An Investigation into the Water Management for

The Proposed New Student Union Building

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Abstract

The AMS of UBC is seeking new ways to manage its water consumption in the new SUB that will be constructed in the year 2012. In hopes of achieving a LEED platinum title, the AMS aims to achieve Net Zero Water Consumption. The objective of this report is to analyze the water management in the SUB and to follow the triple bottom line assessment to examine the results of the collection, storage, and usage of grey water.

After an analysis of the water management in the SUB was completed, results revealed the economic, environmental and social impacts upon grey water. Analysis of the economic results showed that installing water efficient toilets in the SUB can save up to $3,630.85 per year. Environmentally, by reusing grey water and collecting rain water, the scarcity of water will be reduced and with proper management could provide a closed loop system. The social impacts showed that the reuse of grey water will increase awareness to students and the public of the importance of saving water and will promote sustainability. Although there will be less space for student activities and foods services, the new SUB water management will provide jobs and a more appealing social space for students. Based on this analysis, installation of water efficient toilets, reuse of grey water and installation of window gutters is recommended.

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Glossary

Grey water	A form of waste water that remains from domestic activities including laundry, dishwashing, bathing
Black water	Water that comes from toilets and contains human waste
Net Zero Water Consumption	The overall water consumption of a building equals the overall water production of the building over a one year period.
Triple Bottom Line Assessment	Criteria meeting economic, environmental and social issues
Green Roof	The roof of a building that is covered in vegetation and usually includes a drainage system, filtering layer, plants.

List of Abbreviations

AMS	Alma Mater Society
SUB	Student Union Building
LEED	Leadership in Energy and Environmental Design
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
WFP	Water fed poles
HEU	High Efficiency Urinal
HET	High Efficiency Toilet
GPF	Gallons per Flush
LPF	Litres per Flush

INTRODUCTION

The AMS plans on building a new SUB which will be constructed along East Mall and University Boulevard. The new SUB is scheduled to be completed by September 2014 and will be approximately 31,000 square feet in size. The AMS plans on having a net positive impact on ecological health by harvesting rain water and improving water management.

The triple bottom line assessment of grey water in the SUB, in the attempt to achieve Net Zero Water Consumption, will be investigated. The analysis of the most sustainable solution to reduce UBC's water consumption and the environmental, economical and social influences of grey water will be discussed. Specifically, the collection, storage and usage of grey water and how these methods of reusing water will help achieve a more sustainable water management plan will be examined. This report will begin with briefly defining grey water and the LEED certifications needed to achieve a platinum title. This is followed by a detailed analysis of the environmental aspect, discussing the methods to collecting rain water and design implementations such as window gutters and green roofs that will increase the efficiency of grey water collection. Regulatory requirements of the quality of the grey water collected is also discussed and different filtration methods are examined, including UV filtration, slow sand filtration, and reverse osmosis. The report then continues with the calculations of the economic aspect. The usage and storage cost is summarized and the costs of each filtration method is presented. Lastly, the social aspects are discussed where the analysis of how reusing grey water will affect the student body in terms of jobs, washroom usage and space usage. Combining the three triple bottom line aspects, the report concludes with recommendations towards achieving Net Zero Water Consumption.

LEED Certification Requirements

Internationally recognized, LEED in a third-party certification program that promotes sustainability in design, construction and operation of green buildings. LEED aims to promote high-performance, durable, affordable and environmentally sound building design and construction. The prerequisites and credits for LEED certification are based on the following eight topics:

- Location and Planning
- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environment Quality
- Innovation in Design
- Regional Priority

The AMS plans on achieving LEED platinum, the highest ranking standard, requiring 80 points and above to qualify for certification.

GREY WATER

Waste water comes in two forms; black water and grey water. The key differences between the two waste waters is that grey water contains less nitrogen; a pollutant that is hard to remove and affects drinking water, less pathogens such as feces and it decomposes faster than black water.

Compared to grey water, black water cannot be reused because it consists of organic compounds that cannot further decompose when placed in water. Within a domestic household, about thirty-five percent of grey water comes from showers and baths, with toilet flushing being the second highest usage of around thirty percent. Laundry takes up about twenty percent and kitchens, ten percent. The remaining five percent comes from regular household cleaning. Rain water can also be considered as grey water and is largely over looked in domestic uses, however, in such cases as the SUB, with enough surface area and the prime location for rainfall, collecting rain water will contribute a large portion of grey water.

ENVIRONMENTAL ASPECT

Collection

In 2009, approximately 1055.6 mm of rain fell in Vancouver alone [1], which is a great indicator of how much water could be collected into a grey water system at UBC (See Figure 1). In addition to a conventional gutter system on the new SUB, additional water could also be obtained through the use of 'window gutters' (See Figure 2). Windows tilted at a 5-10 degree angle will provide sufficient surface area for water to be efficiently collected. Small lips on the edges of window sills act as gutters that can be tunnelled which then can be collected through a piping system to storage tanks for treatment. In order for this to be fully effective and red listed material safe, we need to use a material that can be used as part of the LEED certification and can withstand leaf litter which causes corrosion to gutters. These windows gutters would be collecting rain water from windows that would otherwise be wasted on the ground and causing storm run-off. The AMS plans on implementing a green roof on the SUB. To collect rain water in these areas, gutters lining the flat areas of the roof could be replaced with a drain system located in the middle of the roof, with the roof sloping towards the center to focus any runoff rain water to the drains (See Figure 3). All external water that is collected would then flow to a central pipe to be fed into the rainwater collection system. Within one year, an estimated 1,286,474 gallons of rain water could be collected just from the SUB roof top alone [2].

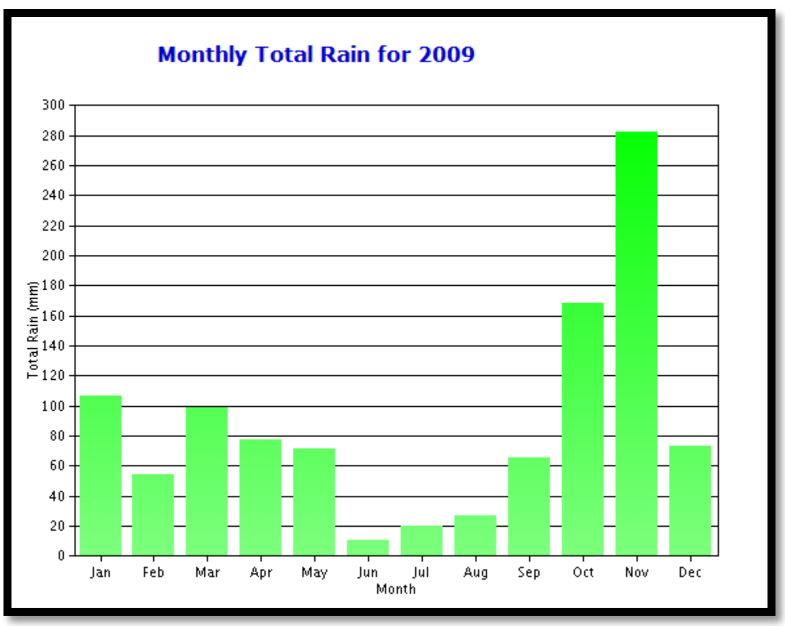

Figure 1. Monthly Total Rain for 2009 [1]

The majority of the grey water collected from within the SUB will come from washrooms. Water collected from toilets, though a plausible option, is classified as black water and would require additional filtration for the public use. Therefore, pre-used water collection would be limited to sink and urinal water, as it would be a cost effective option for obtaining additional grey water. From washrooms alone, assuming that all plumbing fixtures and utilities are standard and not high efficiency, we predict that a total amount of 10,050,103 gallons of water per year could be collected. The daily amount collected from showers and the kitchen would be about 8,997 litters. Due to the lack of information about water collected from showers, calculations for this utility are unable to be computed, however detailed figures are outlined in Appendix A.

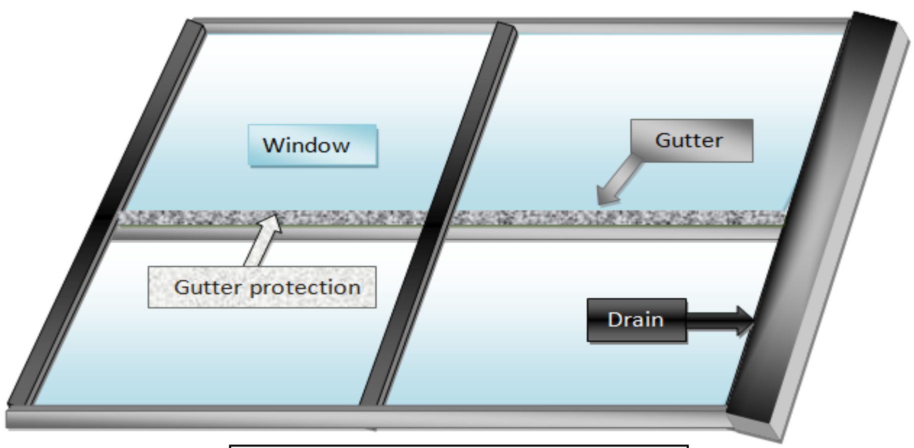

Figure 2. Design for window

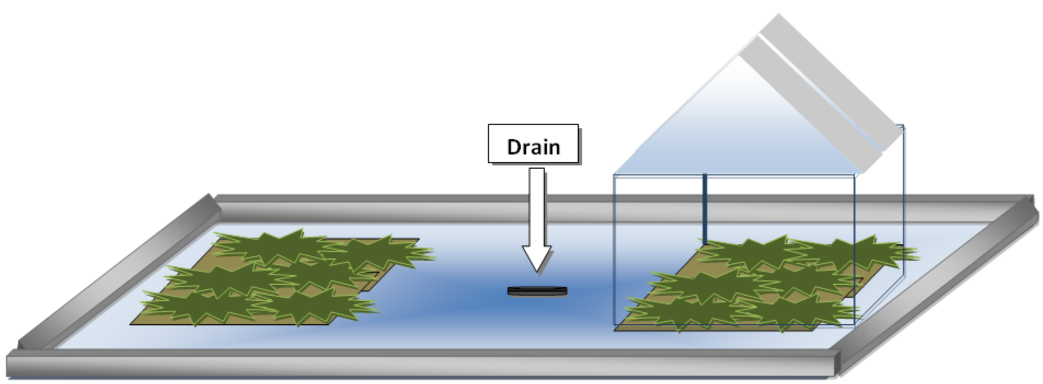

Figure 3. Roof Top Drain

Storage

An important part of collecting water is making sure the water, from where it is collected, is treatable. This ensures that the water collected meets health requirements and is safe to reuse. There are two different types of pollution that can be found in grey water; primary and secondary pollution. Primary pollution levels are measured by BOD, the amount of dissolved oxygen that is needed by aerobic biological organisms to break down organic material in water, and COD, the amount of oxygen that is extracted from water by bacteria when pollutants decompose. Secondary pollution is much worse as it contains algae and plant species in water that are more damaging since they carry high levels of nitrogen, phosphorous, and potassium. Secondary pollution is measured by the amount of fertilizer found in a sample of water. The following is a table describing the amounts characteristics of grey water depending on where it is collected from. There are three methods that could be implemented within the new student union building.

	Bathroom	Laundry	Kitchen	Mixed
pH (–)	6.4–8.1	7.1–10	5.9–7.4	6.3–8.1,
TSS (mg/l)	7–505	68 – 465	134–1300	25–183
Turbidity (NTU)	44–375	50 – 444	298.0	29–375
COD (mg/l)	100–633	231 – 2950	26–2050	100–700
BOD (mg/l)	50–300	48 – 472	536–1460	47–466
TN (mg/l)	3.6–19.4	1.1 – 40.3	11.4–74	1.7–34.3
TP (mg/l)	0.11– > 48.8	ND – > 171	2.9– > 74	0.11–22.8
Total coliforms (CFU/100 ml)	10–2.4 × 107	200.5–7 × 105	> 2.4 × 108	56–8.03 × 107
Faecal coliforms (CFU/ 100 ml)	0–3.4 × 105	50–1.4 × 103	–	0.1–1.5 × 108

Table 1. Water Quality Standards [18]

If water is to be reused, people with sensitive skin and other medical issues need to be reassured that the water they are using is safe. Therefore, testing for nitrogen, potassium and phosphorous is vital.

To ensure the SUB would meet these standards, three different filtration methods were evaluated:

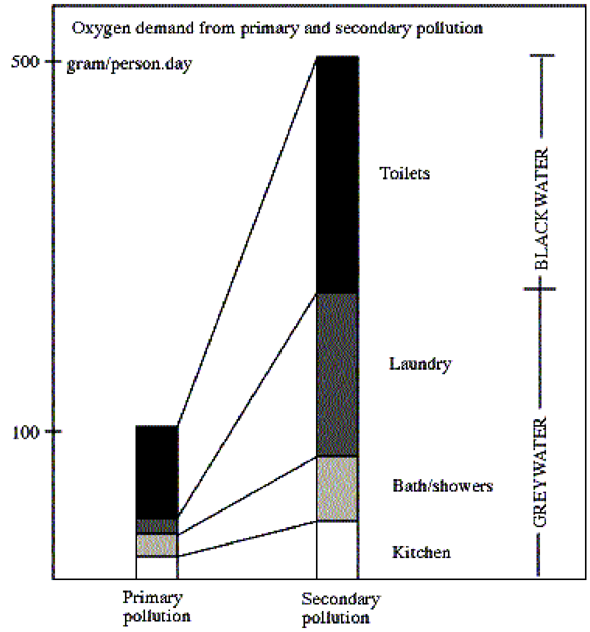

Figure 4. Oxygen demand in grey water [18]

UV Filtration:

A UV filter works by bombarding the grey water with Ultra-violet rays, altering the nucleic acid (DNA) of viruses, bacteria, moulds or parasites, so that they cannot reproduce/ function**.** The optimal wavelength for disinfection is close to 260 nm. Medium pressure UV lamps, used to filter grey water, are approximately 12% efficient, while amalgam low pressure lamps can be up to 40% efficient [3].

Using UV rays to filter grey water can be inefficient since suspended particles, such as microorganisms, can bury themselves within water particles that are shielded from the UV light, making it possible to pass through the filtering unit. However, this can be solved by coupling the system with a pre-filter to remove larger organisms that would otherwise pass through the UV system. Another key factor of UV water treatment is the flow rate. If the flow is too high, water will pass through without enough UV exposure. If the flow is too low, heat may build up and damage the UV lamp. See Appendix B for price details

Slow Sand Filtration:

Cheap and cost effective, a slow sand filter would provide a good filter to the incoming grey water collected by the system. Slow sand filtration involves running the grey water through a tank filled with a bed of fine sand and a layer of gravel to support the sand. A system of drains runs underneath the bed where filtered water is collected. The water is filtered through a sticky mat of biological matter, called a “schmutzdecke”. This forms a sand surface where particles are trapped and organic matter is biologically degraded.

A major advantage to slow sand filtration is it does not require systematic backwashing to clean the filter. This eliminates the cost of wastewater storage as well as handling and reducing the amount of water need to maintain it [5].

A disadvantage to this type of filtration is the space constraints needed to have such a system (See Appendix B). Although the actual performance details of this filtration cannot be determined until the completion of the filtering device.

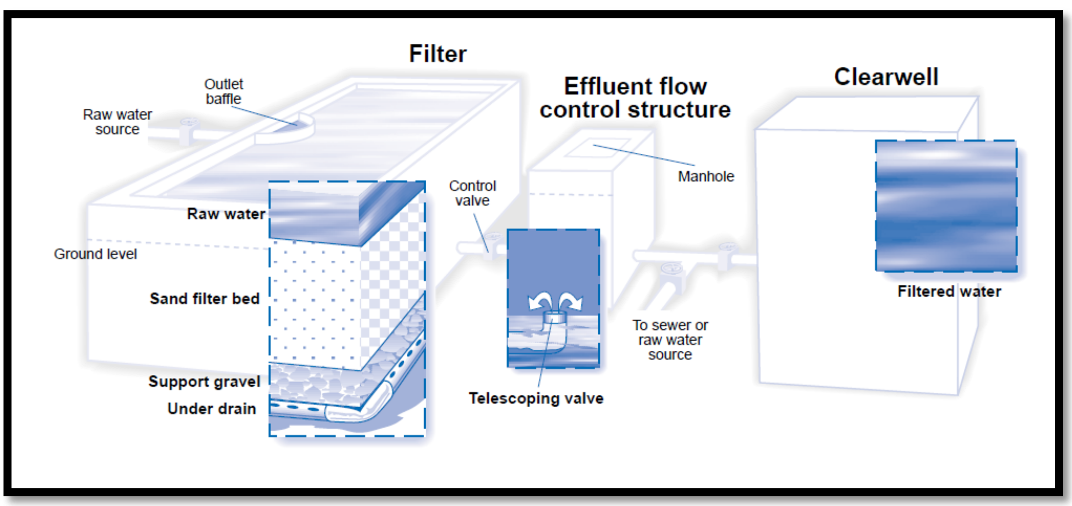

Figure 5. Slow Sand Filter [4]

Reverse osmosis

Reverse osmosis [6] is a water treatment process in which water is forced through a semi-permeable membrane that contains very small holes or "pores". Clean water passes through the membrane while removing impurities that are too big to pass through.

Membrane pore sizes can vary from 0.1 nanometres to 5,000 nanometres depending on filter type. A big disadvantage to a reverse osmosis system is its efficiency. In a large-scale industrial system, the production efficiency is closer to 48% (the rest being a high volume of waste water), meaning that a reverse osmosis system would produce less water than what was put in.

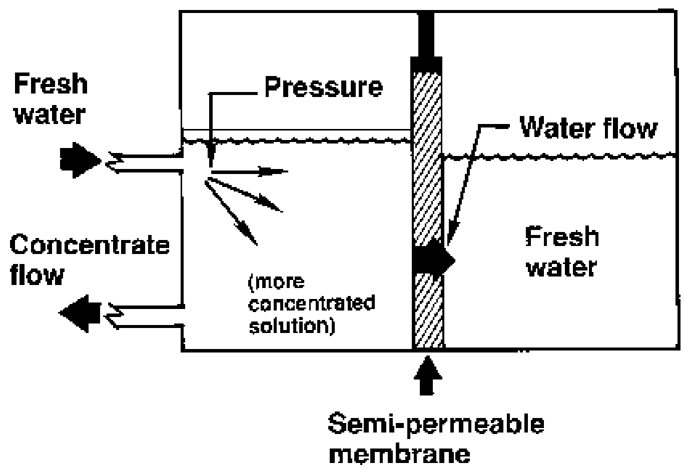

Figure 6. Reverse Osmosis System [11]

Fibreglass Storage Tank

Four different materials (Polyethylene, Galvanized steel or Stainless steel, Fibreglass and Concrete**)** were examined to determine which would be best suited to make the grey water storage tanks. Fibreglass tank was found to be the better choice as the product is chemical resistant, well designed, modular, and would be usable instantly. A Fibreglass tank also has a average lifespan exceeding 35 years, making it more durable than polyethylene and steel tanks. One study [18] shows that fibreglass tanks, when compared to concrete and iron tanks, were also more resilient to contamination. A significant drawback is that it is more expensive than the polyethylene and steel tanks.

Usage

Currently, 4,580 gallons of water are being used daily in the sub for washroom purposes (See Appendix A). Conventional taps use approximately 2.2 gallons per minute, while a conventional toilet uses around 1.6 gallons per flush. Urinals also amount to a flush volume of around 0.52 gpf. In an attempt to achieve Net Zero Water Consumption, changing washroom utilities and using grey water would nearly create a closed loop system.

A recommendation for reducing water usage would include updating to a high efficiency system. HEUs use approximately one-third of the amount of water used to flush the average urinal (0.5-gpf/1.9-lpf or less according to [9]). Based on average usage, a single HEU can save close to 18,000 litres of water per year. While a HET, a toilet that uses a pressure-assisted system could reduce about 20% of current water usage having a gpf/lpf of 1.28/4.8 or less [10].

ECONOMIC ASPECT

Collection Cost Summary

Roof drains can cost anywhere from $100 to $300 depending on the quality of the material and included filter. Pricing on the Window drains is undisclosed as they are not available for public/ haven't been invented. Realistically to implement such a system would cost around $1 a foot as the method basically involves placing a small scale gutter on the window.

Usage Cost Summary

From a metered rate of 7.1 cents per 100L according to [11], we have estimated the SUB spends about $12 dollars a day or $4,430 dollars a year on flushing two high traffic bathrooms in the SUB. Replacing that water with Grey-water will eliminate 520 thousand litres a month or 4,716,170 litres of fresh water a year needed to flush these toilets.

We estimated after including annual maintenance cost, collecting, storing and using Grey-water to flush toilets allow the SUB to save $3,630 every year after 5 years of offsetting initial setup and maintenance cost. A further 1,289,312 litres a year / $900 can be saved with the instalment of HET and HEU systems which more than compensates for their $100-$300 ea.[9,10] investment after a few years.

Storage Cost Summary

The system will consist of two 15,000 gallon fibreglass tanks to store treated water, a 5,000 gallon tank to filter collected water, coarse sand, washed sand and varied sizes of gravel. The total cost of these materials will be $11,500. The installation cost of the tanks, pumps and adding new pipes will need to be quoted from a contracting company. The installation cost for the system is loosely estimated at $10,000 which sums to an initial setup total of $21,500. The sand filter will need to be replenished with more sand every few months. This replacement is estimated to be around $800 annually. Fibreglass tanks are a newly developed product so their lifespan can only be estimated to last well over 35 years. At the end of the fibreglass tank's lifespan, they can be recycled into insulation or put in a landfill. The system should annually eliminate 4.7 million litres of fresh water usage and save the AMS SUB $3,630 after 5 years of offsetting initial start-up and annual maintenance cost.

SOCIAL ASPECT

Collection

In order to conserve water, it must be reused from bathroom and kitchen sinks from the SUB as well as collected from windows and gutters. Certain concerns with health issues over contaminants left behind when not using fresh water and the smell of reused grey water may be problematic. However, by saving water, there is a possibility to reduce the problem of water scarcity. Being sustainable in the washroom also creates awareness among the public of the importance of conserving water. When building the SUB, by implementing the following collection applications, we are also providing jobs. The following section will discuss the collection of grey water from windows, washrooms and kitchen sinks.

Windows

Windows help maximize sunlight coming into the SUB, making it more energy efficient and overall, more enjoyable for students using the space. More windows increase the amount of natural sunlight in the SUB which is better for studying conditions.

Washrooms

Collecting grey water from washrooms has no social impact on students other than having the normal piping rerouted to the storage tanks. Some students, however, may be concerned about sanitary issues when using the washroom utilities.

Kitchen sinks

Within the kitchens, instead of routing the water from the kitchen sinks to the sewage, it will be lead to the storage tanks instead. The only potential loss may be storage space which is important for a small independent food business.

Usage

Even though grey water is treated, it is not perfectly sanitary; therefore there are limited applications to using grey water. Tasks applicable to the SUB and detailed below are: janitorial, such as cleaning windows and floors, washrooms for flushing toilets, and watering plants both on the roof and within the SUB. In addition, food services cannot use grey water under regulatory conditions such as Food Safe.

Janitorial

Janitorial tasks always use clean water to wash windows and floors. There are large amounts of fresh water used in janitorial tasks which is not necessary. Using grey water instead of fresh clean water can save money and help promote sustainability.

Washrooms

With thousands of students using the SUB washrooms every day, we can only imagine the amount of water used in the washrooms. However, students may be concerned with sanitary conditions and the odour of grey water which makes them less likely to be supportive of the new sustainable changes.

Watering Plants

Plants do not need fresh water, so treated grey water will be sufficient. Plants provide oxygen circulation throughout the SUB and are visually appealing. More plants will help the SUB be more environmentally friendly.

Storage

Space Required

A major issue that will arise when dealing with storage is the amount of storage being used up by the storage tanks under the SUB. Students would be concerned with the reduced space available to them as clubs rooms in the SUB if replaced with the storage tanks for grey water. This will also affect food services as fewer companies will be able to serve students. In general, there will be less space for student activities. However, in implementing the grey water treatment and storage tanks in the SUB, this will create more jobs for maintaining the tanks, building the tanks, and doing the plumbing.

CONCLUSION

After reviewing the environmental, economic and social aspects of collecting, using and storing grey water in the SUB, several recommendations are proposed below in order for UBC to achieve Net Zero Water Consumption. Comparing the environmental and economic analysis of each filtration system, it is concluded that the slow sand filtration would be the best system as it more cost effective and reliable than other systems. Analyzing the efficiency and cost of collecting and storing grey water and rain water, results show that the pros of implementing window gutters and installing additional pipes and storage tanks outweigh the cons. However, socially, even though implementing these systems may increase employment and aesthetic appeal of the building, the concerns with health issues of reusing grey water and storage reductions prevail over the student's enjoyment of the building. As a result, apart from negative social aspects, reusing grey water processed through slow sand filtration, implementing window gutters and installing high efficiency utilities are highly recommended as this will save UBC money in the long run and increase the sustainability of the SUB in order to achieve a LEED platinum title.

Appendix A

Collected Water Chart

In litres unless specified otherwise	Hourly	Daily	Weekly[2]	Monthly	Yearly
Average Rainfall:					
From Oct. - Mar. (mm)	0.19	4.64	32.50	130.00	780.00
From Apr. - Sept. (mm)	0.08	1.89	13.25	53.00	318.00
Rainfall Collected:					
Oct. - Mar.	6,290	150,967	1,056,772	4,227,087	50,725,038
Apr. - Sept.	2,565	61,548	430,838	1,723,351	20,680,208
High Season Total Collected[1]	4,718	113,226	792,579	3,170,315	38,043,779
Low Rain Season Total Collected[1]	1,923	46,161	323,128	1,292,513	15,510,156
Utilities:					
Bathroom sink	167	3997.2	22,651	90,603	1,087,238
Kitchen	208	5000	28,333	113,333	1,360,000
Avg. Daily Utilities Total	375	8,997	50,984	203,937	2,447,238
High Rain Season Total	5,093	122,223	843,563	3,374,251	40,491,017
Low Rain Season Total	2,298	55,158	374,112	1,496,450	17,957,394

[1]Assuming 25% rain is not collected according to [16].
[2]Assuming weekend water usage is 1/3 of weekdays.

Toilet Water Consumption Chart

	Hourly	Daily (Mon. to Fri.)	Weekly[2]	Monthly	Yearly
Bathroom Usage Estimate:					
12:30 - 16:00 (High Traffic) (Flushes)	378	1,323	7,497	29,988	359,856
6:00 - 12:30, 15:30 - 24:00 (Low Traffic) (Flushes)	216	2,052	11,628	46,512	558,144
18:00 - 24:00 (Night Traffic) (Flushes)	61	367	2,081	8,323	99,878
Total Flushes[1]	655	3,742	21,206	84,823	1,017,878
Toilet Water Consumption (6Lpf)[1]	2,620	14,969	84,823	339,293	4,071,514
Urinal Water Consumption (1.9Lpf)[1]	415	2,370	13,430	53,721	644,656
Total Bathroom Water Consumption (L)	3,035	17,339	98,254	393,014	4,716,170

[1]Assuming 10% of people only use the sink and 1 out of every 3 people use a urinal.
[2]Assuming weekend water usage is 1/3 of weekdays.

Bathroom Usage Research Chart

Research Data	People/Hour	Flushes/Hour	Flushes/Day
High Traffic (Noon)	420	378	1323
Normal Traffic (Morning, Afternoon)	240	216	2052
Low Traffic (Evening)	68	61.2	367.2
		Total	3742.2

Proposed System Cost

Treatment and Storage	Cost (CAN$)	Quantity	Subtotal (CAN$)
Slow Sand Filter Materials[1]	1000	1	1000
15,000 Gallon Fiberglass Tank	4250	2	8500
5000 Galloon Fiberglass Tank	2000	1	2000
Installation	10000	1	10000
		Subtotal	21500

[1]Costs taken from [13]

System Cost Offset Chart

Break Even Point	Cost(CAN$)	Quantity	Total (CAN$)	Years to Offset Costs
Initial Cost	21500	1	21500	4.85
Yearly Maintenance Cost	800	5	4000	0.90
		Subtotal	25500	
		Total Years to Offset Costs	5.76	

Conclusion Chart

Conclusion	Daily	Monthly	Yearly
Money Saved from Using Fresh Water for Toilets (CAN$)	$12.31	$369.24	$4,430.85
Money Saved After Maintenance (CAN$)	$10.09	$302.57	$3,630.85
Fresh Water Saved (L)	17,339	393,014	4,716,170

Constants Chart

Constants:	
Roof Area (sq/ft)[1]	50000
Roof Area (m^2)	4645.15
Average Liters/Hand-wash	1
Average Liters/Shower	120
Urinals to Toilets Usage	1/3
Toilets to Urinal Usage	2/3
Liters per toilet flush	6
Metered Water Rate ($/100L)[2]	0.071

[1]According to [15]   [2]According to [11]

Appendix B

TABLE 2 Design Summary of a Slow Sand Filter

Design parameters	Recommended range of values
Filtration rate Area per filter bed	$0.15\ m^3/m^2 \cdot h$ ($0.1–0.2\ m^3/m^2 \cdot h$) Less than $200\ m^2$ (in small community water supplies to ease manual filter cleaning)
Number of filter beds	Minimum of two beds
Depth of filter bed	1 m (minmum of 0.7 m of sand depth)
Filter media	Effective size (ES) = 0.15–0.35 mm; uniformity coefficient (UC) = 2-3
Height of supernatant water	0.7–1 m (maximum 1.5 m)
Underdrain system Standard bricks Precast concrete slabs Precast concrete blocks with holes on the top Porous concrete	Generally no need for further hydraulic calculations
Perforated pipes (laterals and manifold type)	Maximum velocity in the manifolds and in laterals = .3 m/s Spacing between laterals = 1.5 m Spacing of holes in laterals = 0.15 m Size of holes in laterals =3 mm

Taken from [4]

Slow Sand Filer: Basic Cost Analysis

	Type	Height	m^3	Cost(m^3)	Total
Top layer	Seachelt	.7m	3.5	32.69877	114.4457
	Washed	.8m	4	45.77827	183.1131
	Bird's Eye Pea Gravel	.3m	1.5	54.93393	82.40089
	Pea Gravel	.3m	1	54.93393	54.93393
Bottom Layer	Drain Rock	.3m	0.5	52.31802	26.15901
				Subtotal	461.0526

*assuming a 5 m^2 surface area

Reverse Osmosis Filtration: Basic Cost Analysis

Product	Source	Capacity	Cost	Complete System
Titan Series	http://www.excelwater.com/eng/b2c/our_product_titan.php	4000 GPD	$5225	NO
ARO Series	http://www.excelwater.com/eng/b2c/our_product_aro.php	5400 GPD	$9048	NO
Model 4000AT	http://www.aquatechnology.net/4000specs.html	4000 GPD	$19950	NO
MUWRO-6000	http://www.aquatechnology.net/6000gpddesal.html	6000 GPD	$88000	YES
TV-RO-4000	http://www.h2obuyersguide.com/croreverseosmosis.html	4000 GPD	$6898	
PRO	http://www.freedrinkingwater.com/pro-commercial-detail.htm	4800 GPD	$5290	

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