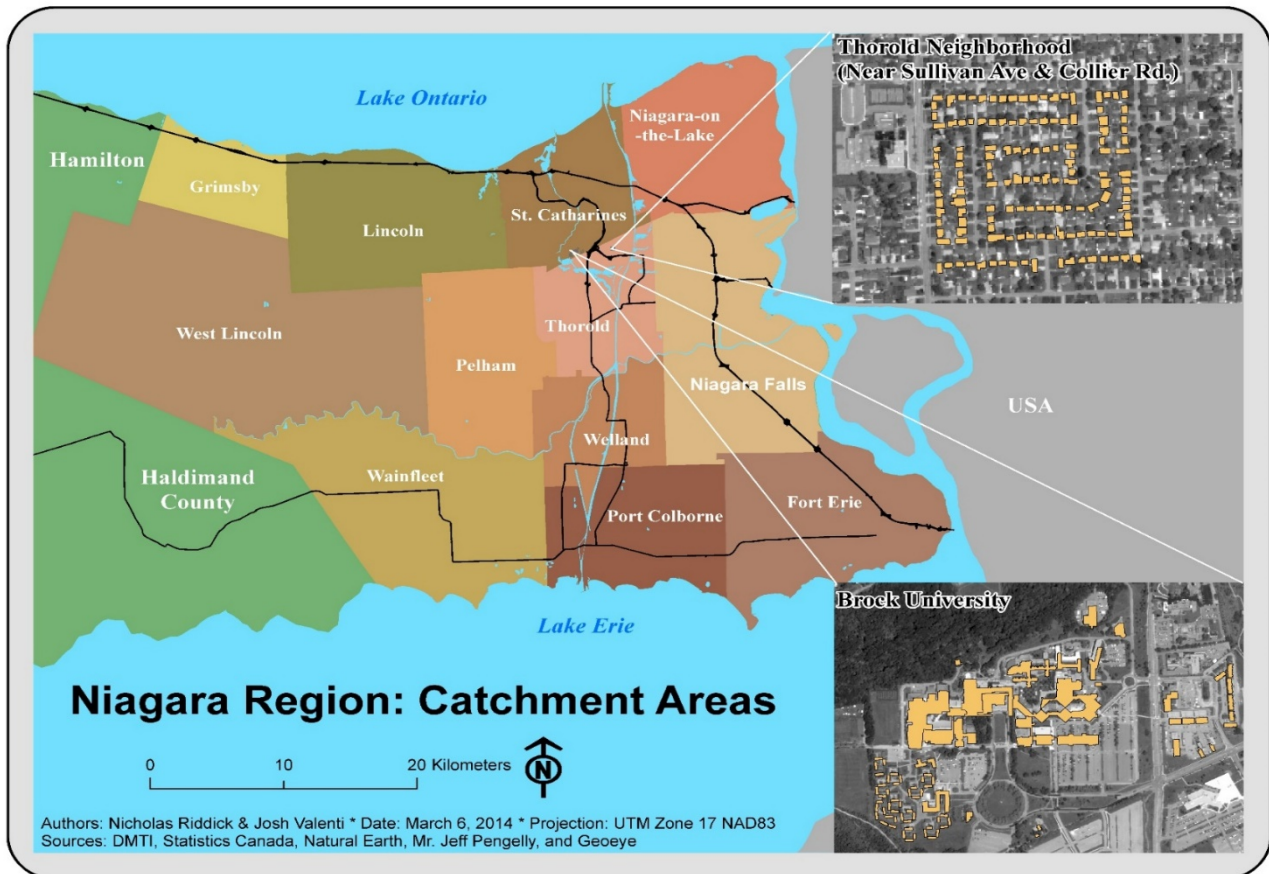

Figure 1: Study Area
★ = St. Catharines Weather Station

2.0 Background

Urban areas have witnessed a growing trend outwards from a downtown core, increasing the amount of impervious surfaces. These impervious surfaces channel large quantities of rainwater into storm-water systems, opposed to allowing natural infiltration. In 2011 the US Census Bureau counted the world's population above 7 billion with estimates that 62% of the world's population will be living in urban areas by 2035 (UN, 2012).   With high-density populations occupying relatively small spaces, demands on water supplies have increased. With such a vast amount of area being allocated to urban settings, roofs represent approximately half of the total impervious surfaces in urban settings and contributing to a majority of storm-water runoff (Farreny *et al.*, 2011). The overwhelming demand of urban development has pressured property developers to plan and utilize every square inch possible (Sheng *et al.*, 2012). Considering the negative effects concerning water in urban settings and the amount of rooftop spaces, rooftops may hold the potential for significant rainwater harvesting (aiding in grown water requirements), while simultaneously reducing runoff effects.

According to Katambara (2013), the amount of water obtained from water supply authorities may be reduced by an average of nearly 70% when rainwater is harvested and utilized to its potential. As Section 3.3 will address, the potential to harvest rainwater is dependent on the rooftop. This is based on building material and slope, which have an impact on the quantity and quality of harvested rainwater. Previous studies have determined the quality of the harvested rainwater varies with roof material; however the pollutant concentration is highest in the first liter collected, decreasing substantially in the subsequent samples (Yaziz *et al.*, 1989).

Harvesting rainwater also has the potential to ease water storage problems, reducing flows downstream that may cause flooding. Easing water storage and flow rates can be substantial when planning a city. As seen on July 8, 2013 in Toronto, Ontario, a storm touched down which produced 126 mm of rainfall, causing over $850 million in damages (Mills, 2007). This disaster was caused by overwhelmed infrastructures that forced infrastructures to backup, resulting in flash flooding across Toronto. Having rainwater harvest systems in place to ease these flows may have been beneficial in reducing the overall runoff into the system, limiting the damage of this particular event.

Water is the most valuable resource on earth, providing life supporting systems for all living things. It is also a vital part of socio-ecological systems and rainwater harvesting is a simple yet effective technique in collecting water (Singh *et al.*, 2011). According to Environment Canada (2013) the average water use by one person is 329 L/day and this can be reduced by the implementation of rainwater harvesting systems. Rainwater harvesting has been around for centuries. For example, India has a tradition of harvesting which came into importance after a drought in 1987 (Singh *et al.*, 2011).

3.0 Methodology

3.1 Data Sets

Climatic data (specifically precipitation) was collected through Environment Canada between the years 1981-2010. This data was obtained on a per month basis and was averaged to determine precipitation norms (thus avoiding extremes). Environment Canada obtains this data from the St. Catharines Airport stations (see Table 1 and Figure 1). This station is located on the northeast side of the Region, below the Niagara Escarpment.

Table 1: St. Catharines Weather Station *(Source: Government of Canada, 2014)*

Latitude:	43°12'00.000" N
Longitude:	79°10'00.000" W
Elevation:	97.80 m

Catchment Area 1 (Thorold Neighborhood): The rooftops of each residence in this area (500m × 500m) have been digitized using ArcGIS 10.1 and ESRI's Air Photo Basemap (see Section 4.1).

Catchment Area 2 (Brock University): The rooftops of each campus building have been provided by Mr. Jeff Pengelly (2014), who has produced this data for a mapping application at Brock University (see Section 4.2).

Catchment Area 3 (Niagara Region): The number of residential dwellings in the Niagara Region has been provided by Statistics Canada, 2012, and the rooftop size was averaged using Catchment Area 1 rooftop data (see Section 4.3).

3.2 Rainfall Data

Averaged precipitation data is presented in Table 2. Note that only rainfall data is used in the analysis.

Table 2: Normal Climatic data from 1981-2010 *(Source: Government of Canada, 2014)*

Precipitation	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Rainfall (mm)	30.8	28.9	39.3	71.2	76.3	86	77.8	70.3	90.6	67	72.1	44	754.2
Snowfall (cm)	38.6	29.3	23.2	5.8	0.4	0	0	0	0	0.1	9.6	30.1	137.1
Total	65.2	54.9	61.7	77	76.8	85.9	77.8	70.3	90.6	67	81.6	71.5	880.1

3.3 Rainwater Harvesting Calculation

Rooftops are constructed in many varieties. Shape, angle, and material may change from building to building, thus effecting the rainwater catchment potential (Thomas and Martinson 2007). Furthermore, in older neighborhoods, it is believed that large trees may deflect rainwater away from rooftops altogether. While analyzing these parameters in any comprehensive way, exceeds the scope for this project. To account for these parameters, the roof areas or 'footprint' will be used to calculate the area of catchment (see Figure 2). Furthermore, catchment efficiency will be added to calculations at the level of 50%, 75% and 100%.
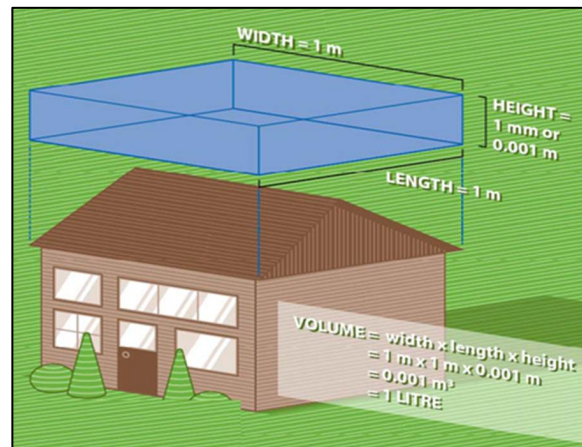
Figure 2: Catchment Area 'Footprints' *(Source: City of Guelph, 2014)*

Aladenola, *et al* (2010), provides a calculation that estimates the volume of rainwater that can be collected per household per month. The calculation is as follows:

$$VR = \frac{R \times H_{RA} \times R_C}{1,000}$$

VR = monthly volume of rainwater per household (m^3)
R = monthly rainfall (mm)
H_{RA} = household roof area (m^2) and
R_C = runoff coefficient (based on roof material and design)

For the purpose of this project, the above calculation was amended, where the R_C was removed and replaced with an 'Efficiency %'. As mentioned, efficiencies of 50%, 75% and 100% are being used to make up for assumptions caused by unknown parameters. The amended calculation is as follows:

Calculation 1: Amended Harvesting

$$\text{Water Collected (m}^3\text{)} = \frac{\text{Rainfall Depth (mm)} \times \text{Roof Area (m}^2\text{)} \times \text{Efficiency (\%)}}{1,000}$$

Example: Using data provided by the Government of Canada, the rainfall in January, averaged over the last 29 years is 30.8 mm. Furthermore, the average household roof area, calculated from Catchment Area 1, is 313 m^2. Assuming an efficiency of 100%, the volume of rainwater that can be harvested in January is as follows:

$$\text{Water Collected (m}^3) = \frac{30.8 \text{ mm} \times 313 \text{ m}^2 \times 100\%}{1{,}000}$$

$$= 9.64 \text{ m}^3 \text{ or } 9{,}640 \text{ L}$$

Assuming an efficiency of 75%

$$= 7.23 \text{ m}^3 \text{ or } 7{,}230 \text{ L}$$

Assuming an efficiency of 50%

$$= 4.82 \text{ m}^3 \text{ or } 4{,}820 \text{ L}$$

Note that results totaling 1,000,000 L (1 mega liter – ML) or more will be reported in ML (1 ML = 1,000,000 L).

3.4 Assumptions

Due to the nature of the project (scope and time constraints), the following assumptions have been made:

1. Rooftop 'footprints' for a single building are assumed to be equal to said buildings contribution to the total catchment area.
2. Rooftops are of consistent design (slope and material). Changes to the style of roof will affect the efficiency of collection.   To overcome this obstacle, several efficiencies will be assumed and compared.
3. Uniform efficiency among catchment areas. It is assumed that each building/rooftop in a catchment area has the same collection efficiency.
4. It is assumed that the rainfall data, household statistics, and digitized rooftop data are correct.
5. It is assumed that the rainfall data is representative of the region.

4.0 Results

This section evaluates the preliminary results describing the potential for rainwater harvesting, using the catchment areas described in Section 1.3 and associated data detailed in Section 3.1.

4.1 Catchment Area 1 (Thorold Neighborhood)

Catchment Area 1 is a section of a north Thorold neighborhood (500m × 500m area) (see Figure 1). Using the calculated catchment area and the Calculation 1 from Section 3.3, Table 3 provides the annual rainwater harvesting potential at three efficiencies (50%, 75%, and 100%). Furthermore, Figure 3 provides a monthly breakdown at the various efficiencies.

Table 3: Annual Rainwater Harvesting Potential (Thorold Neighborhood)

Catchment Area	Area (m^2)	Rainwater Harvesting Potential					
		100% Efficiency		75% Efficiency		50% Efficiency	
		m^3	ML	m^3	ML	m^3	ML
Neighborhood	44,159.6	38,864.9	38.865	29,148.7	29.15	19,432.5	19.43
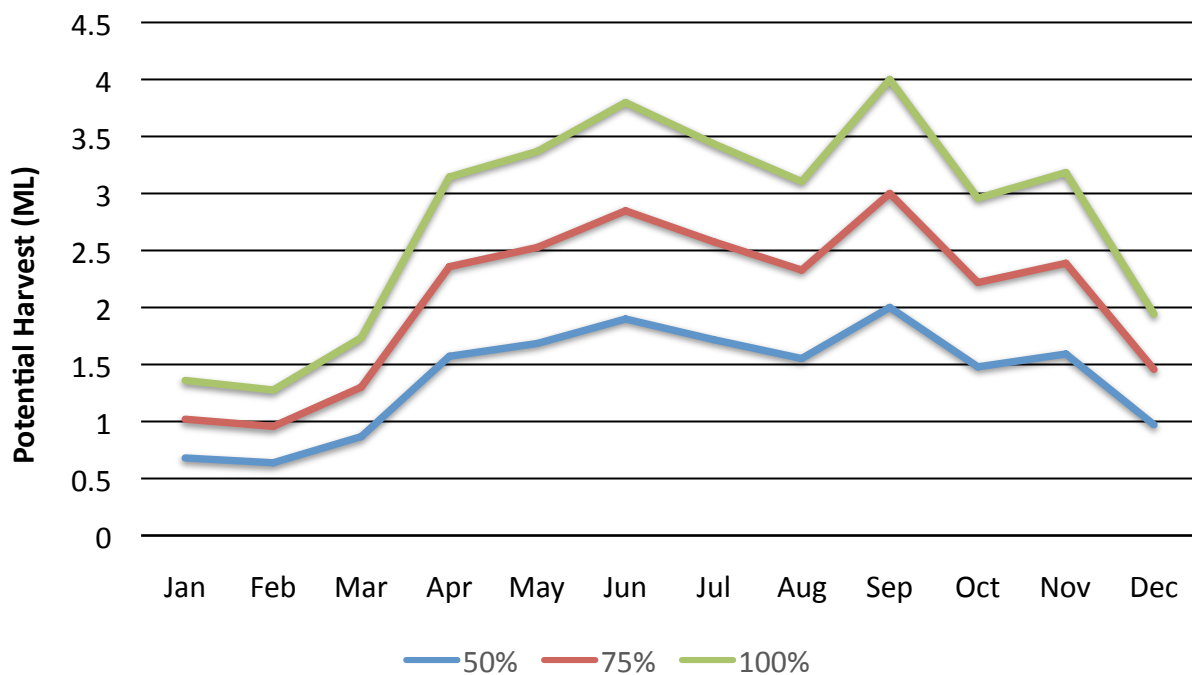
Figure 3: Rainwater Harvesting Potential (Thorold Neighborhood)

Looking at the individual houses that make up Catchment Area 1, the average rooftop area was calculated (used in Catchment Area 3) at ~313.18 m^2. Using this average area and the calculation

detailed in Section 3.3, Table 4 provides the annual rainwater harvesting potential at three efficiencies (50%, 75%, and 100%). Furthermore, Figure 4 provides a monthly breakdown at the various efficiencies.

Table 4: Rainwater Harvesting Potential (Average Dwelling)

Catchment Area	Area (m^2)	Rainwater Harvesting Potential					
		100% Efficiency		75% Efficiency		50% Efficiency	
		m^3	L	m^3	L	m^3	L
Average Individual Dwelling	313.18	275.6	275,637	206.7	206,728	206.7	137,819
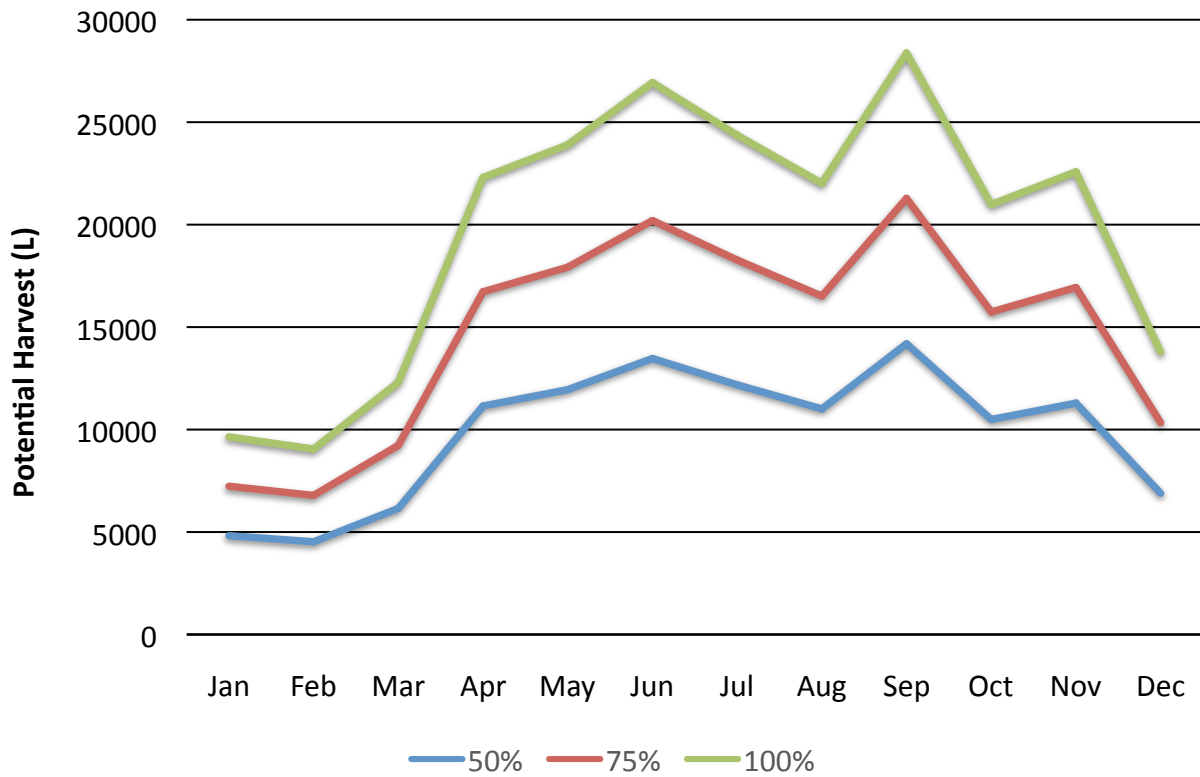
Figure 4: Rainwater Harvesting Potential (Average Dwelling)

4.2 Catchment Area 2 (Brock University)

Catchment Area 2 includes all of the Brock University – Glenridge Campus buildings (see Figure 1). Using the data provided by Mr. Jeff Pengelly, the total rooftop area for the campus was calculated to be 171,352 m^2. Using this area and Calculation 1 from in Section 3.3, Table 5 provides the annual rainwater harvesting potential at three efficiencies (50%, 75%, and 100%). Furthermore, Figure 5 provides a monthly breakdown at the various efficiencies.

Table 5: Annual Rainwater Harvesting Potential (Brock University)

Catchment Area	Area (m²)	Rainwater Harvesting Potential					
		100% Efficiency		75% Efficiency		50% Efficiency	
		m³	ML	m³	ML	m³	ML
Village Residence	17,654	13,314.39	13.31	9,985.79	9.99	6,657.19	6.66
Kenmore Centre	1,016	766.30	0.77	574.72	0.57	383.15	0.38
Harrison Hall	864	651.90	0.65	488.93	0.49	325.95	0.33
Arnie Lowenberger Residence	5,600	4,223.88	4.22	3,167.91	3.17	2,111.94	2.11
Rosalind Blauer Centre for Child Care	982	740.36	0.74	555.27	0.56	370.18	0.37
McDonald's	619	466.48	0.47	349.86	0.35	233.24	0.23
Tim Horton's	486	366.90	0.37	275.17	0.28	183.45	0.18
Heritage Place Plaza	1,906	1,437.41	1.44	1,078.06	1.08	718.71	0.72
Quarry View Residence	6,363	4,798.96	4.80	3,599.22	3.60	2,399.48	2.40
Alan Earp Residence	3,343	2,521.49	2.52	1,891.12	1.89	1260.75	1.26
Alumni Greenhouse	449	338.28	0.34	253.71	0.25	169.14	0.17
Gordon and Betty Vallee Residence	3,283	2,475.95	2.48	1,856.96	1.86	1,237.97	1.24
Decew Residence	8,988	6,778.81	6.78	5,084.11	5.08	3,389.41	3.39
Alphie's Trough	545	411.23	0.41	308.42	0.31	205.61	0.21
Theal House	557	420.26	0.42	315.20	0.32	210.13	0.21
Plaza Building	3,314	2,499.38	2.50	1,874.53	1.87	1,249.69	1.25
Student - Alumni Centre	2,507	1,890.75	1.89	1,418.06	1.42	945.38	0.95
Taro Hall	3,308	2,495.15	2.50	1871.36	1.87	1,247.58	1.25
South Block	7,723	5,825.02	5.83	4,368.76	4.37	2,912.51	2.91
Mackenzie Chown Complex	26,670	20,114.60	20.11	15,085.95	15.09	10,057.30	10.06
573 Glenridge Avenue	2,825	2,130.68	2.13	1,598.01	1.60	1,065.34	1.07
East Academic 1	1,280	965.66	0.97	724.24	0.72	482.83	0.48
East Academic 2	1,280	965.66	0.97	724.24	0.72	482.83	0.48
East Academic 3	1,280	965.66	0.97	724.25	0.72	482.83	0.48
Central Utilities Building	3,932	2,965.34	2.97	2,224.00	2.22	1,482.67	1.48
Concordia Lutheran Seminary	2,209	1,665.87	1.67	1,249.40	1.25	832.93	0.83
Welch Hall	6,221	4,691.80	4.69	3,518.85	3.52	2,345.90	2.35
Scotiabank Hall	2,504	1,888.67	1.89	1,416.51	1.42	944.34	0.94
Thistle Complex	16,440	12,399.06	12.40	9,299.30	9.30	6,199.53	6.20

Table 5 (Cont.): Annual Rainwater Harvesting Potential (Brock University)

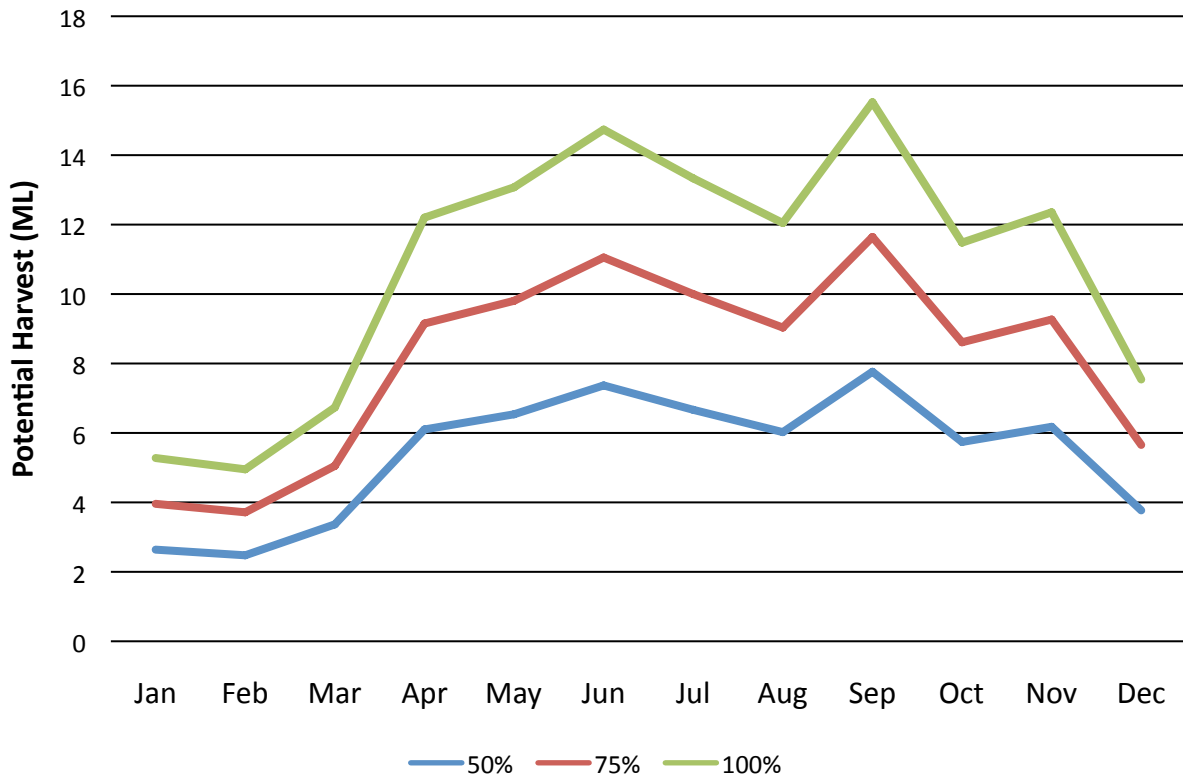| Catchment Area	Area (m²)	Rainwater Harvesting Potential					
		100% Efficiency		75% Efficiency		50% Efficiency	
		m³	ML	m³	ML	m³	ML
Arthur Schmon Tower	6,528	4,923.62	4.92	3,692.71	3.69	2,461.81	2.46
Walker Complex	23,481	17,709.73	17.71	13,282.30	13.28	8,854.86	8.85
Cairns Family Health and Bioscience Research Complex	7,192	5,424.47	5.42	4068.35	4.07	2,712.23	2.71
Total	**171,352**	**129,233.70**	**129.23**	**96,925.28**	**96.93**	**64,616.85**	**64.62**

Figure 5: Rainwater Harvesting Potential (Brock University

4.3 Catchment Area 3 (Niagara Region)

As discussed earlier, to calculate the harvesting potential for the Niagara Region, Statistics Canada (2011) evaluation of the Niagara Region residential dwellings, and the average roof "footpint" (calculated from Catchment 1) was used.

$$\text{Catchment Area (m}^2\text{)} = \text{\# Niagara residences} \times \text{average roof 'footprint'}$$
$$= 188,877 \times 313.19 \text{ m}^2$$
$$= 59,154,387.63 \text{ m}^2$$

Using the calculated Catchment Area and the calculation detailed in Section 3.3, Table 6 provides the annual rainwater harvesting potential at three efficiencies (50%, 75%, and 100%). Furthermore, Figure 6 provides a monthly breakdown at the various efficiencies.

Table 6: Annual Rainwater Harvesting Potential (Niagara Region)

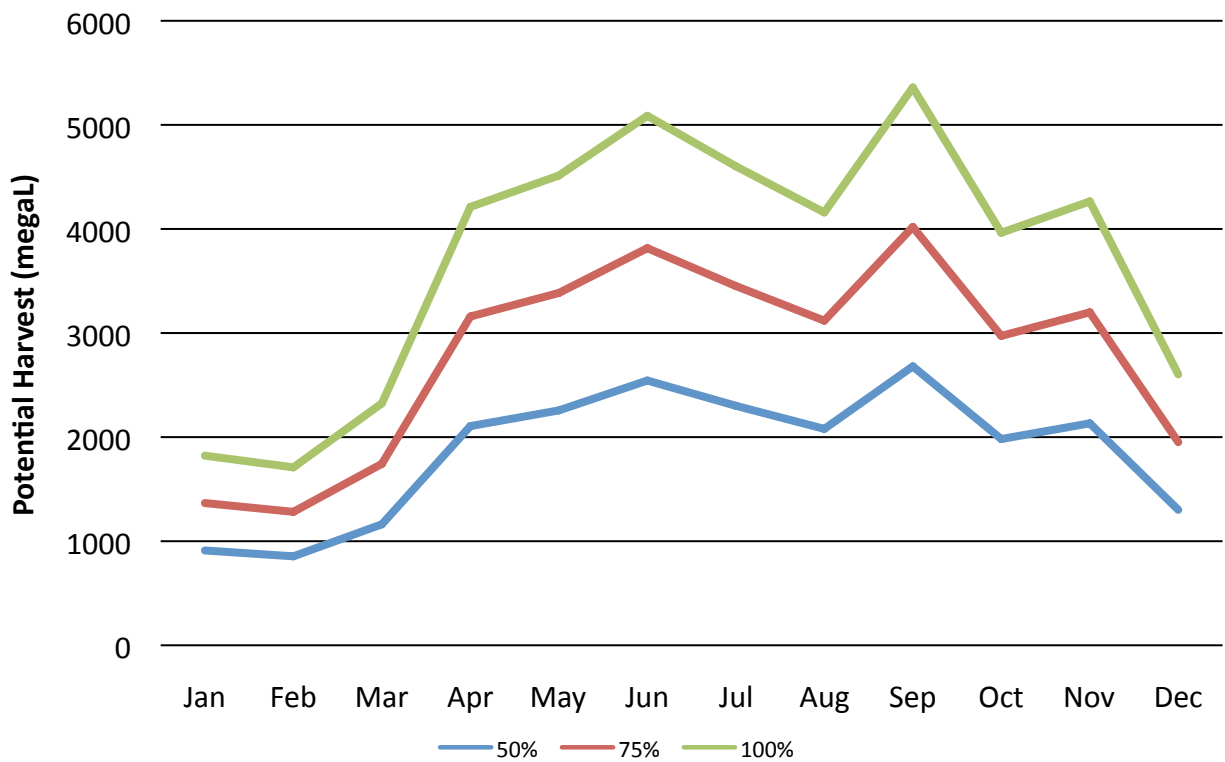| Catchment Area	Area (m²)	Rainwater Harvesting Potential					
		100% Efficiency		75% Efficiency		50% Efficiency	
		m³	ML	m³	ML	m³	ML
Niagara Region	59,154,387.63	4.46E+07	44,614.08	3.35E+07	33,460.56	2.23E+07	22,307.04

Figure 6: Rainwater Harvesting Potential (Niagara Region)

5.0 Water & the Niagara Region

Now that the potential for rainwater harvest had been assessed, these numbers must be allied to the Niagara Region. This section will look at the estimated amount of water consumed for domestic purposes and compare it to the potential harvest estimated for all Niagara Region residences. Furthermore, this will be broken down to the individual household level.

A summary of the rainwater harvesting potentials detailed through Section 5 is provided in Table 7.

Table 7: Summary of Rainwater Collection Potential

Catchment Area	Rainwater Collection Potential		
	100% Efficiency	75% Efficiency	50% Efficiency
Niagara Region	44,614.08 ML	33,460.56 ML	22,307.04 ML
Brock University	129.03 ML	96.93 ML	64.62 ML
Thorold neighborhood	38.87 ML	29.15 ML	19.43 ML
Average Individual Dwelling	275,637 L	206,728 L	137,819 L

The domestic water use in the Niagara Region has been estimated to be approximately 66.1 million m^3/year (Niagara Region & ERSC, 2013). If this number is compared to the maximum collection potential, one can see how much rainwater can contribute to the domestic supply.

$$66,100,000 \text{ } m^3/year = 66,100,000,000 \text{ L/year} = 66,100 \text{ ML/year}$$

At 100% Collection Potential:

$$(44,614.08 ÷ 66,100) × 100 = 67.49\% \text{ of annual water use}$$

At 75% Collection Potential:

$$(33,460.56 ÷ 66,100) × 100 = 50.62\% \text{ of annual water use}$$

At 50% Collection Potential:

$$(22,307.04 ÷ 66,100) × 100 = 33.75\% \text{ of annual water use}$$

While there are limitations regarding these highly speculative numbers, they do give a good indication of the potential rainwater harvest may have (even at 50%). One must consider, as Section 2.0 mentions, the benefits of diverting water in storm events. While these numbers are only calculated on an annual basis, refer back to Figure 6, to see the amount of water than can be diverted from storm water systems, and this is only considering domestic water (not commercial or industrial). By diverting large quantities of water, the infrastructure of urban areas will not only last longer, but negative events

associated with overwhelmed systems (floods, combined sewer overflows) should decrease. Ultimately, this protects our drinking water source.

While it is useful to estimate on a large scale, it is also very important to assess on a small scale. In this case, looking at what rainwater harvest average means on a household level. The estimate of per-capita water use in Canada has been estimated at 329 L/day (Environment Canada, 2013). If one assumes four individuals per house, the annual use is as follows:

Annual Household Water Consumption = (329 × 4) × 365 = 480,340 L/year

At 100% Collection Potential:

(275,637 ÷ 480,340) × 100 = 57.38% of annual water use

At 75% Collection Potential:

(206,728 ÷ 480,340) × 100 = 43.04% of annual water use

At 50% Collection Potential:

(137,819 ÷ 480,340) × 100 = 28.69% of annual water use

Even at 50% efficiency, one can see the significant benefit harvested rainwater could have on an individual household basis. Of course, there are additional considerations such as one's ability to use and collect rainwater. Use of rainwater in a household would be limited to activities where treated water was not needs (ex: could not be used for drinking, cooking or showering).

Information on the implementation and feasibility of harvesting systems is assessed in the following section.

6.0 Feasibility

6.1 Storage

As the previous section detailed, there is a great potential to harvest rainwater at the household level, however, in terms of implementing a harvesting system, there are a wide range of cost depending on the type you would like to build. According to the City of Niagara Falls, 2014, on a household scale harvesting systems have the potential to save anywhere between 30%-50% and up to 80% on a commercial level (which has not been evaluated by this document).

6.1.1   Above Ground: Rain Barrel

For the household, the installation can be as simple as purchasing a rainwater barrel and connecting it to a downspout. These can be purchased for $40.00 CDN. Along with a rainwater barrel an overflow hose must be connected to reduce the chance of an overflowing barrel (these range from $10.00-$15.00 CDN). Rainwater barrels are convenient but in areas that are vulnerable to winters below 0°C, the barrels have the potential to freeze. This can result in downspout back-ups during heaving precipitation events or extreme temperatures (City of Guelph, 2014)

6.1.2   Below Ground

With the Niagara Region being subject to winters below 0°C, a second choice, is to install an underground tank. These types of tanks are more expensive, as they need to be buried below the frost line (3-4 ft.) to prevent freezing.   The price of an underground tank succeeds $12,000.00 CDN plus the cost of excavation which costs another $90.00/m^3. Along with an underground tank, a pump and adequate pipes must be installed to utilize the water available increasing the cost once again (City of Guelph, 2014).

6.1.3   Integrated Storage

On a commercial size scale, there is the potential to implement integrated storage into a building. Typically these are found within the walls of underground parking, but can be placed within any available space with adequate engineering. These systems do not take up yard space, and can be manufactured to a specific size, but are much more expensive than others (City of Guelph, 2014).

6.1.4   Gray Water Use

In addition to the Purace and installation of a collection system, in order to use rainwater to its full potential, homes must be able to add collected rainwater to their domestic supply. This is understandably easier to do, when systems are planned during house construction, opposed to retrofitting. The cost of this is unknown. It is assumed that the cost would vary house to house.

6.2 Water Savings

With implementing a rain water harvest system, the potential to collect and reuse rain water can be substantial. Collecting rainwater at 50% efficiency, each household (with an average of four people per home) can save 28.69% of annual water use, and if the collection efficiency is increased to 75%, the annual water use can be reduced to over 43.04%. These levels are consistent with the estimate provided by the City of Niagara Falls (see Section 6.1). Note again, that these savings are not only assuming collection efficiency, but the installation of gray-water system (i.e. rainwater added to appropriate domestic supply). Finally, there is the assumption that the harvesting system you have is large enough to benefit from rainwater at given efficiencies.

Up to this point, the potential of rainwater harvest has been evaluated in volume. The following will look at individual households and evaluate in dollars. Table 8 details the Water/Wastewater rates for the cities of St. Catharines and Welland.

Table 8: Water/Wastewater Rates

City	Type	Base Charge	Usage Charge (per m^3)
St. Catherines	Water	$12.50/month	$1.199
	Wastewater	$6.75/month	$1.688
Welland	Water	$16.03/quarter	$1.6154
	Wastewater	$12.15/quarter	$2.6578

For each municipality, there is a minimum charge implemented even if the home consumes no water. This base charge is for being connected to water/wastewater systems/infrastructure. In St. Catharines the minimum charge per month is $19.25 (waster + wastewater) while in Welland they charge on a quarterly basis at $28.18 (waster + wastewater) per quarter. In addition to these charges, there are usage changes every month per cubic meter of water/wastewater (City of St. Catharines, 2013; City of Welland , 2014).

Using the rates provided in Table 8, and the following scenario, a monthly household water bill will be calculated below.

<u>Scenario</u>
- Water use per/capita = 329L/per
- Individuals per/house = 4
- Monthly household water consumption = ~40,028L/month

Assuming a 100% consumption charge, with a return factor of 92%, a monthly household water bill is calculated by the equation:

Total water cost = Water base charge + (water usage charge × m^3 consumed × 100%) + wastewater base charge + (wastewater usage charge × m^3 consumed × 92% (RF)*)

A household in St. Catharines will have a monthly charge of $129.41/month ($1,552.88/year) while a household in Welland while have a monthly charge of $171.93/month ($2,063.18/year). If a rainwater harvest system is implemented, this can reduce your monthly water cost according to the following equation:

Calculation 2: Amended Water Savings

$$\text{Total water cost with RWH system} = \text{Water base charge} + (\text{water usage charge} \times ((\text{m}^3 \text{ consumed} \times 100\%) - \text{collected rainwater})) + \text{wastewater base charge} + (\text{wastewater usage charge} \times \text{m}^3 \text{ consumed} \times 92\% \text{ (RF)*})$$

The change in cost is represented in red. The total amount of water consumed is reduced by the amount of rainwater harvested, however the amount of wastewater outputted does not change and is equal to all water used, whether from the city or from the stored rainwater. Therefore the total cost of water with a rainwater harvesting system is reduced only by the incoming water use. These costs are summarized in Table 9, showing the savings with different efficiencies from St. Catharines and Welland, Ontario. These Savings range from the amount of rainwater harvested and the city from which your water is supplied from, ranging from $294 - $353 per year with 50% efficiency and upwards to $500 per year if the RWH is maximized at 100%.

Table 9: St. Catharines & Welland Water/wastewater Savings per year

City	Cost without RWH	Efficiency	Cost with Harvesting	Savings
St. Catharines	$1,552.88	50%	$1,199.50	$353.37
		75%	$1,128.69	$424.19
		100%	$1,057.88	$495.00
Welland	$2,063.18	50%	$1,769.04	$294.14
		75%	$1,673.64	$389.54
		100%	$1,578.23	$484.95

6.3 Benefits for the Niagara Region

Economic: Although cost savings are noted in Section 6.2, a study out of the United Kingdom, completed by Roebuck *et al* (2010), found that rainwater harvest is not as cost effective for households. Furthermore, the study states that harvesting systems typically resulted losses comparable to the initial capital cost. While this is certainly not encouraging, this conclusion did not consider other potential economic benefits. An example of an additional benefit may be reduced infrastructure stress (i.e. less water moving through the system, decreased treatment costs, etc.).

Environmental: As discussed in previous sections, the major benefit of harvesting rainwater would come from the reduction of water required from major sources and the reduction of water hitting storm water systems during storm events.

7.0 Recommendations for Further Study

The purpose of this project was to estimate the potential for rainwater harvest in the Niagara Region and assess some benefits. As such many assumptions had to be made and statistics used. Furthermore, specific requirements for rainwater harvesting systems were not explored in any great detail, as they are outside the scope of this preliminary investigation. Having said this, the numbers presented in this report are encouraging and BUGS recommends the Region investigate the use of rainwater further. The following are a set of recommendations, which will assess the use of rainwater in more practical terms.

1. Expand research to include industrial and commercial properties: With the inclusion of commercial and industrial properties, water use in the region and rainwater harvesting potential can be calculated on a much larger scale. The extreme variability of industrial and commercial operations combined with their variable water use, led BUGS to exclude them from this project, however we recognize the need to look at these properties.

2. Expand research to estimate storm conditions: As mentioned, collecting rainwater can reduce the burden on storm water systems during heavy precipitation events. It would be interesting to assess the extent to which collection systems may help have in these events.

3. Include rainwater harvesting and gray water use into a household in Niagara: In a typical development for middle class families, implement rainwater harvest and gray water integration during construction. Once complete, the added cost of said systems can be evaluated and the collection potential can be assessed over a year (or more). This document provided an excellent estimate for the size of system, however the criteria for implementation are largely left out. Once a house is completed, this document can be referenced again, to fully compare cost of systems vs. water savings through harvest.

4. Retrofit a rainwater harvesting and gray water system into an existing house: Retrofitting systems in existing residential properties will be the most challenging, however the cost and procedures of doing so are well worth exploration. Again, this document can provide estimates for sizing systems and once the retrofit is completed, this document can be referenced again, to fully compare cost of systems vs. water savings through harvest.

Recommendations 2-4 are of particular importance as it will aid the region in cost-benefit-analysis. The implementation of rainwater harvesting systems on any large scale should be done after said recommendations are followed through. While the numbers in this report are encouraging, as mentioned, they are estimates and cannot be taken as fact. Further experimentation is required. Finally, if the region were to go ahead in implementing to promoting such systems, BUGS recommends some sort of rebate program to reduce the cost concerns for residence (thus eliminating or reducing concerns stated by Roebuck *et al*, 2010).

8.0 Conclusions

BUGS was retained by Dr. Jayson Childs at the Niagara Region, in January of 2014 to conduct a preliminary assessment on the potential for rooftop rainwater harvest within the region. Furthermore, BUGS is to explore the potential benefits, relating to rainwater harvest.

This document does not go into detail regarding the use, installation, and implementation of rainwater harvesting systems. For more information, see the Canada Mortgage and Housing Corporation's (CMHC) document titled 'Guidelines for Residential Rainwater Harvesting Systems Handbook'.

BUGS completed preliminary rainwater harvesting estimates for four areas (includes data sources):

Catchment Area 1 (Thorold Neighbourhood): The rooftops of each residence in this area (500m × 500m) have been digitized using ArcGIS 10.1 and ESRI's Air Photo Basemap.
> Catchment Area 1 (Average Dwelling): Based on the digitized rooftop data, an average household size was determined.

Catchment Area 2 (Brock University): The rooftops of each campus building have been provided by Mr. Jeff Pengelly (2014), who has produced these data for a mapping application at Brock University.

Catchment Area 3 (Niagara Region): The number of residences in the Niagara Region has been provided by Statistics Canada, 2012, and the rooftop size was averaged using Catchment Area 1 rooftop data.

It is estimated that rainwater can be harvested at a quantity equal to 33.75% - 67.49% of domestic water consumption in the Niagara Region. Furthermore, on a household level, it is estimated that rainwater can be harvested at a quantity equal to 28.69% - 57.38% of water consumption. Furthermore, despite sources believing rainwater harvest is ineffective in terms of reducing cost, we find the potential much greater (savings between $294.14 and $495.14 per year). While it may take many years to pay off the retrofitting of a harvesting system, if implemented into new developments, the savings may be significant.

Due to the number of assumptions and statistics used in this preliminary investigation, further study is recommended. Recommendations are primarily made with the intention of completing a cost-benefit analysis to determine if the region should go ahead with the implementation or promotion of such systems. These recommendations include:
1. Expand research to include industrial and commercial properties
2. Expand research to estimate storm conditions
3. Include rainwater harvesting and gray water use into a household in Niagara
4. Retrofit a rainwater harvesting and gray water system into an existing house

BUGS believes that implementing rainwater harvesting systems will yield benefits economically and environmentally. These systems will reduce storm water flow in high precipitation events, protect source waters and reduce the demand on infrastructure.

9.0 Works Cited

Aladenola & Adebove 2010, 'Assessing the Potential for Rainwater Harvesting', Water Resour Manage, 24, pp. 2129–2137.

Brock Buildings [computer file]. Thorold, ON: Mr. Jeff Pengelly, 2014 (March 7, 2014)

Canada Mortgage and Housing Corporatio 2013, 'Guidelines for Residential Rainwater Harvesting Systems Handbook', viewed 3 April 2014, < http://www.cmhc-schl.gc.ca/en/inpr/su/waho/waho_002.cfm >.

CanMap Streets [computer file]. Markham, ON: DMTI, 2011. Available: Scholars GeoPortalhttp://geo2.scholarsportal.info/ (March 7, 2014)

CanMap MJWTR [computer file]. Markham, ON: DMTI, 2012. Available: Scholars GeoPortalhttp://geo2.scholarsportal.info/ (March 7, 2014)

City of St. Catharines 2013, WATER/WASTEWATER CONSUMPTION CALCULATOR, viewed 3 April 2014, <http://www.stcatharines.ca/en/livein/WaterWastewaterConsumptionCalculator.asp?_mid_=11181>

City of Guelph 2014, Residential Rainwater Harvest Design and Installation Best Practices Manual

City of Niagara Falls 2014, Rain Barrel Sale, viewed March 20, 2014 from <http://www.niagarafalls.ca/living/environment/rain-barrel-sale.aspx>.

City of Welland 2014, Water, viewed 3 April 2014, <http://www.welland.ca/Finance/Water.asp#wtrrates>

Environment Canada 2013, Wise Water Use, viewed 3 April 2014, < http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=F25C70EC-1>

Environmental Sustainability Research Center & the Niagara Region 2013, Liquid Assets: Assessing Water's Contribution to Niagara, viewed 3 April 2014, < http://www.niagararegion.ca/living/water/pdf/NR-Liquid-Assets-Paper-2013-FINAL.pdf>.

Farreny, R, Morales-Pinzon, T, Guisasola, A, Taya, C, Rieradevall, J, & Gabarrell 2011, 'Roof selection for rainwater harvesting: Quantity and quality assessments in Spain', Water Research, 45, 10, pp. 3245-3254.

Government of Canada 2010, Climate Normals 1981-2010: St Catharines Airport, viewed February 25, 2014 from <http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?stnID=4683&autofwd=1>.

Katambara, Z 2013, 'Quantifying Rooftop Rainwater Harvest Potential: Case of Mbeya University of Science and Technology in Mbeya Tanzania', Engineering, 5, 10, p. 816.

Mills, C 2007 'Toronto's July flood listed as Ontario's most costly natural disaster', Toronto Star, 14 August, p. 17, viewed 6 March 2014, <http://www.thestar.com/business/2013/08/14/july_flood_ontarios_most_costly_natural_disaster.html>.

Provinces and Territories [computer file]. Ottawa, ON: Statistics Canada, 2011. Available: Scholars GeoPortalhttp://geo2.scholarsportal.info/ (March 7, 2014)

Rain Water Harvesting, How much will it cost to catch rain?, viewed March 20,2014 from <http://www.rainwaterharvesting.org/Urban/Costs.htm>.

Roebuck, R, Oltean-Dumbrava, C, & Tait, S, 2010, Whole life cost performance of domestic rainwater harvesting systems in the United Kingdom', Water and Environment Journal, 25, pp. 355–365.

Sheng, L, Mari, T, Ariffin, A, & Hussein, H 2012, 'Integrated Sustainable Roof Design', Procedia Engineering, 21, p. 846.

Singh, V, Kumar, A, & Santosh, D 2011, 'Planning and Design of Roofwater Harvesting System', International Journal Of Agriculture, Environment & Biotechnology, 4, 4, pp. 375-381.

Statistics Canada 2012, Niagara, Ontario (Code 3526) and Ontario (Code 35) (table). Census Profile. 2011 Census. Statistics Canada Catalogue no. 98-316-XWE. Ottawa. Released October 24, 2012. Viewed February 25, 2014, from <http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/index.cfm?Lang=E,>.

Thomas & Martinson 2007. Roofwater Harvesting: A Handbook for Practitioners. IRC International Water and Sanitation Centre.

UN 2012, World Urbanisation Prospects: The 2011 revision. United Nations Population Division. United Nations, Department of Economic and Social Affairs, Population Division: New York.

Yaziz, M., Gunting, H., Sapari, N., Ghazali, A 1989, 'Variations in Rainwater Quality From Roof Catchments', Water Research, 23, 6, pp. 761-765.

1-10m Land [computer file]. Unknown: Natural Earth. Available: Online at http://www.naturalearthdata.com/downloads/10m-physical-vectors/ (March 7, 2014)