SCALING UP DOMESTIC RAINWATER HARVESTING
ST. CUTHBERT'S MISSION, GUYANA

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ABSTRACT

Guyana Water Inc (GWI), Guyana’s state water utility, is currently pursuing a Hinterland Water Strategy with the goal of ensuring clean water for 80% of rural areas. Under the new national water strategy the Amerindian community of St. Cuthbert’s Mission has been receiving increased government attention and support to develop their community water infrastructure. In St. Cuthbert’s Mission, much like many rural communities, household water security is achieved through the combined use of a number of different water sources. This report argues that facilitating the installation of formal DRWH systems will have a large impact on household water security, and can be supported in conjuncture with the Guyanese government’s current plans for improving the efficiency and reliability of piped water in the community. Despite the fact that rainwater was not shown to have a better, or worse, impact on water quality than other sources, DRWH systems were shown to be a relatively low cost option for universally improving a households’ geographical and temporal access to a water source, increasing convenience, decreasing collection times and overall increasing a households’ ‘felt’ water security.

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Introduction

Over the past two decades significant gains have been made in increasing global access to safe drinking water. The Millennium Development Goals midterm progress assessment found that in 2002, 83% of the global population had access to an improved source of drinking water. Despite noteworthy advancements in drinking water coverage in most regions of the world, 1.1 billion people still lack access to safe drinking water. Globally one in six people thus have no alternative but to consume unsafe water. (WHO/UNICEF, 2004) In the face of increasing global water stress the difficulties associated with assuring access to clean drinking water will only escalate. By 2050 it is estimated that two-thirds of the global population will be living in water scarce countries with 1,800 million people living in areas of absolute water scarcity. (WHO, 2007) The importance of continuing to increase accessibility to safe drinking water cannot be underestimated and remains a critical issue for both global and national development agendas. The continued failure of the modern water sector to reach 20-30% of the world's population has provoked increasing attention towards decentralized rural water supply and household level water management. (Moriarty et al., 2004) One of the many technologies being promoted within this paradigm is rainwater harvesting. Domestic rainwater harvesting (DRWH) is receiving increased attention from NGOs, International Organizations and governments as a viable drinking water technology. Improvements in water quality, security and consumer convenience are supporting the installation of DRWH not only as an alternative where no safe drinking water sources exist, but as a mainstream potable water source.

Despite the officially reported high rates of drinking water coverage in Guyana, the national water supply infrastructure remains plagued with problems of access, reliability and quality. Concerns of inadequate and inefficient water supply are most acutely felt in the rural or hinterland areas. Guyana Water Inc (GWI), the country's state water utility, is currently pursuing a Hinterland Water Strategy with the goal of ensuring clean water for 80% of rural areas. (IRCa, 2009) Under the new national water strategy the Amerindian community of St. Cuthbert's Mission has been receiving increased government attention and support to develop their community water infrastructure. As domestic rainwater harvesting (DRWH) is already accepted and used by the majority of community residents, albeit mainly in an informal manner, this report seeks to identify the potential benefits to community water security and water quality wrought from scaling up DRWH in St. Cuthbert's Mission.

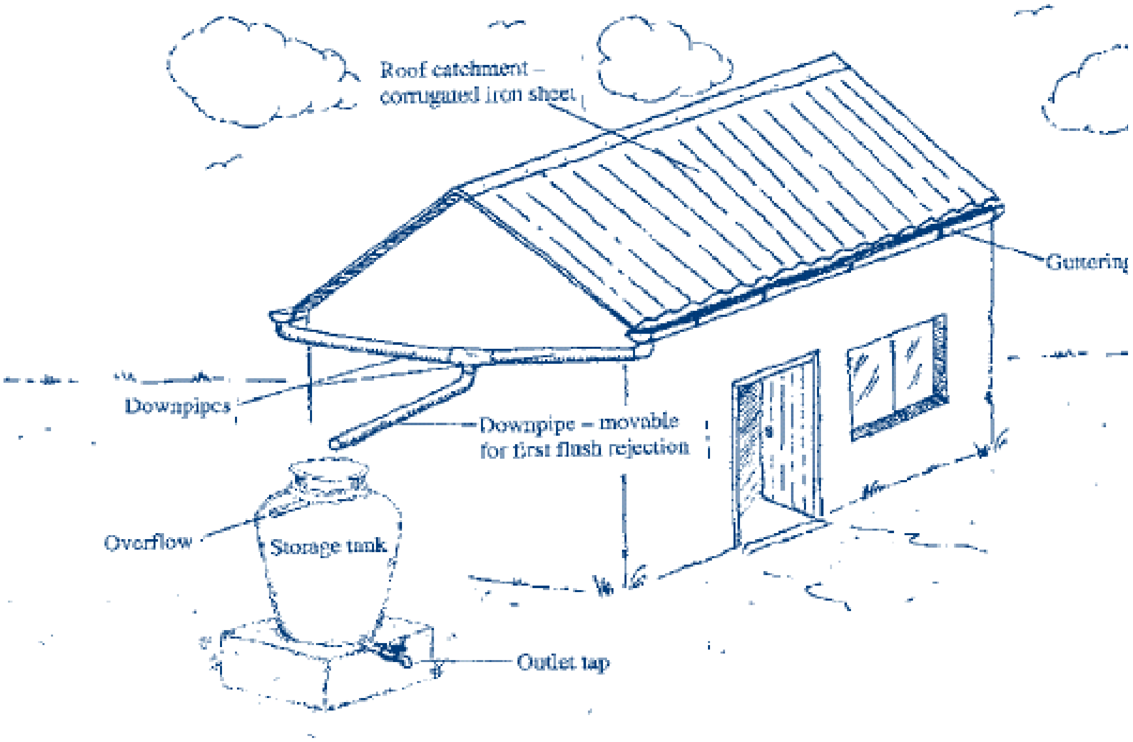
1 Project Background

This report is an adjunct to an ongoing research project on the Comparison of Household Water Treatment (HWTS) Options in St. Cuthbert's Mission, Guyana. The study led by Mrs. Candice Young-Rojanschi is part of the CARIWIN project on Integrated Water Resources Management (IWRM) in the Caribbean, led by the Brace Centre for Water Resources Management at McGill University and the Caribbean Institute for Meteorology and Hydrology (CIMH), Barbados. With the goals of poverty reduction and gender equality through a process of institutional capacity building in integrated water management, the project aims to improve existing capacity in 3 pilot countries by involving local community organizations, water use associations and regional and national networks.

As part of the Comparison of HWTS Options study 203 households in St. Cuthbert’s Mission were surveyed. The first survey, done between August and December 2008, questioned residents on their knowledge, attitudes and practices surrounding household water use. From March to June 2009 water samples were taken from each household and tested for a number of quality indicators, including PH, turbidity and the formation of thermotolerant coliform colonies. All data and findings within this report have graciously been provided by Mrs. Young-Rojanschi and remain under her ownership.

2 Domestic Rainwater Harvesting

Figure 1: Typical Domestic Roofwater Harvesting System



Source: Thomas and Martinson, 2007

Rainwater harvesting is a broad term referring to the small-scale concentration, collection, storage, and use of rainwater runoff for productive purposes. (Kahinda et al, 2007) Domestic Rainwater Harvesting (DRWH), a subset of rainwater harvesting, refers to the collection of rainwater from various sources, including rooftops, courtyards, and plastic sheeting. Rainwater is then stored in underground or aboveground tanks, buckets or barrels to be used for domestic purposes. The collection and storage of rainwater has the potential to improve a household's water security by ensuring access to water over dry periods, increasing convenience, and offering a high quality alternative to other unprotected community water sources. In focusing on DRWH as a potable water source this report will only consider roofwater harvesting, as it is the most common source of rainwater collection and provides the highest quality water. (Thomas, 1998) Above is an image (Figure 1) of a typical roofwater harvesting system that illustrates the three main components: a collection system (roof), a conveyance system (gutters or pipes) and a storage system (tank or cistern).

2.1 Water Security

The definition of household level water security has been evolving since its conception in 1997. Its most recent incarnation is the "accessibility, reliability and timely availability of adequate safe water to satisfy, basic human needs" (Ariyabandu, 2001, p.3). This definition can be broken down into three components; 1) Geographical Access: proximity of source to the household, 2) Temporal Access: assured access to such sources at any time of need, and 3) Convenience: access against a reasonable effort in time of collection and energy. (LRHFa, 2001) Roofwater harvesting easily satisfies the first and third condition as rainwater is accessible at every house on which rain falls. Roofwater also delivers water directly to the household, relieving the burden of water carrying, and significantly reducing the time taken for collection. (Thomas and Martinson, 2007) There are multiple benefits that arise from improving the proximity and convenience of a potable water source: time that had been spent collecting water is freed up for more productive activities; a ready reserve of rainwater offers residents a sense of water security; and it has been well documented that the ease with which water can be obtained positively influences the amount of domestic water consumption. (Thomas, 1998) The question of whether DRWH can meet the second condition, i.e., offer assured temporal access, depends largely on the locale, as the available quantity of rainwater depends not only on the characteristics of the systems, including roof and storage size, but also climactic conditions, such as duration and intensity of rainfall and length of the dry season.

2.2 Water Quality

In encouraging the use of rainwater harvesting systems in rural areas one of the main benefits that is often praised is the improvement to the quality of a household's drinking water. As rainfall is generally viewed as chemically clean and usually biologically low-risk water (Thomas and Martinson, 2007), proponents claim that it provides a safe alternative for rural areas that often have no choice but to collect water from unprotected sources such as creeks and rivers. "Rainwater itself is of excellent quality, only surpassed by distilled water – it has very little contamination, even in urban or industrial areas, so it is clear, soft and tastes good" (Thomas and

Martinson, p.38). However, with increasing attention being placed on DRWH systems, confidence in the quality of rainwater is starting to be questioned.

Table 1: Types of Contaminants in Rainwater Tank Systems

Contaminant	**Source**	**Risk of entering Rain Tank**
Dust and Ash	Surrounding dirt and vegetation, Volcanic activity	*Moderate*: Can be minimized by regular roof and gutter maintenance and use of a first-flush device.
Pathogenic Bacteria	Bird and other animal droppings on roof, attached to dust	*Moderate*: Bacteria may be attached to dust or in animal droppings falling on the roof. Can be minimized by use of a first-flush device and good roof and tank maintenance.
Heavy metals	Dust, particularly in urban and industrialized areas, roof materials	*Low*: Unless downwind of industrial activity such as a metal smelter and/or rainfall is very acidic (this may occur in volcanic islands)
Other Inorganic Contaminants (e.g. salt from sea spray)	Sea spray, certain industrial discharges to air, use of unsuitable tank and/or roof materials	*Low*: Unless very close to the ocean or downwind of large-scale industrial activity
Mosquito Larvae	Mosquitoes laying eggs in guttering and/or tank	*Moderate*: If tank inlet is screened and there are no gaps, risks can be minimized.

Source: Mosley 2005

Rainwater quality is considered to be acceptable if there is no bacteria of faecal origin present that may cause human diarrhoea or other life-threatening diseases (e.g. typhoid fever), there is an absence of chemicals (e.g. heavy metals) or chemical substances that would cause harm to human health, and the water does not have a bad taste or smell. (Mosley, 2005) As can be seen in Table 1 contaminants with the highest risk of entering rainwater tanks are dust, mosquito larvae and pathogenic bacteria. Diseases that have been attributed to the consumption of untreated rainwater include bacterial diarrheas due to *Salmonella* and *Campylobacter*, bacterial pneumonia due to *Legionella*, botulism due to *Clostridium*, tissue helminths, and protozoal diarrheas from *Giardia* and *Cryptosporidium.* (Lye, 2002) Furthermore, poorly installed and maintained DRWH systems provide ideal breeding grounds for disease vectors, such as mosquitoes, and can contribute to outbreaks of Malaria and Dengue.

In their review of recent studies on rainwater harvesting systems Meera & Ahammed (2006) found that DRWH systems often do not meet microbiological drinking-water quality standards. “All studies suggest that some form of treatment of the harvested rainwater is necessary before it can be used as a source of drinking water” (Meera & Ahammed, p. 266). The importance of treating rainwater for potable uses has been echoed throughout the literature. In their report on DRWH water quality the Indian Institute of Technology (ITT) found in their literature survey that the percentage of DRWH samples that met potability standards varied from 10-70%; not a single case was found where 100% of the samples met bacteriological standards. (ITT, 2000)

2.2.1 Factors Affecting Rainwater Quality

For rural areas the two most important factors affecting the quality of harvested rainwater are exposure to contaminants during collection, and the characteristics of the storage system.

2.2.2 Exposure to Contamination During Collection

When it comes to collection, the main determinants of rainwater quality are roof and rainfall characteristics. The bacteriological quality of rainwater from metallic roofs is higher than from other roof materials because the dry heat of a metal roof under direct sunlight supports pathogen die-off and desiccation. (Meera & Ahammed, 2006; Thomas and Martinson, 2007) Rainwater contamination during collection is most often the consequence of accumulation of material on the roof and in the gutters. Pathogen presence has been observed to increase during longer dry periods between rainfall events as a result of increased levels of material deposition on roofs. (Lye, 2002) Pathogen concentrations in the first few minutes of a rain event are often extremely high, consequently diverting the first 2 mm of runoff has shown dramatic increases in rainwater quality, known as the ‘first-flush phenomenon’. (Meera & Ahammed, 2006) Other researchers have found that for each mm of first flush the contaminate load will halve. (Thomas and Martinson, 2007) Improper installation or cleaning of gutters can also encourage debris and organic matter to build up, and if they do not drain properly, the debris-laden gutters can be important breeding sites for disease vectors.

However, even if particles and organic matter are present on roofs or gutters, if DRWH systems are properly installed and maintained, the likelihood of their entrance into the storage tank is limited. Furthermore it is important to note that potential paths for a human pathogen to a roofwater tank are quite limited. While some contend that fecally-contaminated dust blowing onto the roof may be one pathway, Thomas and Martinson (2007) argue that pathogen survival through the desiccation process is unlikely. For that reason the frequent presence of fecal contamination found in many DRWH quality studies is often found to be of animal origin (Meera & Ahammed, 2006).

2.2.3 Treatment and Storage

Storage is often understood to be a key opportunity for purifying rainwater through processes such as sedimentation and bacterial die-off, which result from air and nutrient limitations because of anaerobic conditions. (Vasudevan and Pathak, p. 12; Thomas and Martinson, p. 39) However, studies have shown that this is not always the case; poorly designed, used or maintained storage can in fact result in increases of contamination. For example, if the top of the tank is not properly covered, light and oxygenation can create an active ecosystem in the tank, resulting in stagnant water of very poor quality. (Thomas and Martinson, 2007) Studies have also shown that tank capacity influences microbiological water quality, with smaller tanks having higher levels of contamination. This is due to the fact that smaller tanks receive a relatively greater share of contaminating microorganisms. Also, with a smaller tank, there is a higher probability that accumulated sediment may be agitated and re-mix with the standing water. (Meera & Ahammed, 2006) Open or unscreened storage tanks can also be breeding grounds for mosquitoes, resulting in outbreaks of Malaria and Dengue.

3. Guyana

3.1 National Drinking Water Coverage

Guyana's name, translated from the Amerindian as "land of many waters", sums up one of the main problems for successful water management within the country. The publicly available data on Guyanese water resources puts forth an outward appearance of water resource abundance that hinders an accurate understanding of the current supply context, issues and potential management solutions. If we are to look for example at drinking water coverage data on Guyana, the variation of data depending on the source and the overestimation of drinking water coverage in both rural and urban areas are dramatic. Below is a table (Table 2) summarizing the most current data available on access to improved drinking water sources.

The fact that Guyana Water Incorporated (GWI), the country's state water utility, is *currently* carrying out several projects under the Hinterland Water Strategy in an attempt to ensure clean water for *80%* of surrounding settlements brings into question all of the prevailing rural coverage data in Table 2. (IRCa, 2009). GWI has also just recently announced a *10-year strategy* to increase access to safe water for *90%* of the country's population. (IRCb, 2009)

Table 2: Improved Drinking Water Coverage in Guyana

	Total		Urban		Rural	
	Total %	Household Connection %	Total %	Household Connection %	Total %	Household Connection %
World Bank (1993)	-	-	95	-	93	-
Global Water Supply and Sanitation Assessment Report WHO/UNICEF (2000)	94	-	98	-	91	-
Report of Multiple Indicator Cluster Survey Guyana, Bureau of	-	-	97	80	86	48

Statistics, Guyana (July 2001)*						
WHO/UNICEF (2004)	83	53	83	66	83	45
Aid Indicator Survey (AIS), Guyana, (2005)*	-	-	100	81	93	61

* Source: WHO/UNICEF. 2008

3.2 National use of DRWH as a Potable Water Source

The acceptance and use of rainwater harvesting as a drinking water source is quite predominant throughout Guyana. In terms of drinking water coverage it is considered as an ‘improved’ source from the perspective of the data providers listed in Table 2. Data from Guyana’s 2002 census show 14.6% of the population depends on rainwater harvesting as their primary source for drinking water. (PSCG, 2007) Data from 2005 and 2006 show that in urban areas 12.8-16.4% of the population use rainwater collection as a drinking water source and in rural areas the percent is even higher at 25.6-27.2%. (WHO/UNICEF, 2008) The fact that rainwater accounts for 14.6% of household drinking water supply but only 4.8% of total household water supply suggests that the Guyanese population views rainwater as high quality water and harvests it specifically for drinking purposes.

The mainstreaming of rainwater harvesting has the potential to be an important tool over the coming years in Guyana Water Inc (GWI)’s national campaign to increase coverage and ensure access to safe water. The Government of Guyana suggests that the key challenges related to water and sanitation provision are 1) the high cost of power which accounts for 55% of total expenditures, 2) affordability and willingness of customers to pay for services, 3) reliance on donor agencies for investment, 4) lack of working capital for operations and maintenance, 5) leakage and 6) collection efficiency. (EPA, 2004) By focusing on decentralized household level water management, specifically DRWH, GWI can circumvent the high costs of power. Furthermore as DRWH is already widely used and accepted in Guyana it is probable that residents would be willing to invest in the purchase, operation and maintenance of DRWH systems, although some subsidization may be required to ensure affordability for marginal groups. This could dramatically reduce government provision and maintenance costs and potentially reduce reliance on donor agencies for investment.

4 St Cuthbert’s Mission

St. Cuthbert’s Mission is one of the 148 Amerindian settlements in Guyana. The Amerindian population, estimated at 60,000, comprises 8% of the total Guyanese population. (Janki, FAO) Amerindian villages in Guyana are located in the Hinterland (rural areas), often at a great distance both from urban centers and each other. Of the 148 Amerindian settlements 106 have access to an improved source of water. GWI has supported the construction of water infrastructure in some villages, and there are currently 52 hand driven pumps installed, 8 engine driven pumps, 19 windmill driven pumps, 5 solar pumps and 3 electric sub-pumps. (Janki, FAO) It is important to note that most villages are very geographically dispersed and therefore the presence of an improved water point does not ensure universal community access.

Situated along the left bank of the Mahaica River in Region 4, St. Cuthbert's Mission is the closest Amerindian community to the capital, Georgetown, which is approximately 90km distance by road. The community has a population of approximately 1300 people (203 households) and is administered by a village council in keeping with the Amerindian Act.

4.1 Drinking Water Sources

There are three main water sources in St. Cuthbert's Mission. A deep groundwater well with a solar-powered pump located in the centre of the community provides the supply for 9 community standpipes as well as 8 reported personal yard pipes and household connections. Residents who are not located near the community's centre, or who wish to supplement the pipe water, collect rainwater or unprotected surface water from nearby creeks. Results from the surveys show that the majority of St. Cuthbert's residents rely on multiple sources for their domestic needs. Sources for drinking water depend on the season. In the rainy season (see Figure 2) the use of rain and pipe water is nearly equal, with a significant percent of residents relying on creek water. In the dry season rainwater use decreases drastically, with pipe and creek water use increasing to compensate.

Figure 2: Wet Season Drinking Water Sources

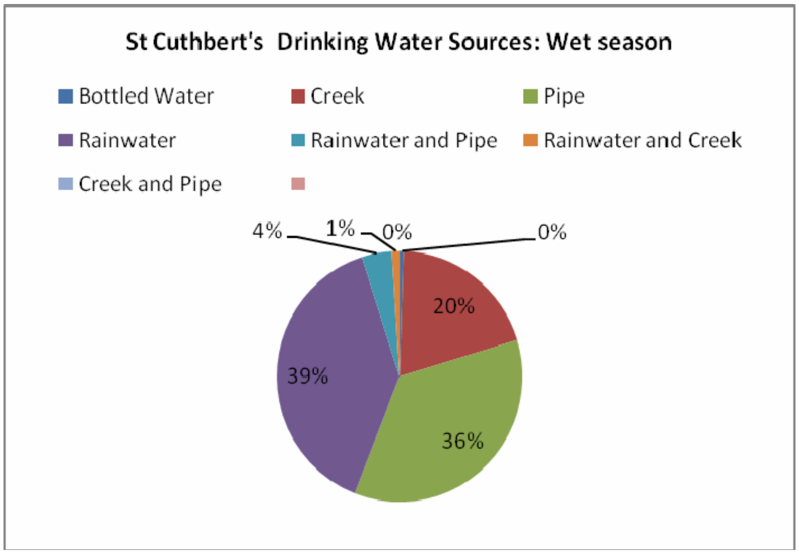
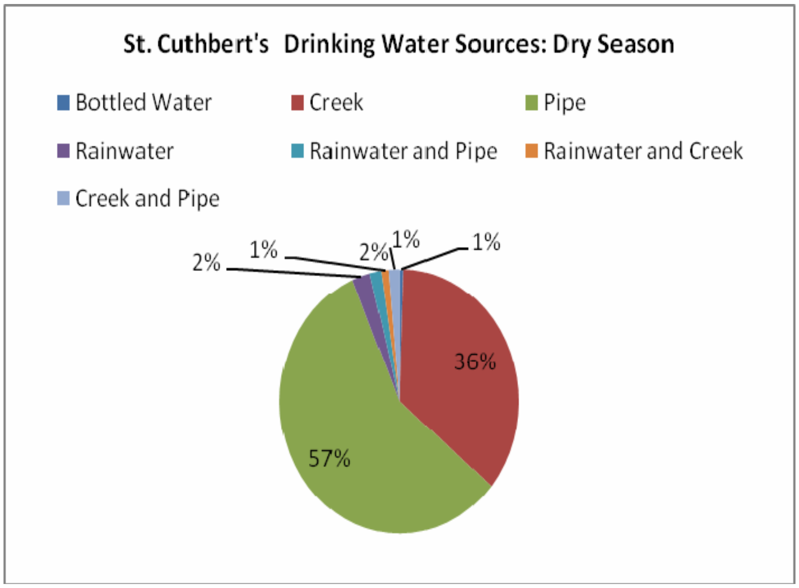


Figure 3: Dry Season Drinking Water Sources



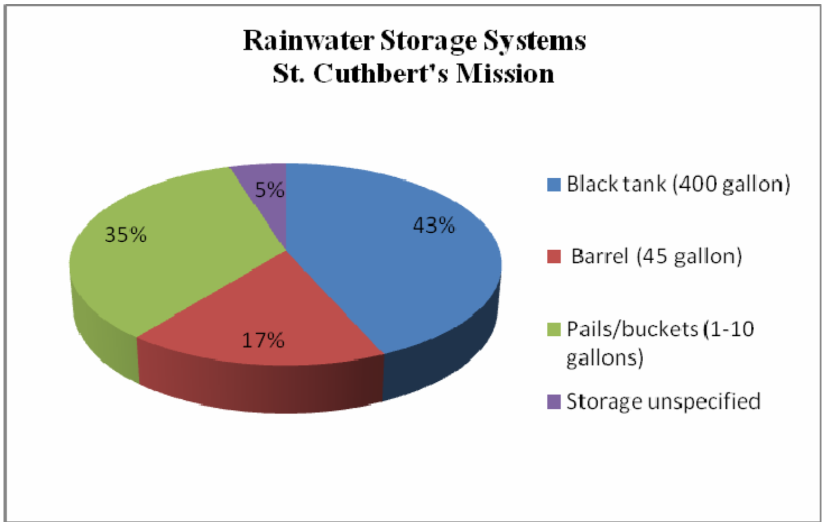
4.2 Current Use of Rainwater Harvesting

Despite Janki's (FAO) assertion that Amerindian communities in Guyana do not collect and store rainwater due to the predominance of thatched roofing and the prohibitive purchase and transport costs of DRWH systems, rainwater harvesting is a well accepted practice in St. Cuthbert's Mission. Results from the surveys show that at the time of the study 146 of the 203 households' surveyed reported some form of rainwater collection. This may be due to the fact that the majority of households in the community have zinc roofing. Only 14 households reported having thatched roofs and, of these, a number had adjoining kitchens with zinc roofing. Furthermore, the proximity of the community to Georgetown decreases relative transportation costs of DRWH systems.

Typically DRWH is used to "provide full coverage during the wet season, partial coverage during the dry season, along with providing short-term security against the failure of other sources". (Thomas and Martinson, p.9) St. Cuthbert's use of rainwater corresponds to the common practice of rainwater harvesting in the humid tropics, where DRWH is used as a partial domestic source in combination with other sources during the rainy season and is largely unused during the dry season. (LRHFb, 2001) The surveys found that only 40 households used rainwater for full coverage of all their domestic needs during the wet season, including drinking, cooking, washing wares and clothes, bathing and cleaning. In the dry season, only 8 households used rainwater at all.

Thomas and Martinson (2007) define two types of rural DRWH, informal and suburban, both of which are present within St. Cuthbert's Mission. Informal DRWH, by definition, refers to the practice in poorer households of setting out bowls, buckets, tubs and barrels under the roof during rainfall. In the case of informal DRWH, most roofs are not equipped with gutters, and if they are, the gutters are usually handmade. These systems intercept only a fraction of roof runoff and the lack of storage capacity means water is available only on rainy days, offering little impact on the long-term water security of a household. Furthermore, the quality of water is generally very poor as the receptacles are prone to contamination and are breeding grounds for disease vectors. In the second form of self supply, suburban DRWH, households have more formal systems. The one commonality among the formal systems used in St. Cuthbert's is the use of black high-density polyethylene (HDPE) plastic 400-gallon tanks. There is a great variation among the conveyance modes used by such households. Thomas and Martinson (2007) claim that suburban formal systems are largely the result of increased income and occur where public supply is deemed unattractive by consumers. As can be seen in Figure 4, nearly half of St. Cuthbert's residents who harvest rainwater have purchased a black tank. The other half use 45 gallon barrels or set out pails and buckets during rainfall.

Figure 4: Rainwater Storage Systems



4.3 Water Security

While the surveys did not turn up physical or geographic limitations to water security, they did show a significant felt limitation, or dissatisfaction on the part of St. Cuthbert's residents. Distance to source and collection time plays a large role in considerations of water security. The World Health Organization recommends a distance no greater than one kilometer, or a total collection time no greater than thirty minutes (Howard and Bartram, 2003). Despite the fact that the majority of St. Cuthbert's population falls well below the WHO's collection time threshold, fetching water was a major issue brought up by respondents in the surveys. Only 10 households reported collection times of over 30 minutes total, and of those respondents only 4 did not have a closer alternative source. Yet 58 of the 177 responses to the question 'What is the biggest water-related problem you face at home?' were related to the need to fetch water every day. In addition, 60 responses noted the unreliability of the community pipe as the biggest water-related problem faced by their households. Sixty-seven of the responses also said that the unreliability of the community pipe was the biggest water-related problem faced by the community.

As noted in section 2.1 DRWH has the potential to address these problems by increasing geographical access and convenience. As can be seen in Table 3 the ownership of a formal DRWH system has a large impact on improving a household's felt water security, through increasing convenience, decreasing collection time and allowing for reserve storage to protect households against failures from other sources. Owners of a black tank were much less likely to identify fetching water and lack of reliable pipe water as the number one water-related problems faced at the household or community level.

Table 3: Impact of Black Tank Ownership on Felt Water Security

	Black Tank	No Black Tank
Fetching water #1 water related problem faced by the household	30%	78%
Lack of reliable pipe water #1 water related problem in the community	37%	63%

However, one of the most important concerns with DRWH in terms of water security remains quantity. How much water can a DRWH system provide; what percent of domestic needs can be fulfilled by rainwater; and what is the temporal availability of rainwater? The answers to these questions depend on climactic conditions such as the duration and intensity of rainfall and the length of the dry season, the characteristics of the DRWH system, including roof and storage size, and household water demand. In determining the potential increases to water security that could be wrought from DRWH in St. Cuthbert's Mission, three calculations were undertaken.

The first calculation was to determine the annual roof runoff (ARO), establishing the potential increase to a household's water availability provided by DRWH. Thomas and Martinson in their handbook for practitioners (2007) suggest that the rainwater reaching a roof in a year can be estimated as the annual rainfall times the roof's plan area. However they caution that in the tropics "only about 85% of this water runs off the roof, the remaining 15% is typically lost to evaporation and splashing" (Thomas and Martinson, 16). Roof runoff was further calculated based on monthly average rainfall to establish the temporal availability of rainwater, both to identify any seasonal restraints and to determine the potential for DRWH to be used year-round. Finally roof runoff was calculated on a household per capita[1] basis to ascertain whether rainwater could be relied upon as the sole source for satisfying daily drinking water requirements.

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[1] The average population of a St. Cuthbert's household is 4.7

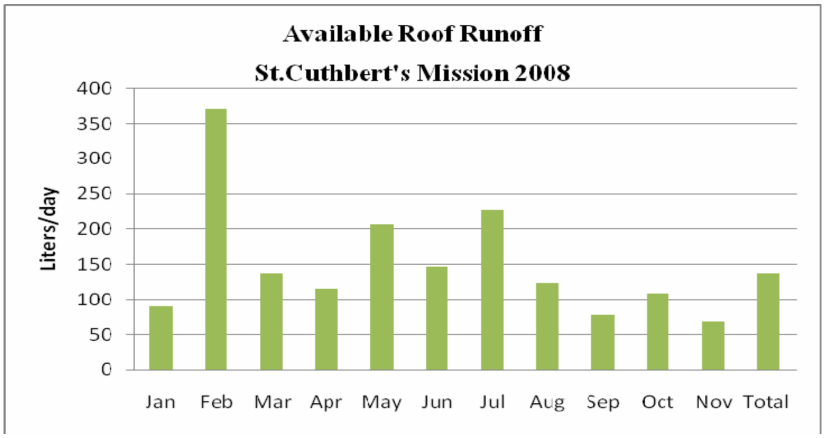
The ARO calculation is based on the method presented in Thomas and Martinson's *Roofwater Harvesting: A Handbook for Practitioners* (2007). It is commonly referred to in the literature as the supply side method.

Q = 0.85 x R x A

Where:
R is the total rainfall in millimetres for 2008[2]
A is the guttered roof area in square metres based on the blueprints for the scheme houses designed by Food for the Poor Inc.
0.85 is a 'run-off coefficient'. It takes into account evaporation from the roof and losses between the roof & any storage tank; its value is around 0.85 for a hard roof in the humid tropics, where rain is often intense.

Q = 0.85 x 2194.10 x (6 x 4.5)
Q = 50,354.60 litres a year or 137.96 L/day

Figure 5: Monthly Available Roof Runoff (L/d)



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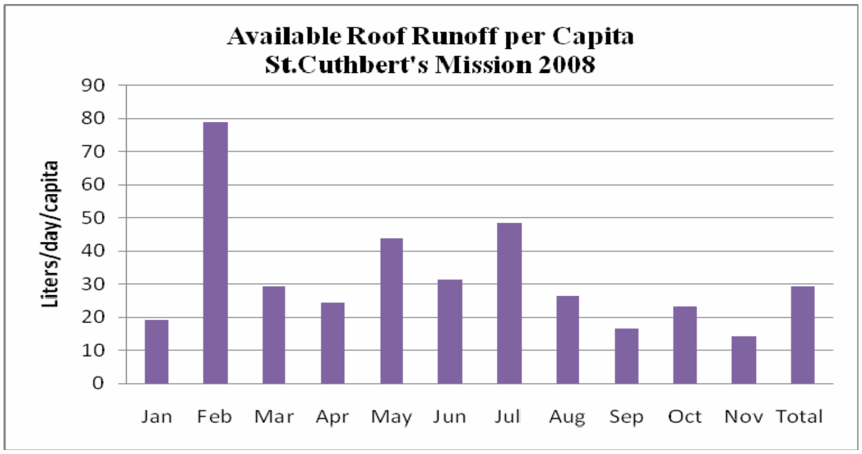
[2] Due to problems with data availability December has been omitted from the calculations.

Figure 6: Per Capita Monthly Available Roof Runoff (L/d)



As can be noted in the calculations, the annual roof runoff (ARO) of 137.96 L/day appears to more than satisfy the WHO basic access recommendation of 20 liters/per person/per day for an average St. Cuthbert's household of 4.7 residents. (Howard and Bartram, 2003) However if we look at the monthly average rainfall (Figure 5) there is significant variation and not all months reach the basic access threshold. There has been some suggestion that the WHO threshold is not reflective of actual household consumption in rural tropical communities. (Thomas and Martinson, 2007) Looking deeper into the WHO water security requirements, they suggest that the highest requirement of water for hydration per day is for male adults at 2.9 liters, and that taking into account drinking water plus water for foodstuffs preparation, "a minimum of 7.5 liters per capita per day will meet the requirements of most people under most conditions" (Howard and Bartram, p. 8). Not only does Figure 6 show that daily per capita water availability is continuously above the latter threshold, furthermore only three months fall under the WHO threshold, with the lowest availability in November at 14 Liters per capita/per day. What these findings suggest is that DRWH can provide quite a high quantity of water throughout the year, even during the dry months.

It is important to note some of the limitations to these calculations. The first is that due to the lack of rainfall data availability the results are based on only 11 months of 1 year and therefore may not be representative of current or future climactic patterns. The second limitation is that as Thomas and Martinson (2007) note the ARO does not represent the actual amount of water available for use by the households. The fraction of ARO available to households is greatly dependent on the specifics of the DRWH system. For example, an informal DRWH system with sparse guttering and little storage may access only 10% of the ARO while a system with full guttering and a very large tank may have access to 90%.

Therefore while the ARO calculation accounts for roof area and local precipitation, the storage component of a DRWH system also plays an important role in the quantity of rainwater available for household use. In order to account for storage a rainwater tank performance calculator, developed by Warwick University[3], was used to calculate the ‘reliability’, ‘satisfaction’ and ‘efficiency’ of a typical St. Cuthbert’s DRWH system.

Location: St. Cuthbert’s Mission
Roof area: 27 m^2
Storage Capacity: 1,514 Liters (400 Gallons), the typical size for a formal rainwater harvesting tank in St. Cuthbert’s Mission.
Mean daily runoff: 147 liters. As the calculator requires 12 months of rainfall data November and January were averaged in order to give a value for the month of December.
Nominal Demand: Two nominal values were inserted into the calculator; 94 l/d the WHO recommended 20 L per household capita (4.7) and 35 l/d the lower threshold of 7.5 L per household capita (4.7). The calculator also provides calculations on nominal demand equal to mean daily runoff, 147 l/d.
Water management strategy: Constant Demand. The user draws a set amount of water from the tank every day if there is enough in there to do so; otherwise the user takes what is left in the tank.

Table 4: Rainwater Tank Performance Calculator

1,514 Litre Tank			
	147 L/d	94 L/d	35L/d
Reliability	62%	83%	100%
Satisfaction	70%	86%	100%
Efficiency	69%	55%	24%

Results from the calculation can be seen in Table 4. The rainwater tank performance for a 35 l/d nominal demand is excellent in terms of both reliability and satisfaction. The reliability indicator calculates the fraction of days that demand is met and the satisfaction indicator calculates the fraction of demand volume that is met. The third indicator, efficiency refers to the fraction of run-off water that is used. Despite the fact that the efficiency is low, and reflects the fact that only a small fraction of runoff is being used, in the 35 l/d nominal demand scenario rainwater can provide total household water demand year round without the need to supplement from other sources. In the 94 l/d scenario efficiency is increased, although demand is met only 83% of days and only 86% of demand volume is met. The 147 l/d scenario is even worse in terms of reliability and satisfaction. However, the results suggest that, even at the 147 l/d level, the formal DRWH tanks can provide for a significant amount of the demand for a majority of the year.

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[3] http://www2.warwick.ac.uk/fac/sci/eng/research/civil/dtu/rwh/model/

Figure 7: Daily Precipitation, St Cuthbert's Mission 2008

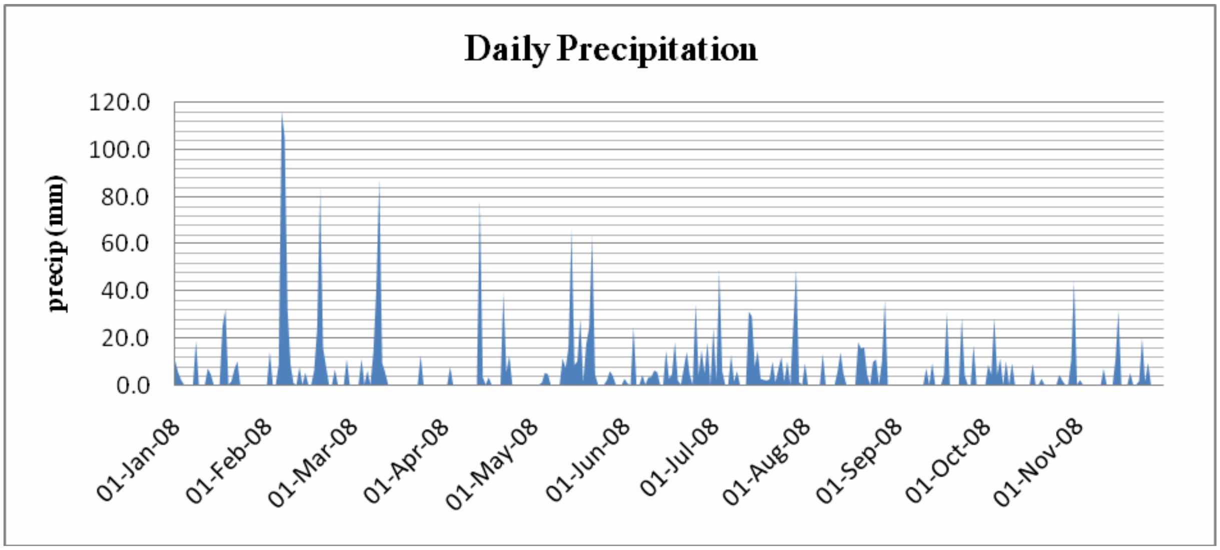
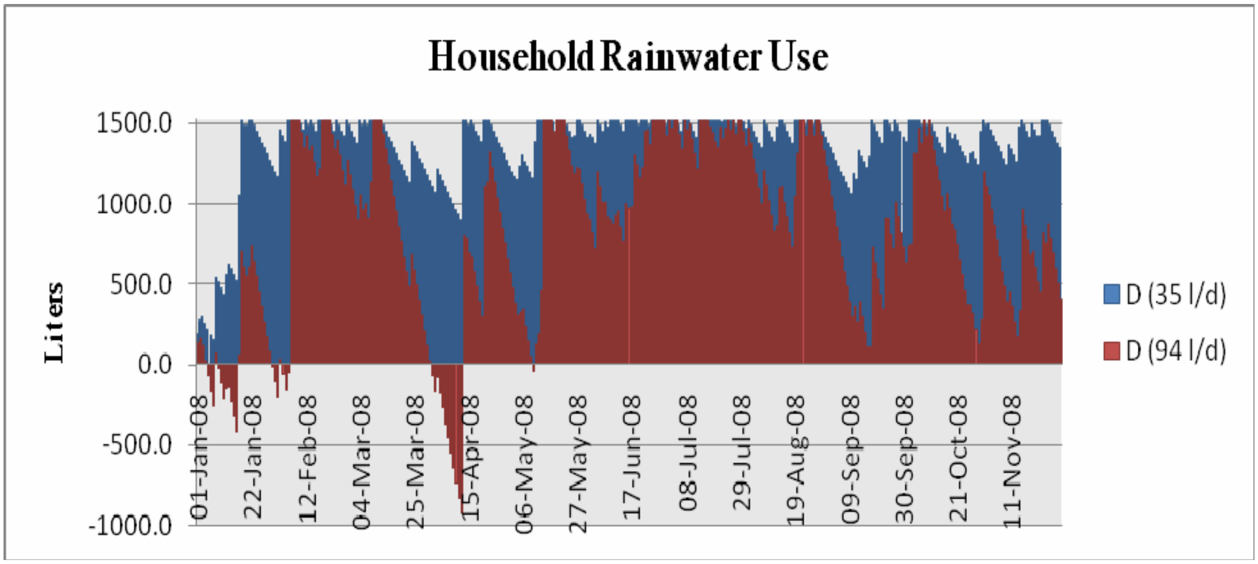


Figure 8: The Effect of Household Demand on Rainwater Availability



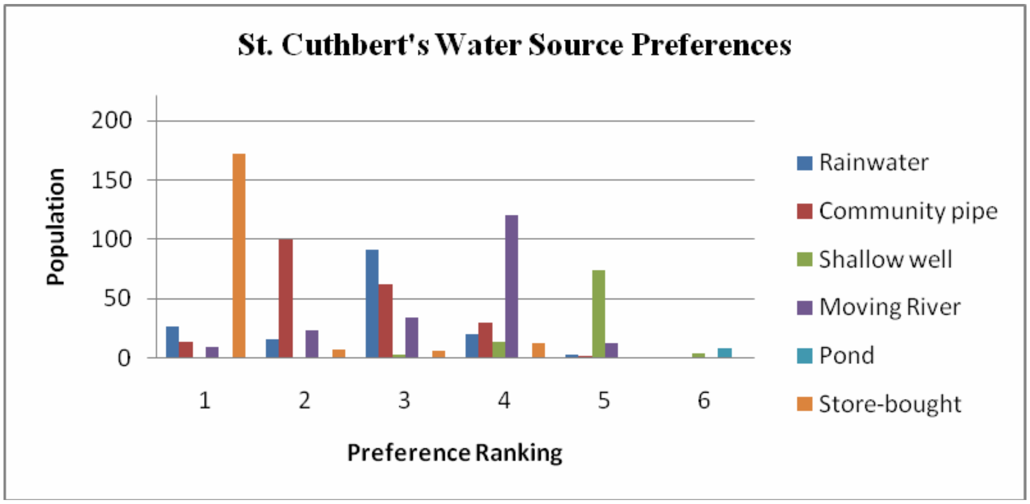
The final calculation was an attempt to further identify temporal availability of rainwater, and specifically to distinguish at what points of the year DRWH could not provide adequate domestic water security. Based on the ARO method, the calculation took into account daily temporal variation in runoff availability, a storage capacity cap of 1,514 liters (400 gallons) and the two different demand thresholds, 35 l/d and 94 1/d. Figure 8 shows the amount of water left in the tank after the daily water demand has been withdrawn. As can be seen in Figure 8, DRWH easily satisfies the 35 l/d demand scenario all year round, with close to full levels of storage to spare. The lower levels in January are due to the fact that storage was considered to be zero on January first, and a few weeks were needed to build up the storage level. The second demand scenario of 94 l/d, while not leaving such a constantly high level of water for other uses, does satisfy the WHO threshold for all but 30 days. If we assume that the decreased availability in January is a result of the lack of storage build up, there is only one significant dry period where residents would have had no access to rainwater over a period of 12 days at the beginning of April.

There are notable limitations in the above calculations and in order to adequately calculate the variability in available rainwater quantity and its effect on household water security there is a critical need for increased data availability. However, what the available data does suggest is that DRWH systems could have a significant impact on water security in St. Cuthbert's Mission. At minimum, it appears that these systems could supply potable water requirements all year round and, for much of the year, DRWH reserves can provide for many of the other domestic needs.

4.3.1 Scaling up DRWH: Increasing Use

Despite the fact that the data suggests DRWH could be a year-round source of potable water, as was noted in section 4.2, of the 71 % of St. Cuthbert's residents who collect rainwater during the rainy season, only 39% use it as a source of drinking water. In addition, only 8 households reported using rainwater during the dry season. Two possible reasons for why residents might choose not to use rainwater as a potable source are preference and lack of access.

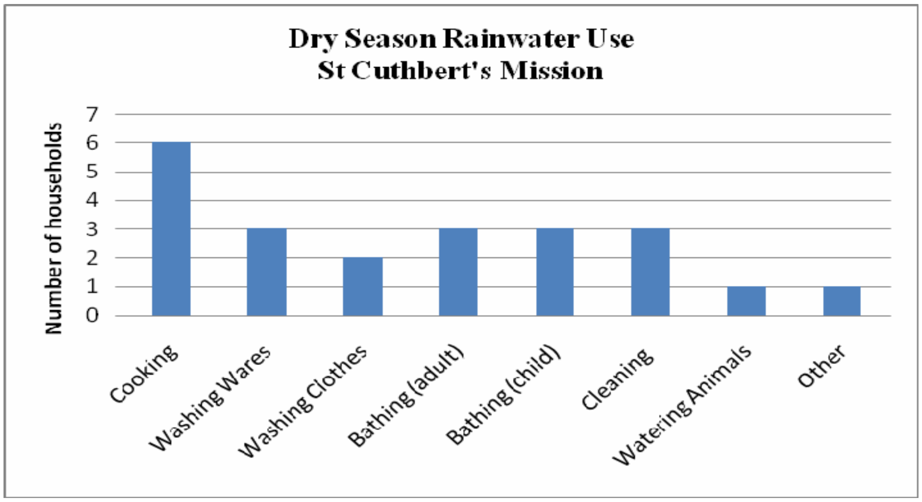
Figure 9: Community Water Source Preferences



As can be seen in the above graph residents, as part of the first survey, were asked to rank water sources based on which they thought was the best source of drinking water. While responses greatly favored store-bought water, when asked directly if they ever pay for water only 11 residents said yes. This disparity could be the result of participants responding with what they believe is the appropriate response, or it could be reflective of a genuine preference that is restricted by income. Regardless, this stated preference in not reflected in actual consumption patterns. Therefore, if we ignore the impact of store-bought water, pipe water becomes the first choice, favored over the consumption of rainwater. While this accounts for the 36% of residents who drink pipe water instead of rainwater in the wet season, 20% still fetch creek water for drinking purposes. Of the 40 residents who drink creek water, only one had access to another source (rainwater). Therefore it appears that while choosing pipe water over rainwater may be based on preference, drinking creek water is less of a preferential choice than a lack of access to other sources (DRWH or pipe water).

Section 4.3 illustrates that a DRWH system in St. Cuthbert's Mission can provide year round water availability. Therefore, that the fact that residents are not using rainwater during the dry seasons is surprising. One hypothesis is that during the dry season rainwater is reserved for other domestic purposes, but as can be seen in Figure 10, this does not appear to be the case since there is almost a complete lack of rainwater use for any purpose.

Figure 10: Dry Season Rainwater Use



Other possible explanations are a possible miscommunication in the surveys or a genuine preference against dry season rainwater use. As part of the surveys residents were asked to identify which source of water they used for a number of household activities, both during the dry and wet season. Due to the way the question was posed, residents may have assumed that rainwater was not available for use during the dry season and therefore responded accordingly. However, research done in Sri Lanka has shown that "perceptional quality" plays a large role in temporal consumption of DRWH. In the research area, despite year-round availability only 10% of the rainwater users drank rainwater as an accepted domestic water source during the dry months. "People also strongly believe that quality of rainwater is better during the times of rainfall and two weeks thereafter. In storage, people believe, that rainwater deteriorates in quality. This presumption is propelled by the appearance of different species of larvae and discoloration of stored water" (LRHFa, p.9).

In order to scale-up the use of DRWH in St. Cuthbert's Mission both throughout the year and as a potable water source there is a need for further investigation into residents' perceptions surrounding rainwater.

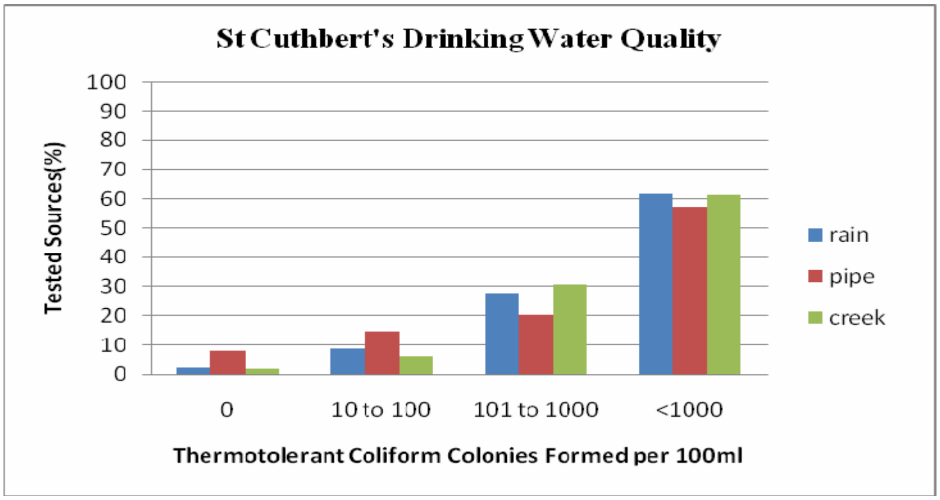
4.4 Water Quality

As part of the survey process 100 ml drinking water samples were taken from 203 households in St. Cuthbert's Mission. The source of the drinking water was recorded and samples were tested for a number of parameters including turbidity, pH and thermotolerant coliform colonies formed to determine microbiological water quality. Results from the sampling showed that rainwater turbidity levels, which averaged 0.93 NTU, were well below the WHO recommended 5 NTU, and slightly lower than pipe (1.0 NTU) and creek water (1.6 NTU). (Mosley, 2005) In terms of pH, it is recommended that rainwater not be below <5.6 pH due to the fact that levels below this may cause corrosion of metal roofs and fittings. (Mosley, 2005) This should not be a cause of concern in St. Cuthbert's as the average rainwater pH was close to the recommended guideline at approximately 5.46. Although these results were positive, findings from testing the samples for thermotolerant coliform colonies formed were disappointing.

In order to identify if rainwater provided higher quality water than other community sources a chi-squared analysis comparing source water and coliform levels was performed (see Appendix, Table A1). The chi-squared test showed that the variables could not be deemed dependent, and thus it was not possible to prove that source water had an effect on coliform levels. As can be seen in figure 11, drinking water from all three sources (pipe, creek and rain) showed high levels of coliform contamination. All three sources had approximately 60% of samples in the highest category (greater than 1000 thermotolerant coliforms colonies). The World Health Organization (WHO) 1996 drinking water guidelines suggest that faecal bacteria should not be detectable per 100 ml. However, a number of rainwater harvesting proponents have argued that this indicator is too strict and that standards should be relaxed. For example, Fujioka (1994) argues that the WHO's low risk category of 10 faecal coliforms/100 ml is a more realistic standard. (Mosley, 2005) Unfortunately, switching from the strict 0-TC per 100 ml to a more relaxed <10 TC per 100 ml standard, in this case, would have no effect on the number of households with acceptable water quality. The vast majority of households' potable water would still be considered microbiologically unsafe.

Low levels of thermotolerant coliforms in samples taken directly from community pipes suggest that a high degree of contamination is occurring during the household storage period (see Young- Rojanschi's study on HWTS Options in St. Cuthbert's Mission, Guyana for further discussion).Furthermore, as residents provided surveyors with water samples in household wares (cups, bowls) there is a chance that the high coliform levels were a result of improperly washed wares.

Figure 11: Drinking Water Quality Survey Results



High presence of thermotolerant coliform levels is not uncommon in DRWH water quality studies. As noted in section 1.2, the fact that collection surfaces (roofs) are so isolated from the main sources of human fecal contamination (e.g. sanitation systems) has many practitioners questioning the validity of thermotolerant coliforms as an indicator organism for microbiological water quality. (Mosley, 2005) Research from tropical countries (Gleeson and Gray, 1997) has shown that the presence of thermotolerant coliforms is not directly associated with the presence of fecal contamination and that they form an integral part of the normal bacterial flora of tropical environments, often naturally occurring in tropical waters. Thomas and Martinson (2007) have further argued that not only does the number of detected indicator bacteria in roofwater have no correlation to pathogen levels (merely indicating the presence of opportunistic environmental bacteria) the bacteria detected may in fact be a potentially important part of beneficial biofilms lining the rainwater tank.

Therefore, due to uncertainty on the reliability of the indicator organism it would not be prudent to condemn the source water quality of St. Cuthbert's Mission based on the survey data. However, based on the data, DRWH does not appear to offer any quality improvements over the other two sources, but at the same time, it does not appear to offer a lower quality than the other options.

4.5 Economic Considerations

In aiming to scale-up DRWH in St. Cuthbert's Mission two main factors must be considered. As noted in section 3.3.1 community views, preferences and beliefs will play a significant role, especially in terms of scaling up from partial DRWH to year-round DRWH. However for 86 of the 146 households who use DRWH but have not yet scaled-up to a formal 400 gallon black tank system economic considerations are a key barrier to universal community access.

4.5.1 Cost Comparison

Thomas and Martinson (2007, p. 35) suggest two main economic tests applicable for a proposed DRWH investment. 1) “In this location, is DRWH a cheaper way of achieving a particular level of service than any of the alternatives?”2) “Is the payback from investing in DRWH good enough?” If the desire is to scale up DRWH in St. Cuthbert’s Mission the response to both questions needs to be answered from the point of view of both the consumer and the supplier.

Currently in St. Cuthbert’s Mission all drinking water sources, both unprotected (creeks and rivers) and protected (community and private standpipes) are freely available to residents. At the time of the study the village council was considering establishing a 1000$ GYD (5$ CND) fee per month for residents using pipe water. However, given the proposed increased government investment in the water infrastructure of the community it is unlikely that this plan will be implemented. Therefore the need to invest in a formal, large capacity DRWH system would make rainwater the only source where residents would be required to pay for access. One would assume then that there is little economic incentive for community members to invest in DRWH. However in St Cuthbert’s Mission nearly half of the residents currently using roofwater harvesting have invested in large-capacity black tanks. Therefore clearly some St. Cuthbert’s residents feel that the payback from DRWH is worth the investment.

In terms of the supplier, by comparing the costs of alternative water infrastructure investments to DRWH investment, DRWH does appear to be the cheaper way of ensuring universal increases to water security in St. Cuthbert’s Mission. While the cost of a typical DRWH system in Guyana is not available, Thomas and Martinson suggest that the tank is the largest single cost of a system. The authors estimate that the tank accounts for 90% of the total system cost in high capacity systems and 70% in low-cost small capacity systems. In St. Cuthbert’s Mission the upfront cost of a 400 gallon black tank is 15, 000 – 20, 000$ GYD ($80-100 CND), with the addition of a 15, 000$ GYD transportation cost for the tank to be delivered into the Mission[4]. Scaling up DRWH so that all residents would have a 400 gallon black tank would necessitate 140-150 tanks. Presently the proposed strategy for investment in community water supply infrastructure is focused on increasing the capacity of the community pump and well. GWI is currently spending $620,000 (3,188$ CND) to upgrade the water storage facility of the current well, and the Ministry of Housing and Water have committed to setting aside $15M (77,140 $ CND) of the 2010 budget to install an electrical pumping system and a new well. (Stabroek News, 2009) If we compare these costs to those reported by a DRWH project done in Kabakaburi, Guyana, where black tanks were provided to 150 households, total project cost was only 20, 000$ US. (Rotary International News, 2008) The lower cost is not the only benefit to be considered. The government’s initiative to upgrade the community well and pump will most likely increase the reliability of water supply, decrease waiting times and potentially increase the number of community standpipes and household connections. However, since the households in

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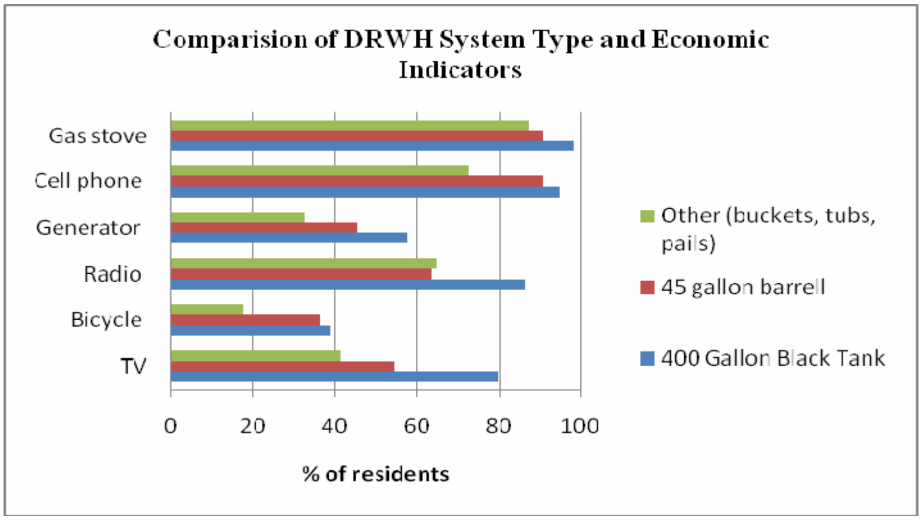
[4] Information on costs provided by the local project assistant, Juanita Simon.

St. Cuthbert’s are very geographically dispersed, improvements to water security will only be felt by residents living in the immediate vicinity of a community standpipe. Scaling up DRWH systems on the other hand could improve the water security of all residents, regardless of their location. Furthermore studies have shown that “where protected sources are currently too widely spaced to achieve a good access standard it is much cheaper to install main source or even wet-season DRWH than to greatly increase the density of protected point sources” (Thomas and Martinson, 33).

4.5.2 Scaling-Up DRWH: Economic Implications

There are two modes of DRWH system supply, self supply and public supply. DRWH in St. Cuthbert’s Mission is currently operating on a self supply model. The self-supply of DRWH systems places all of the responsibly for financing and technology choice on the individual household. Thomas and Martinson (2007) caution that this method may encourage households to choose very cheap low-performance variants of DRWH. As noted in section 3.2 there is currently a mix of informal and formal DRWH systems in St. Cuthbert’s. If we are to compare a household’s DRWH system type with other economic indicators (See Figure 12), the ownership of certain material goods, it does appear that in St. Cuthbert’s the use of black tanks is positively associated with higher income. See Candice Young-Rojanschi’s upcoming paper on Household level Water Treatment (HWTS) Options in St. Cuthbert’s Mission, Guyana for further discussion on economic indicators in St. Cuthbert’s Mission. As the acceptability of DRWH in St. Cuthbert’s is quite high, accounting for a water source for 70% of the community population, it would appear then that economic limitations pose the greatest barrier to scaling-up DRWH in the Mission.

Figure 12: Comparison of DRWH System Type and Economic Indicator



Scaling-up DRWH in St. Cuthbert's Mission will therefore necessitate some form of subsidization. Public-private cost-sharing approaches, where household contribute to part of the system, are most often recommended as they encourage ownership of the system. In the DRWH project done in Kabakaburi, Guyana, the cost of the tank was fully subsidized but residents were required to build their own stands and gutters. (Rotary International News, 2008) However, as the research on water quality has shown, the importance of proper DRWH installation is paramount in reducing health risks. Therefore concerted effort should be made to subsidize all of the system components, in addition to the storage containers, in order to ensure that each system is fitted with the appropriate equipment.

5 Conclusions

Thomas and Martinson (2007) offer a short checklist to assess whether DRWH systems are viable for a community. Responding to these questions provides some insight into the potential and benefits of scaling-up DRWH in St. Cuthbert's Mission.

Q1. Is current water provision thought by some householders to be seriously inadequate in quantity, cleanliness, reliability or convenience?

The vast majority of St. Cuthbert's residents have access to a source of water (not all protected sources) that fit the WHO requirements for basic access: at a distance of less than one kilometer with a total collection time of less than 30 minutes. Despite this fact, the survey responses highlighted a strong 'felt' lack of water security from the residents. The need to fetch water every day was the largest water-related problem faced at the household level, and the lack of reliable pipe water was found to be the largest water-related problem for the community. Table 3 in section 4.3 showed that ownership of a black tank has a large impact on improving a household's felt water security, through increasing convenience, decreasing collection time and allowing for reserve storage to protect households against failures from other sources.

Q2. Is there adequate hard roofing area per inhabitant?

Currently the majority of St. Cuthbert's residents have hard zinc roofing, with only 14 thatched roofs in the community. As shown in section 4.3, based on the available data, DRWH can easily provided the 7.5 litres/per capita/per day minimum potable water requirements all year round. Moreover, DRWH can provide the WHO recommended 20 litres/per capita/per day for the majority of year, with significant water to spare for other uses.

Q3. Is there an existing capacity to specify and install DRWH systems in the area, or could one be created in a suitable time?

Based on the findings the two main limitations to scaling–up DRWH in St Cuthbert's are residents' views, preferences and beliefs as a barrier to using DRWH all year round, and economic cost as a barrier to universal formal DRWH system ownership. Since the general acceptability of rainwater harvesting as a potable water source is quite high in the community the provision of some form of public-private subsidization coupled with workshops on use and maintenance would have a significant impact on scaling-up DRWH in St. Cuthbert's Mission.

In St. Cuthbert's Mission, much like many rural communities, household water security is achieved through the combined use of a number of different water sources. This report argues that facilitating the installation of formal DRWH systems will have a large impact on household water security, and can be supported in conjuncture with the Guyanese government's current plans for improving the efficiency and reliability of piped water in the community. Despite the fact that rainwater was not shown to have a better, or worse, impact on water quality than other sources, DRWH systems were shown to be a relatively low cost option for universally improving a households' geographical and temporal access to a water source, increasing convenience and decreasing collection times and overall increasing a households' 'felt' water security.

6 Recommendations

The final section of the report offers a number of recommendations for improving the water quality of DRWH systems in St. Cuthbert's Mission. These recommendations should be considered both in regards to scaling up DRWH and for currently installed systems.

6.1 Water Quality: Ensuring Effective DRWH Barriers to Contamination

Roofing

Rainwater harvesting should be discouraged in households with thatched roofing as they have a very small runoff coefficient and produce poor quality water (Thomas and Martinson, 2007). Therefore, the 14 households in St. Cuthbert's Mission with thatched roofing should not be encouraged to harvest rainwater for potable use.

First-Flush Systems

The literature has shown that simple first flush devices can result in drastic improvements to water quality. However there is some evidence questioning the reliability of these systems as users may be encouraged to bypass them for fear of losing water (DRHRP, 2001). Therefore depending on the perception of the users prefiltration may be a more appropriate technology. Occasional cleaning of the roof and gutters can also greatly reduce the necessary amount of diverted water. For further information on choosing the appropriate first flush device the

Warwick University Development Technology Unit provides a good overview of the four main technologies.[5]

Storage

As the literature has shown that tanks with a higher capacity have less pathogen contamination than smaller receptacles residents should be encouraged to switch to the formal 400 gallon black tanks.

Of the 146 DRWH systems in St. Cuthbert's Mission, 85 households responded yes when asked if their system had a cloth cover. However, it is important to note that depending on the type of material these covers may still allow light to enter. In ensuring that storage systems effectively reduce contamination through sedimentation and bacterial die-off, systems should have covers that exclude light so as not to support algae and larval growth, while allowing for ventilation to prevent anaerobic decomposition of any organic matter. (Thomas, 1998)

Treatment

The majority of the literature suggests that consuming untreated rainwater poses health risks. As the source water quality studies were inconclusive DRWH users should be encouraged to treat their rainwater. This may necessitate an educational campaign. As the literature shows the idea that rainwater is inherently safe is often very ingrained, especially as rainwater has low turbidity and low mineral content, and thus appears and tastes quite 'clean'.

Maintenance

Interestingly tank cleaning is noted in the literature as the least important aspect of maintenance. Furthermore it has been found that excessive cleaning may actually destroy the beneficial biofilm layers that form on the tank walls and aid in killing pathogenic bacteria. Cleaning of the tanks should be limited to scooping out settled material when appropriate and scrubbing the tank walls should be discouraged. (Thomas and Martinson, 2007, p.119) Maintenance should therefore be focused on cleaning the roof and gutters.

Household level Water Quality Testing

Due to the high temporal variability of rainwater quality (for example, quality may be decreased after a lengthy dry spell) there may be some interest from residents to self-test their DRWH systems. Simple, inexpensive water quality testing equipment is available, such as hydrogen sulphide, H_2S, tests that have shown to be reliable in assessing microbial water quality.

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[5] http://www2.warwick.ac.uk/fac/sci/eng/research/dtu/rwh/technology1/technology_5/

(Kromoredjo and Fujioka, 1991) The ability to self-test their water may also increase residents' use of rainwater harvesting throughout the year by disproving opinions and beliefs surrounding 'perceptional' quality of rainwater.

Institutional Support

The research has shown that the majority of risks to water quality can be greatly reduced by ensuring the proper installation and maintenance of DRWH systems. Therefore if the desire is to scale up DRWH in St Cuthbert's concerted effort should be made not only to subsidize storage containers but all of the system components to ensure that each system is fitted with the appropriate equipment. The provision of operational and maintenance workshops should also be encouraged.

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Appendix:

Table A1: Chi Squared Analysis

Null hypothesis, Ho: Variables are independent
Predetermined Cutoff: 0.05

Observed Cell Counts				
	0 to 100	101 to 1000	<1000	Marginal Row Totals
rain	5	13	29	47
pipe	20	18	51	89
creek	4	15	30	49
Marginal Column Totals	29	46	110	185
Expected Cell Counts				
	0 to 100	101 to 1000	<1000	Marginal Row Totals
rain	7.37	11.69	27.95	47
pipe	13.95	22.13	52.92	89
creek	7.68	12.18	29.14	49
Marginal Column Totals	29	46	110	185
Calculating the test statistic	0 to 100	101 to 1000	<1000	
rain	0.76	0.15	0.04	
pipe	2.62	0.77	0.07	
creek	1.76	0.65	0.03	
Chi-Sq	**6.85**			
Degrees of freedom (DF)	**4**			
Approximate p value	**0.10**			
cut off probability	0.05			

Approximate p value < cut off probability
0.05 < 0.10

Conclusion: Fail to reject Ho. Therefore variables cannot be deemed dependent.