UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation to the Implementation of Rainwater Harvesting and Filtration System in the New Student Union Building (SUB) at UBC

Shuyi Lu

Mostafa Oraei

Aaron Sangha

Kingson Wong

University of British Columbia

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AN INVESTIGATION TO THE IMPLEMENTATION OF RAINWATER HARVESTING AND FILTRATION SYSTEM IN THE NEW STUDENT UNION BUIDLING (SUB) AT UBC

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ABSTRACT

The University of British Columbia is under its way in designing and constructing the New Student Union Building (SUB). To be completed in 2014, the New SUB will be a unique facility that serves as a dynamic gathering place for students to interact and grow a vibrant student community on the UBC-Vancouver campus.

Aiming for Leadership in Energy and Environmental Design (LEED) Platinum Certification, which is the highest green building rating in North America, the design and construction of the New SUB will serve as a model for future sustainable development around the world. LEED promotes five key areas of sustainable approach, including sustainable site development, materials selection, indoor environmental quality, energy efficiency and water efficiency. In order to achieve the LEED platinum standards, the New SUB will significantly lower its water consumption by collecting, filtering and storing rainwater in cisterns for various uses, including irrigating rooftop garden and flushing toilets.

This project starts by outlining the components of rainwater harvesting (RWH) system, which consists of ten parts: gutter guards, leaf screens, first-flush diverters, roof washers, sand filters, settling tanks, in-line filter, storage system, distribution system and purification system. Followed by that is the detailed introduction of five types of filtration methods, including UV light, chlorination, ozonation, reverse osmosis and thermal treatment. The report then goes further to analyze two currently implemented RWH projects in North America in terms of water collection and usage. And finally the project concludes with triple-bottom line analysis and recommendation to the feasibility of implementing RWH system on the New SUB.

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LIST OF ABBREVIATIONS

LEED	Leadership in Energy and Environmental Design
RWH	Rainwater Harvesting
UV	Ultraviolet

1.0 INTRODUCTION

The New SUB to be constructed on UBC Point Grey Campus is aiming for LEED Platinum Certification. Among numerous high level standards of Platinum Certification, "net zero water" is one of the most important requirements. There is limited supply of fresh water on the earth, and the consumption is ever increasing. It is essential to reuse as much water as possible, and one of the ways is to make use of captured rainwater instead of allowing it to drain into the sewage system.

Rainwater harvesting (RWH) is a technology where surface runoff is effectively collected during rain periods. Harvested rainwater can then be used for agriculture or water supply for buildings. Unfortunately, bacteria and hazardous chemicals might pollute rainwater, thus water treatments are required before usage. A RWH system is consisted of catchment, conveyance, roof washing, storage, distribution and purification facilities. Purification methods include UV light, chlorination, ozonation, thermal treatment and reverse osmosis.

There are many cases of implementation of RWH around the world. In order to provide the best suitable option for the New SUB at UBC Point Grey Campus, two cases of them are selected to be studied and evaluated in this project.

2.0 COMPONENTS OF RAINWATER HARVESTING SYSTEMS

The function of rainwater harvesting system is to capture, divert, purify and store the rainwater for different purposes such as landscape irrigation, drinking and domestic use, aquifer recharge, stormwater abatement and so on (Krishna, 2005). It is worth noting that as soon as rainwater contacts the ground it is no longer termed rainwater, but stormwater. According to Schemenauer et al. (2005) one of the definitions of rainwater "harvesting" refers to the process of *first* "seeding" and stimulating the cloud to induce rain. This definition of rainwater harvesting is not discussed in this paper. Every rainwater harvesting system, regardless of its complexity, comprises of six basic components: collection system, conveyance system, roof washing, storage, distribution, and purification/disinfection. Note that some articles identify more than six components (such as recharge structures) or may break one of the basic components into 2 or more components. The components of rainwater harvesting system and the processes involved (see Figure 2.1) are discussed in greater detail in the subsequent sections.

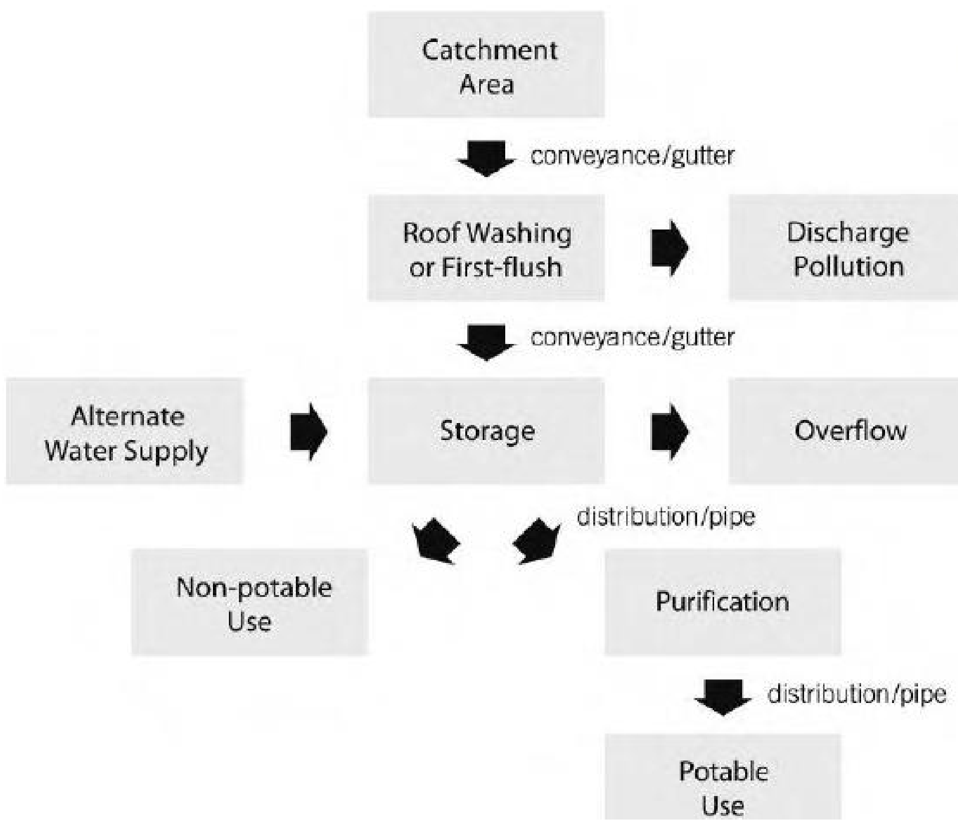

Figure 2.1 Process of rainwater harvesting and components of rainwater harvesting system (after Kinkade-Levario, 2007)

2.1. Rainwater Collection System

2.1.1. Catchment Area (Krishna, 2005; Kinkade-Levario, 2007)

Catchment area refers to any surface, in most cases rooftops, that is used to collect and provide the system with rainwater. The capacity of the catchment area can be increased by means of rain-barns also known as pole-barns. Rain-barns are open-air sheds consisting of a large roof to serve as an additional catchment area. The large roof of the rain-barn enables the structure to be used for other purposes such as use as a patio, carport, storage of water tanks, and rainwater system equipment. The rainwater collection varies with the size and texture of catchment area, but usually about 90% of rainwater can be effectively captured through rooftop rainwater harvesting. The quality of water collected from different catchments is a function of the type of roof material, climate conditions, and the surrounding environment (Vasudevan, 2002). The best water quality is usually yielded from the smoother, more impermeable roofing materials, some of which is discussed below (Krishna, 2005):

- Metal

  Metals are impervious and can provide a smooth texture. Galvalume®, a 55% aluminum/45% zinc alloy-coated sheet steel, is a common roofing material. Some caution should be exercised regarding roofing materials in that roofs with copper flashing can cause discoloration of porcelain fixtures.

- Clay/concrete tile

  This type of tiles can be utilized to in both potable and nonpotable systems. Clay and concrete types are both porous and may result in bacterial growth or as much as 10% water loss due to their texture, inefficient flow, or evaporation. This can be overcome by means of painted/coated tiles; however, to avoid leaching of toxins, a special sealant or paint should be used.

- Composite or asphalt shingle

  According to Radlet (2004), the composite shingles are not a suitable choice for potable use due to production of toxins. Also a 10% loss due to inefficient flow or evaporation is associated with this type of roofing material.

- Wood shingle, tar, and gravel

  These roofing materials are not suitable in that they are rare, and the yielded water is only useful for irrigation due to the leaching associated with them. Wood shingles can also reduce the pH of water and make it more acidic (Chang et al. 2004).

- Slate

  The smooth texture of slate makes the ideal roofing material for potable use assuming no toxic sealant is used. However, it might not be economically feasible due to its relatively high cost.

2.1.2. Gutter System (Stubbs, 2006; Krishna, 2005)

The purpose of gutters is to capture stormwater running off the eaves of buildings. Gutters are commonly made of PVC, vinyl, pipe, seamless aluminum, and galvanized steel and typically come in square, half-round, or trapezoidal shapes (see Figure 2.2).

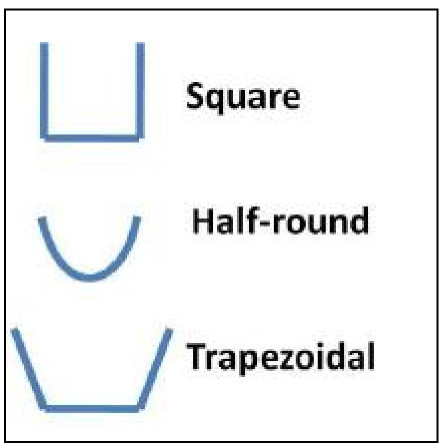

Figure 2.2 Common shapes of gutters (after Lawson et al. 2009)

When designing the gutter system, it should be consider the overflow of water at valleys of roofs. Valleys occur when two slanted roof planes meet each other. At roof valleys the volume of stormwater is yielded from two roof planes and therefore concentrated. The chance of spillage or overrunning at the portion of gutter located where the valley water leaves the eave of the roof is dependent upon size of the roof areas terminating in a roof valley, the slope of the roofs, and the intensity of rainfall. These factors should be accounted for when designing the gutter system.

Some authors (Krishna, 2005) recommend that the gutter system design should be in accordance with flow during highest intensity rainfall and the capacity of the gutter should be 10 to 15 percent greater than the design capacity to account for overflow. In general, in addition to presence of roof valleys, factors such as inadequate number of downspouts, excessively long roof distances from ridge to eave, steep roof slopes, inadequate gutter maintenance, etc. make it difficult to apply a gutter sizing rule of thumb. Some important criteria to keep in mind in designing of gutter systems are listed below.

- The installation of gutter must ensure that the collected storm water is directed away from the building during heavy rainfalls. One of the techniques to accomplish the forgoing is to install gutters so that the outside face is lower than the inside face. This encourages drainage away from the building.
- Gutters should be installed with a continuous downward slope (minimum 1:500) to encourage proper drainage of water. Furthermore, (Still and Thomas 2002) recommend a 5% slope for 2/3 and 1% slope for 1/3 of the length of gutters for optimum drainage efficiency. Standing water results in congregation and growth of small animals and insects as well as decay of accumulated organics.
- Debris accumulation near gutter outlets is a common issue and should be prevented. Trimming of the trees, installation of screens, and maintenance of gutters and screens could help prevent such problems.

2.2. Conveyance System

The function of conveyance system is to transport the collected water to cistern. There are three types of conveyance systems (Stubbs, 2006):

1) Gravity flow system

In gravity flow systems, also known as "dry systems", all conveyance piping slopes downward, consequently, water drains into the cistern. This system is the simplest and least expensive to construct and maintain.

2) Gravity head system

Gravity head system is a closed “wet system”, in which water flows through full pipes from the gutter or downspout to the storage system that is situated at the same level of collection system. Since the cistern is located at the same elevation of collecting system, storm water tends to remain in the pipes between rainfall events.

3) Surge pump system

In this system the storm water is transported by means of gravity to a smaller tank where a non-oil-bearing sump pump transfers the water to a cistern that is at a higher elevation than the collection system. This system is the most complex and most expensive to construct and maintain.

Instead of conventional conveyance piping systems, Lawson et al. (2009) recommend use of siphonic roof drain systems (especially for large, flat roofs) because they are cheaper and require fewer, and smaller, downpipes resulting in less underground piping. The use of siphonic drain system enables the downpipes to be closer to the system. On the other hand, conventional roof drains require the pipes to be brought longer distances resulting in additional pipe and site work as well as burial depth of cistern due to required slope on the pipe (see Figure 2.3).

If pipes are used outdoor and above ground, they are recommended to be rated to handle ultraviolet (UV) light exposure and withstand cold temperatures. A type of PVC pipe referred to as “PVC System 15” pipe is the suitable choice for such conditions. If pipes are installed below ground, they should be rated for burial. “Sewer grade pipes” or a “PVC SDR35” as well as ABS pipes are examples of such pipes (Residential Rainwater Harvesting Design & Installation Best Practices Manual, 2010).

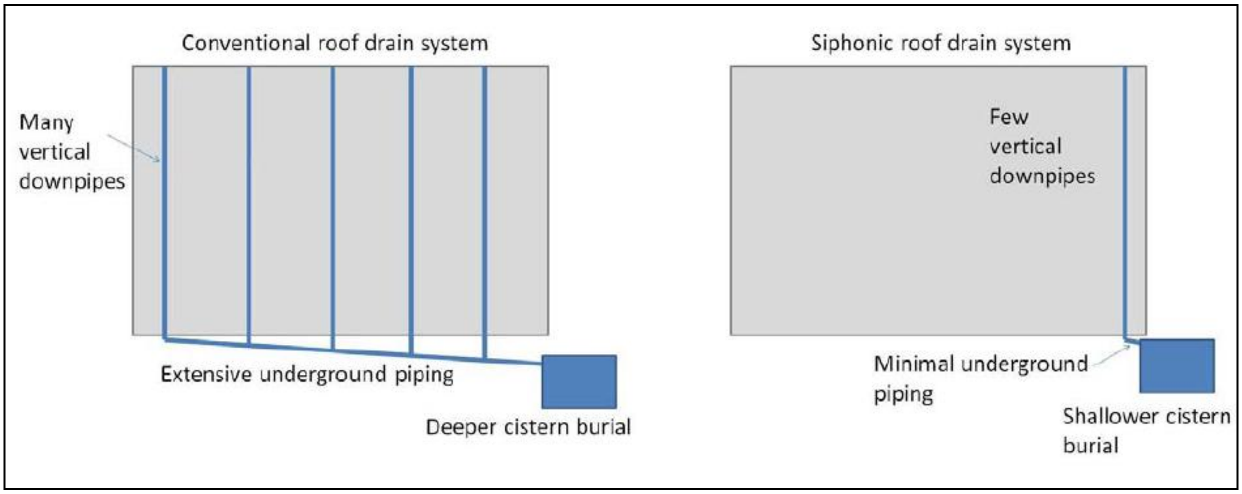

Figure 2.3 The schematic diagram of a conventional drain system and a siphonic drain system (after Lawson et al., 2009)

2.3. Roof Washing System/Pre-storage Treatment

Roof washing is the initial treatment process in which sediment, leaves of trees, needles, soluble pollutants etc. are removed from the rainwater harvesting system. This is a necessary process in that a build-up of organic debris in the tank would lead to build-up nutrients in the tank. Greater decomposition will occur resulting in low oxygen levels which can lead to the development of odors as well as favor the growth of harmful bacteria in the tank (Lawson et al., 2009). Another advantage of roof washing is alleviation of clogging problems. Roof washing can have one or several filtering components, some of which are described in the subsequent subsections.

2.3.1. Gutter Guards

Gutter guards, also referred to as Eaves trough screens, are installed on top of gutters to prevent ingress of larger debris into the gutters and the conveyance network. Gutter guards are available as a flexible material that can be "rolled out" onto the Eaves troughs, or as rigid materials made of plastic or metal.

2.3.2. Leaf Screens

Leaf screens are usually installed within the downspout, and have a sloped screen that traps leaves, directing them toward the ground. It is important to maintain the leaf screens as accumulation of debris and leaves can harbor bacteria and the products of leaf decay. Some types of leaf screens are mentioned below.

- Leaf guards

  Leaf guards are usually necessary only in locations with tree overhang and are usually ¼-inch mesh screens in wire frames that fit along the length of the gutter. Guards with profiles conducive to allowing leaf litter to slide off are also available.

- Funnel-type Downspout Filter

  This type of filter is made of PVC or galvanized steel fitted with a stainless steel or brass screen. This type of filter offers the advantage of easy accessibility for cleaning. The funnel is cut into the downspout pipe at the same height or slightly higher than the highest water level in the storage tank.

- Strainer Baskets

  They are spherical cage-like strainers that slip into the drop outlet of the downspout.

- Rolled Screens

  A cylinder of rolled screen inserted into the drop outlet serves as another method of filtering debris. The homeowner may need to experiment with various grid sizes, from insect screen to hardware cloth.

- Filter socks

  They consist of a nylon mesh that can be installed on the PVC pipe at the tank inflow

2.3.3. First-Flush Diverters

Roofs are considered a large exposed surface that allow continuously deposition and collection of debris, leaves, blooms, insect bodies, animal feces, pesticides, airborne residue and other pollutants. All of the mentioned materials and pollutants are washed off and collected by the first rainfall event, called “first flush”, resulting in high concentrations of pollutants in the initial portion of stormwater. The first flush generally rinses the roof and results in a cleaner water as rainfall continues. To avoid mixing of the contaminated water with the clean water, a first flush device (Figure 2.4) is used to divert the contaminated water away from the cistern.

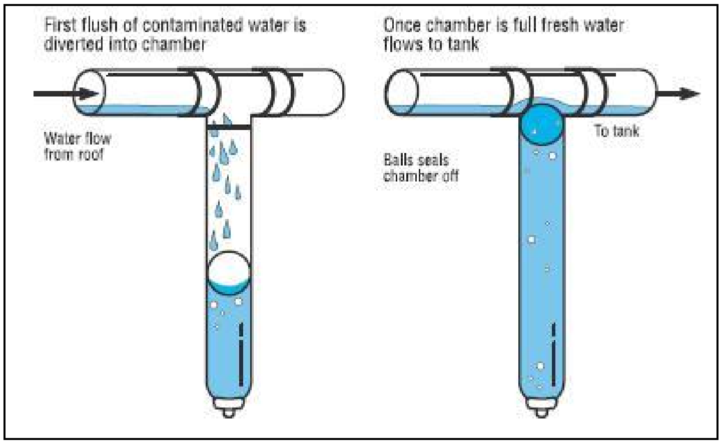

Figure 2.4 Schematic representation of first flush diverter (adopted from First Flush Diverters, undated)

It is usually recommended that the first 1 mm (25 gallons per 1000 ft^2 or approximately 100 liters per 100 m^2) of rainwater should be diverted away to preserve the water quality. However, it is important to note that there is no accurate estimation for the amount of water that needs to be diverted. There are lots of factors(e.g. the inclination and smoothness of the roof, the intensity of the rainfall, the time interval between rainfall events, and the nature of contaminants) that contribute to the effectiveness of the ability of first flush to rinse/wash the contaminants. According to Krishna (2005), in order to effectively wash a collection surface, a rain intensity of one-tenth of an inch of rain per hour for a sloped roof and 0.18 inches of rain per hour for a flat or near-flat roof is required.

2.3.4. Roof Washers

Roof washers filter small debris for potable systems and also for systems using drip irrigation. They are normally placed just ahead of the cistern. Roof washers consist of a 30- or 50-gallon capacity tank with leaf strainer and a 30 micron filter. Roof washers must be regularly cleaned in that lack of maintenance results in clogging of the filter and in turn growth of pathogens. The box roof washer (Figure 2.5) is a commercially available component consisting of a fiberglass box with one or two 30-micron canister filters.

2.3.5. Sand filters

Sand filters are common due to their simplicity and inexpensive cost of construction. These filters can be effectively reduce/remove turbidity (suspended fine particles such as silt or clay), color, and other microorganisms. A typical sand filter comprises of 3 layers. The top layer consists of coarse sand underlain by a layer of gravel which is underlain by a layer of pebbles or boulders or mixture of pebbles and gravels (Figure 2.6).

Figure 2.6 Illustration of a typical sand filter (after Shivakumar, 2005)

2.3.6. Settling Tanks

Settling tanks are used for further treatment of the storm water. In the settling tanks, or settling chambers, the suspended particles are allowed to settle before conveyance to the storage system. Usually ahead of the inlet a filter is used to convert turbulent flow (if present) to laminar flow. This process prevents mixing of the settled sediments as a result of turbulent flow.

2.3.7. In-line Filter

In-line filters are specialty devices designed exclusively for RWH systems, and typically are designed for burial (connected in-line with the conveyance pipe) or installed directly within the rainwater storage tank. These devices tend to be the most expensive option for pre-storage treatment; however, they have been specifically designed to remove the maximum amount of contaminants, while minimizing clogging/maintenance issues.

2.4. Storage System

The storage system is one of the main components and the most expensive part of any RWH system. The reservoir used to store storm water is referred to as storage or holding tank or cistern. Usually the choice of cistern type is influenced by several technical and economic factors (Kinkade-Levario, 2007): option available locally, availability of space, storage quantity desired, cost of the vessel, cost of excavation and soil composition, aesthetics, personal preference, and length of intervals between rainfall events. When designing a storage system the following factors should be taken into consideration: tank material, tank size, and tank location.

Tank Material

Storage tanks can be made of metals, wood, concrete, fiberglass, etc. The advantages and disadvantages of each material are summarized in table 2.1. In general, concrete tanks are considered suitable for cases were cistern is situated below ground. Plastic tanks are usually deemed appropriate for small storage and use above-ground (although below-ground plastic tanks are available). Fiberglass tanks are most often used for large commercial or industrial applications as they can be manufactured in customized large sizes.

Table 2.1 Different types of cistern material as well as their advantages and disadvantages (after Lawson et al., 2009)

Tank Material	Advantages	Disadvantages
Plastic		
Fiberglass	commercially available integral fittings (no leaks) durable with little maintenance light weight	must be sited on smooth, solid, level footing (for aboveground) expensive in smaller sizes
Polyethylene	commercially available affordable, available in variety of sizes easy to install above or below ground little maintenance	can be UV-degradable must be painted or tinted for aboveground installations
Trash cans (20-50 gallon)	commercially available inexpensive	must use only new cans small storage capabilities
Metal		
Galvanized steel tanks	commercially available available in variety of sizes	possible corrosion and rust must be lined for potable use only above ground use

Steel drums (55-gallon)	commercially available	verify prior to use for toxics corrosion and rust can lead to leaching of metals, small storage capabilities
Concrete		
Ferroconcrete	durable suitable for above or belowground installations neutralizes acid rain	potential to crack and leak
Monolithic/Poured-in-place	durable, versatile install above or below ground neutralizes acid rain	potential to crack and leak permanent in clay soil, will need sufficient drainage around tank
Stone, concrete block	durable, keeps water cool in hot climates	difficult to maintain expensive to build
Wood		
Pine, redwood, cedar, cypress	attractive, durable can be disassembled to move available in variety of sizes	expensive site built by skilled technician not for use in hot, dry locations only above ground use

Tank Location

The storage tanks, based on their location, have been classified into three categories (Residential Rainwater Harvesting Design & Installation Best Practices Manual, 2010):

1) Surface or above ground

   This is one of the simplest options since the storage tank can be situated at the side or back of a house in vicinity of the conveyance system and downspouts for easier transportation of stormwater. One of the disadvantages of this option is that the water is subject to freezing in cold weather conditions and can consequently damage the cistern, the piping system and the pump. This problem can be overcome by means of a winterized design.

2) Below-grade or underground

   The below-grade tanks are advantageous in that they can be installed below frost penetration depth to prevent freezing of water in the tank during cold temperatures. Once below the frost penetration depth, rainwater stored in a tank or within buried pipes will not freeze, permitting year-round use of rainwater. Tanks that are installed below ground do not receive much light and store water at colder temperatures; this combination leads to lower/minimal bacterial growth rates. The drawback associated with this method is the need for excavation of ground and associated costs. Additionally, for retrofit applications, extra work is required to compensate for the damaged landscape. Also this type of tanks might experience differential settlement due to sediment wash-off under the tank resulted from overflow drainage.

3) Integral cisterns or tanks built into a dwelling or a commercial building

This type of tank can be used above ground without worrying about freezing of water (in case of proper insulation of the area in which tank is located). One of the concerns associated with this option is that during extreme rainfall events, overflow may be occur; as a result, the designers should make sure that in such cases, the overflow does not damage the building and is properly handled. This option also limits the indoor space and may cause inconvenience.

Tank Size

Generally, larger tanks are advantageous in that they provide more water; however, increase in size of the tank is associated with elevated price of the system. Therefore, one should try to find the *optimum size* of the tank that maximized the water storage while minimizing the cost. The forgoing is a variable in local rainfall patterns, capacity of collection system, future daily water demands and so forth.

Table 4. Rainwater tanks	
	15,000 gallon fiberglass tank *Image courtesy Containment Solutions*
	1,700 gallon polyethylene below ground tanks *Image courtesy Rainwater Management Solutions*
	1,000 gallon polyethylene above ground tank *Image courtesy of Rainwater Management Solutions*
	100 gallon recycled plastic rain barrel *Image courtesy Rainwater Harvest Specialists, LLC*
	35,000 gallon modular plastic rain tank *Image courtesy Rainwater Management Solutions*
	3,000 gallon steel tank *Image courtesy Aqua Irrigation*

Table 2.2 Different sizes and materials for cisterns (after Lawson et al., 2009)

3.0 Disinfection/Purification System

Harvested rainwater should be purified when it is used as a potable source of water or if it is used for growing edible plants. There are several stages in the purification process and they include filtering, disinfection, and pH balancing. Fine filters are required to remove sediments and particulates that have made it past the initial filtering before entering the cistern. The removal of sediment enhances the use of ultraviolet treatment as the disinfection process (different disinfection systems will be covered in the next section). Even if the water is not used drinking, filtration of sediments is important to prevent the clogging of the distribution system.

Filtering of the water is usually accomplished with a series of sediment filters. A 5-micron filter is used in the first stage to screen out the relatively larger particulates and then a second filter is used to filter out smaller particulates. In the second stage, a smaller screen size filter of 1-3 microns is used before the water goes through the disinfection process.

In the next section, different options available in disinfecting the harvested water will be discussed. Disinfection is required in order to kill bacteria, viruses, and parasites (HealthLinkBC).

3.1 UV Light

The use of UV light to kill micro-organisms is very popular because there is no byproducts produced and there is very little maintenance upkeep. For UV light to be successful the water needs to be pre-filtered for sediment to maximize the UV penetration because sediments can block the unwanted pathogens from absorbing the UV radiation. The only maintenance in the UV light system is the regular change of the bulb as directed by the product manual (Ministry of Agriculture Food and Fisheries).

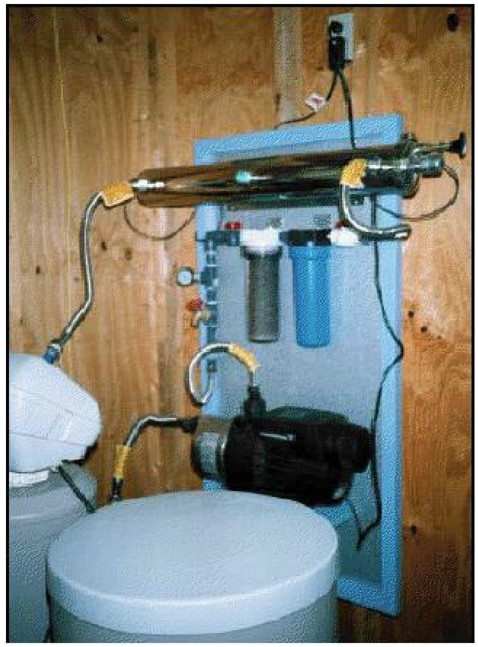

Figure 3.1 Example of UV treatment setup
Note: The UV light treatment can be seen at the top as the silver cylinder (Texas manual of Water Harvesting)

3.2 Chlorination

The use of chlorine to disinfect water was very widely used because it is highly effective and reliable. A concentration of only 1 ppm is required to disinfect the water. The disadvantages of chlorination are the need to store quantities of chlorine and the need to continually monitor the chlorine concentration level in the water. Also, when chlorine combines with organic matter a byproduct known as trihalomethanes is formed and has known to cause adverse health effects. Chlorine can kill bacteria and viruses, but it is unable to kill cysts (Krishna, 2005).

3.3 Ozonation

Ozonation is not only effective in killing bacteria and viruses, but is also effective in removing odor and color, and improving the taste. Heavy metals such as iron and manganese can be reduced to low levels with the use of ozone. One way to generate ozone is by through ultra-violet rays. The UV rays split oxygen molecules into individual atoms, and then into ozone. The ozone is very unstable and reacts with contaminants and pathogens. The bacteria and viruses are destroyed through oxidation upon contact (Food Safety Network).

3.4 Thermal Treatment

This is a classical method in the disinfection of water through the use of heat. The water is boiled for around 15-20 minutes to kill all the bacteria, viruses and diseases the water might have. The disadvantage to thermal treatment is that it consumes a large amount of energy and does not remove heavy metals from the water. This method is normally not used in the disinfection of harvested rain water.

3.5 Reverse Osmosis

Reverse osmosis utilizes a selective membrane and differential pressure to filter out micro-organisms. The pressure on one side forces the water to go through the membrane leaving behind bacteria, viruses, other organisms and ions. The membrane usually filters out contaminants smaller than one ten-thousandth of a micron. One of the things to note is that the filtered micro-organisms are not destroyed but are left behind on the pressurized side of the membrane. This method of disinfection is usually not popular for rainwater harvesting because it takes a long time to filter, and it wastes water in the filtration process.

3.6 Recommendation

In formulation of our recommendation, the top requirements are the effectiveness in the removal or killing of micro-organisms, and the operating cost.

Our recommendations for the disinfection system would be the UV light system. It uses little power and is very effective against micro-organisms. The operating cost only consists of the electrical energy required and the periodic replacement of the UV bulb. The only disadvantage of UV treatment is that it does not improve the taste of the water. For potable considerations, using ozone with UV treatment can be a solution. But for non-potable use, the implementation of sand filters is sufficient if grey water quality is sufficient.

4.0 Case Studies

4.1 – Overview

There are many examples of buildings throughout North America that incorporate rainwater harvesting into the design and architecture. The following case studies explored include a wide range of building types including industrial, municipal, and the on most applicable to the SUB Project, commercial. To provide bases of comparison to the other cases studies, table 1 provides the proposed available information for the Sub Project (BH, 2010).

	Annual Rain Fall	Catchment Area	Annual Collected	Containment	Usage	
Option 1	1,202mm	2,719m^2	2.5 million liters	48,000 liter cistern	60% all fixtures	50% flow
Option 2	1,202mm	2,719m^2	2.5 million liters	1.1 million liter cistern	94% all fixtures	100% flow

Table 4.1 - Available information for the Sub Project (BH, 2010)

Fixtures include – toilets (flow), urinals (flow), lavatories, kitchen sinks, showers

The previous information was retrieved from the 75% schematic design report. All cases studies with the exception of one had less annual rainfalls by an average of 300mm. but this does not have any affect on comparison because most of the other buildings capture much more water than the new sub is planned to due to their larger catchment area (Kinkade-Levario, 2007). The two most comparable projects are Seattle's City Hall, and Seattle's King Street Center, which is home of the Department of Transportation and Department of Natural Resources.

4.2 – City Hall – Seattle, Washington

Seattle's City Hall is a seven-story office building with an average occupancy of 320 people (City of Seattle Department of Planning & Development, 2008). The building received five out of the possible five points for water efficiency and achieved LEED Gold certification. The City Hall's annual catchment and containment is very similar to option 2 of the Sub Project. The catchment area of the Hall is 15% smaller resulting in a 20% annual availability of water from precipitation (Kinkade-Levario, 2007). City Hall intended to use the water collected for non-potable use including 50 toilets and irrigation. The rainwater collection system decreases storm water runoff by 75% and reduced their dependence of the city waterline by 30% (City of Seattle Department of Planning & Development, 2008). The water lines within the building are also integrated to the potable city line incase shortages are observed in the collection tanks.

The City Hall is an example of how rainwater harvesting is an effective and efficient component to a sustainable building and to gain valuable LEED points. This building is comparable to the new SUB project because it receives similar rainfall, uses similar amount of water, and has a similar cistern size as shown in table 4.2. The SUB, however, may demand more water due to the amount of people what will be passing though.

	Annual Rain Fall	Catchment Area	Annual Collected	Containment	Usage	
			UBC Sub			
Option 2	1,202mm	2,719 m^2	2.5 million liters	1.1 million liter cistern	94% all fixtures	100% flow
			Seattle City Hall – Seattle Washington (2003)			
City Hall	940mm	2,300 m^2	1.9 million liters	848,000 liters	Toilets 50, irrigation	Debris filter
Difference	21%	15%	20%	23%		

Table 4.2 - Information for the City Hall (City of Seattle Department of Planning & Development, 2008) (Kinkade-Levario, 2007)

4.3 King Street Center – Seattle, Washington

King Street Center is a typical eight-story office building in downtown Seattle that is occupied by Department of Transportation and Department of Natural Resources. The building is 30,000m^2 and is occupied by 1,500 employees (Cascadia Region Green Building Council). The building received five out of the possible five points by the LEED rating system resulting the Gold certification. King Street has 33% larger catchment area resulting in 53% more annual water collected. Even though the building collects more water than the SUB, three cisterns totaling 61,000 liters is used for storage. The 5.3 million liters of water collected by the whole system reduces the amount needed by the city waterline by 60% (Cascadia Region Green Building Council).

The King Street Center is an example of a building with large annual catchment but small storage tanks (refer to table 4.3). The rainwater harvest is only used for the toilets and occasional irrigation, which is similar to the SUB project. This is an example how a simple rainwater collection system is save large amounts of water by eliminating the use of city line water for toilets and urinals.

UBC Sub						
Option 2	1,202mm	2,719 m^2	2.5 million liters	1.1 million liter	94% all fixtures	100% flow
King Street Center – Seattle Washington (1999)						
Municipal offices	940mm	Roof – 4,100 m^2	5.3 million liters	61,000 liters	120 Toilets, irrigation	4x10μm filters
Difference	21%	-33%	-53%	94%		

Table 4.3 - Information for The King Street Center (Cascadia Region Green Building Council) (Kinkade-Levario, 2007)

4.4 Comparison Table

The following is a table (table 4.4) comparing different building types based on water collection and usage.

Building Type	Annual Rain fall	Catchment Area	Annual Collected	Containment	Usage	Filters Used
EL MONTE SAGRADO – Taos, New Mexico (2003)						
Living Resort and Spa	305mm 89cm snow	Roof – 6500 m^2 Ground-19500 m^2	7.2 million liters	2 X 50000 liters underground tanks	Landscape Irrigation	Sediment and micron
Earth Rangers Headquarters - Woodbridge, Canada (2004)						
Animal Rehabilitation	813mm	Roof – 5800 m^2	4.2 million liters	320,000 liters underground	Non-potable, grey water	Zenon filter
Prairie Paws Adoption Center – Grand Prairie Texas						
Animal Shelter	840mm	Roof – 7000 m^2	525,000 liters	57,000 liters above ground	Washing machine	Unavailable
America Honda Northwest Regional Facility – Gresham, Oregon (2001)						
Office/ Warehouse	930mm	Roof - 12,500 m^2	10.6 million liters	340,000 liter underground	Typical Grey water	Carbon filter and UV light
Hawaii Volcanoes National Park – Hawaii (1916)						
Military Base	1,033mm	Roof, catchment fields – 26,300 m^2	43.5 million liters	11.3 million liters, above	All water needs	Sand and chlorination
Heritage Middle School – Raleigh North Carolina (2004)						
Middle School	860mm	Roof - 14,000 m^2	10.6 million liters	473,000 liter underground	Grey water	50-micron filter
Portland State University – Portland Oregon (2003)						
Stephan Epler Residence Hall	890mm	Roof – 1,090 m^2	870,000 liters	32,500 liters	Toilets, irrigation	UV light
Seattle City Hall – Seattle Washington (2003)						
City Hall	940mm	Roof – 2,300 m^2	1.9 million liters	848,000 liters	Toilets (50), irrigation	Debris filter
King Street Center – Seattle Washington (1999)						
Municipal offices	940mm	Roof – 4,100 m^2	5.3 million liters	61,000 liters	Toilets (118)	4x10-micron filters

Table 4.4 - Comparing different building types based on water collection and usage (Kinkade-Levario, 2007)

5.0 EVALUATION AND CONCLUSION

A triple-bottom-line assessment is conducted to evaluate the applicability of implementing RWH system on the New SUB in terms of its social, environmental and economic costs and benefits.

- **Economic**

The total cost of the RWH systems installed at King Street Center is $320,000 (Kenkade-Levario, 2007). Information on the cost of RWH system of the City Hall is unavailable, but is estimated to be relatively higher than that of King Street Center due to its larger cisterns. In the case of the New SUB, the initial capital cost will obviously be relatively higher than not having the RWH systems, however the extra cost will eventually get paid off through water saving. The maintenance cost is very low. Only the filters need to be replaced every few months, thus the maintenance cost is the cost of purchasing and installing new filters.

- **Environmental**

It is sustainable to reduce the amount of water usage in the building. There is a wide range of materials for tanks and pipes to choose from, and many of those are recycled materials, both of which help to minimize the environmental impact. UV filters and sand filters are both recommended to be used in the New SUB. UV light system is very effective against micro-organisms, making the water quality high enough to satisfy the food safe standards to irrigate rooftop garden. In addition its operating cost only consists of electrical energy and UV bulb replacements. Therefore, UV light is recommended as the purification system.

- **Social**

The users of the building do not need to do much to adapt into the new system, as the infrastructure is built to save and reuse water. People might not be used to flush toilets with grey water, however they will quickly get used to it, since there are already many buildings implemented with waterless urinals.

We would recommend the implementation of RWH system with a large cistern (1.1 million liters) and UV light purification facility in the New SUB, since it is economically efficient in terms of long-term operation, environmentally friendly and socially adaptable.

The New SUB is emerging to be an excellent model to practice the green building concepts. As a LEED Platinum Certified building, many of its facilities can be transferred and adapted to a number of conditions and cultures in a global scale in the new future.

LIST OF REFERENCES

BH, D. +. (2010). *75% schematic design report.* Schematic Report, Univercity of British Columbia, Vancouver.

Canada Green Building Council. (2011). Introduction to LEED. Retrieved on March 30, 2011 from http://www.cagbc.org/AM/Template.cfm?Section=LEED

Cascadia Region Green Building Council. (n.d.). *Cascadia Green Building Case Studies.* Retrieved March 15, 2011 from http://cascadiagbc.org/resources/case-studies/cascadia-region-green-building-case-studies/

Chang, M., M.W. McBroom, and R.S. Beasley. Roofing as a source of non-point water pollution. Journal of environmental management. 2004, 73:307-315.

City of Seattle Department of Planning & Development. (2008, December). *Seattle City Hall.* Retrieved March 15, 2011 from www.seattle.gov/dpd/greenbuilding

Components of a Rainwater Harvesting System. Retrieved on March 17, 2011 from www.rainwaterharvesting.org/urban/Components.htm

Despins, C. (2010). Ontario Guidelines for Residential Rainwater Harvesting Systems, First Edition. Ontario, Canada

Food Safety Network. (2008). *Ozone Treatment.* Retrieved from http://www.emo3.com/files/Ozone-Treatment-University-of-Guelph.pdf

HealthLinkBC. (May 2007). *How to Disinfect Drinking Water.* http://www.healthlinkbc.ca/healthfiles/ hfile49b.stm

Kinkade-Levario, H. (2007). Design for Water: Rainwater Harvesting, Stormwater Catchment, and Alternate Water Reuse. New Society Publishers. Gabriola Island, BC, Canada.

Krishna, H.J., Brown, C., Gerston, J. & Colley, S. (2005). The Texas Manual on Rainwater Harvesting. Texas Water Development Board, 3rd Edition, Austin, Texas, United States of America

Lawson, S., A. LaBranch-Tucker, H. Oho-Wack, R. Hill, B. Sojka, E. Crawford, D. Crawford, and C. Brand. 2009. Virginia Rainwater Harvesting Manual, Cabell Brand Center, Salem, Virginia, United States of America

Low Impact Development Center. (2008, December). Managing Wet Weather with Green Infrastructure. United States of America: Environmental Protection Agency.

Ministry of Agriculture Food and Fisheries. (Jan 2003). *Treating Irrigation and Crop Wash Water for Pathogens.* http://www.agf.gov.bc.ca/resmgmt/publist/500Series/512000-3.pdf

My New Sub - The project. Retrieved on March 18, 2011 from http://mynewsub.com/site/?page_id=9

Radlet J, Radlet P. (2004). Rainwater harvesting design and installation workshop. Boerne (TX): Save the Rain.

Schemenauer, Robert S., Pilar Cereceda, and Pablo Osses. (2005). Fog Water Collection Manual. FogQuest and Margarita Canepa: Thornhill, Ontario.

Shivakumar, A. R., 2005, Amruthavarshini - A Guide for Rainwater Harvesting. Karnataka State Council for Science and Technology (KSCST), Indian Institute of Science, Bangalore

Stubbs, D. F. (2006). Rainwater Harvesting on the Gulf Islands Guide for Regulating the Installation of Rainwater Harvesting Systems– Potable and Non-Potable Uses (Salt Spring Island, BC: The Islands Trust Fund, 2006)

Vasudevan L. (2002). A study of biological contaminants in rainwater collected from rooftops in Bryan and College Station, Texas [Master thesis]. College Station (TX): Texas A&M University