UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into South Campus Stormwater Catchment and Filtration Technologies

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APSC 262

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ABSTRACT

UBC Farm currently uses Metro Vancouver as a source of water for irrigation. Statistics shows that water consumption during the peak season from June to September is almost four times of that during off-peak season, and such a big difference creates a heavy cost to the Farm. Due to the coastal climate of Vancouver, the peak season for irrigation is in drought condition whereas precipitation during off-peak season is more than enough for irrigation purpose in off-peak and even peak season. Thus, in order to save water consumption and be environmentally friendly, three sustainable stormwater catchment systems were proposed and triple bottom line assessment was conducted to evaluate these systems with economic, social, and ecological factors. These three systems include pond, rain garden and Rooftop Water Harvesting System, which are all designed to catch precipitation and stormwater runoff at UBC South Campus and thus to provide filtration and conserve the water for irrigation during peak season. The economic assessment determines which system costs less and needs less years for investment payback, and the pond solution achieves the best score for its relatively lost cost and hence less years of payback. The social evaluation indicates how each system would affect the neighbourhood and the society. Rain garden has the most social benefits, but it also brings significant disturbance to the neighbourhood community. Lastly, the ecological assessment shows how each system will alter the environment and what are the benefits to the environment. In this aspect, both rain garden and water pond bring similar ecological benefits, while the third one has no noticeable benefits since it is mostly industrialized and artificial. Hence, from the overall judgement of the three aspects, the water pond solution obtains the highest overall ranking. Therefore, it is suggested to implement a water pond with a mini ecosystem in UBC Farm for stormwater catchment and filtration, and a habitat test and additional funding are required.

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GLOSSARY

UV light is light with a shorter wavelength than visible light, and can be used to kill bacteria.

Rain Garden is a planted depression or a hole that allows rainwater runoff from impervious urban areas

LIST OF ABBREVIATIONS

UBC University of British Columbia

SUB Student Union Building

RHS Rooftop Water Harvesting System

1.0 Introduction

UBC has been striving very hard to achieve all aspects of economic, environmental and social sustainability. In order to achieve better sustainability, there are many possible areas to work on. Water usage has been one of the big issues on campus and irrigation is a significant component of water consumption in UBC.

The amount of water used for irrigation at UBC Farm contributes to about 15% of the total water consumption at UBC (Hood & Seabrooke, 2012, p. 5). Currently, UBC purchases water from Metro Vancouver, and it pays \$0.7176/m^3 during off-peak season (January to May, and October to December) and \$0.897/m^3 during peak season (June to September). According to Table 1, it is easily calculated that the cost of water used in the farm in 2012 was 4573 x \$0.7176/m^3 = \$ 3282 for off-peak season usage and 18221m^3 x \$0.897/m^3 = \$16344 for peak season usage.

UBC Farm Irrigation Water Meter Reads and Consumption in 2012 (m3)

Facility	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12	TOTAL	PEAK	OFF-OEAK
UBC Farm - Irrigation West	500	500	500	505	685	no read	1145	1785	2135	no read	2320	2320			
MW21-21		0	0	5	180		460	640	350		185	0	1820	1450	370
UBC Farm #3	5350	5350	5350	5390	6675	no read	13075	17110	19700	no read	21775	21775			
MW20-07		0	0	40	1285		6400	4035	2590		2075	0	16425	13025	3400
UBC Farm Irrigation East	3863	3863	3863	3870	4184	no read	5254	6500	7930	no read	8412	8412			
MW25-14		0	0	7	314		1070	1246	1430		482	0	4549	3746	803
YEAR-ROUND CONSUMPTION		0	0	52	1779		7930	5921	4370		2742	0	22794	18221	4573

Table 1.0-1 UBC Farm Irrigation Water Meter Reads and Consumption in 2012 (Information from the Stakeholder, Campbell, V.)

The great difference between water consumption during peak season and off-peak season can be noticed easily, and such a difference can be explained by the large amount of precipitation received annually in Vancouver (Environment Canada, 2010). Figure 1.0-1 below shows the graph of monthly precipitation at UBC. By comparing the data from Table 1.0-1 and Figure 1.0-1, it is clear that off-peak season is rainy, and drought condition is always encountered during peak season; during off-peak season, the amount of rainfall largely exceeds the amount of water consumption. Thus, there is high possibility to catch and store year-round precipitation for irrigation during the period from June to September.

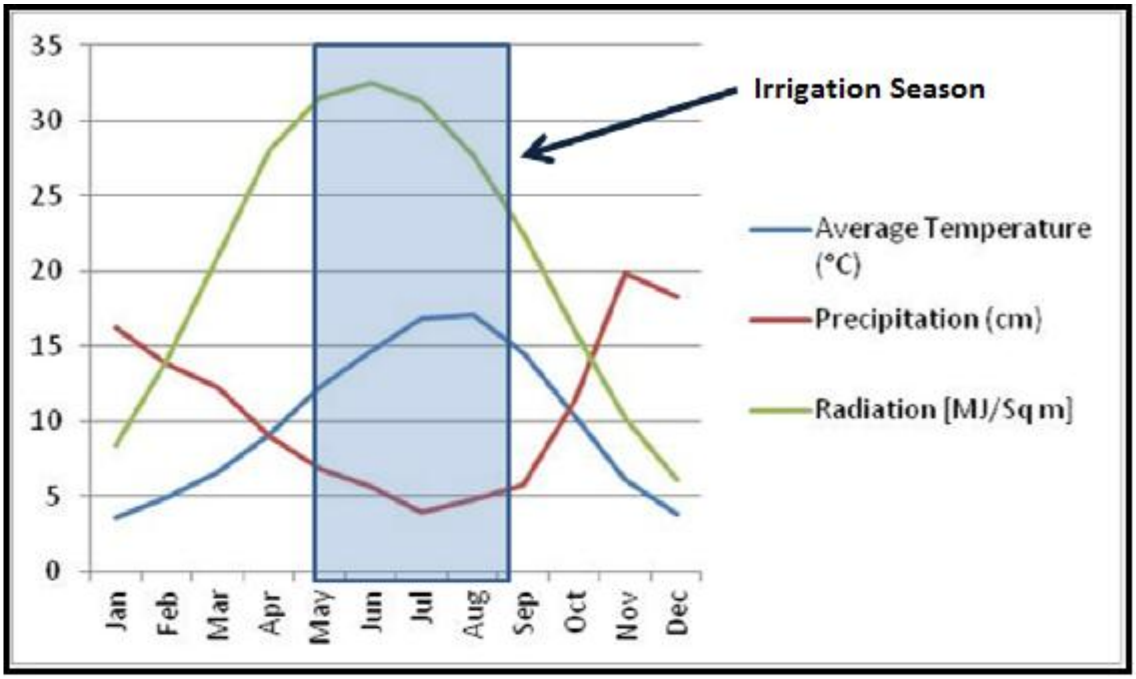

Fig 1.0-1. Moderate Coastal Climate and Seasonal Irrigation at UBC (Hood, I., & Seabrooke, A. (2012). UBC Irrigation Action Plan DRAFT REPORT. (personal communication, March 5, 2013).)

Also, UBC Farm has a lower altitude than its neighbourhood areas, and it is located along the path of stormwater outfall on South Campus (UBC Vancouver Campus Integrated Stormwater Management Review, p. 4). Hence, it can be assumed that stormwater runoff from South Campus (more specifically, Wesbrook Village) will flow towards the Farm, which might be stored and used for irrigation as well.

Therefore, a system for stormwater catchment and filtration can be designed and used to conserve both precipitation and runoff water for the purpose of agriculture in the Farm. Based on above information, three possible methods - water pond, rain garden, and Rooftop Water Harvesting System - are proposed for stormwater catchment and filtration at UBC Farm, and the effects of these three methods are investigated through triple bottom line assessment.

2.0 Possible options

In this part, each of the three possible systems is further discussed in details. The purpose and the operation principles will be elaborated with respect to their application to the UBC Farm.

2.1 Water Pond

The first option for stormwater storage is a water pond located at the southwest corner of the UBC farm where the lowest altitude point is (circled with blue in Fig 2.1-1). There is currently a wetland at the farm where most rain water flowed from Wesbrook accumulates and small puddles appear frequently (as shown in Fig 2.1-2). Because of the continuous accumulation of stormwater at this point, this location is prefered over other parts of the farm for stormwater catchment, and the idea of having a pond will allow storing much more stormwater.

Fig 2.1-1: Highlighted area is where the pond will be planned. (Retrieved from Google Map.)

Fig 2.1-2: Small puddles have already appeared at the wetland.(self-taken photo)

The estimated area from Fig 2.1-1 is 5,000m^2. According to Table-1, the peak season consumption from June to Sept is 18,221≈18,000m^3, which divided by 5,000m^2 will give us 3.6m. Therefore, we estimate the depth of the pond required to hold the demand of the peak season to be at least 4m in order to supply for one peak season, under the perfect condition of no further precipitation during the peak season and loss of water is not considered in this case. Although evaporation is neglected in the estimation, in real life situation, evaporation has to be considered based on local temperature and humidity. If the average cost for processing one meter cube of soil approximates to \$53 (Adam, 2012) , the total cost for the pond will be \$53 x 4 x 5,000 ≈ \$1,060,000.

In order to conserve water and maintain the water quality at an acceptable level, local natural ecosystem is used. Many of the local vegetation will be planted by the shore of the pond to stabilize soil structure and to maintain water quality. For examples, some common plants are Beaked Sedge, Common Rush(Stevens, 2002), Dwarf Purple Willow(Dickerson, 2002) and

Sawbeak Sedge (Sound Native Plants, 2001). Most of these plants are already found near the wetland area of the UBC Farm, therefore, it will not be difficult to replant these vegetations for the purpose of the pond. Planktons and microorganisms are also critical in maintaining water quality(Voutilainen,2012), since they can consume some toxic materials such as metal and chemical, and maintain decent amount of nutrition and oxygen in the pond water.

When it comes to the peak season, it is expected to use electrical pumps to deliver water to the farm center (highlighted with red rectangle in Fig 2.1-1) where its altitude is relatively higher in the farm. Due to gravity, water will flow to other locations through a pipe system.

2.2 Rain Gardens

A rain garden is a vegetated area which allows stormwater runoff to be collected and filtered with a sustainable biological process. While being located at the lowest point around the area, rain garden collects surface runoff from the residential area through drainage paths, and then provides biofiltration to the runoff water by leaking through the vegetation and the soil. The filtered runoff water will be kept in the reservoir underneath the rain garden and overflow will be directed into other storage system such as a pond or a tank.

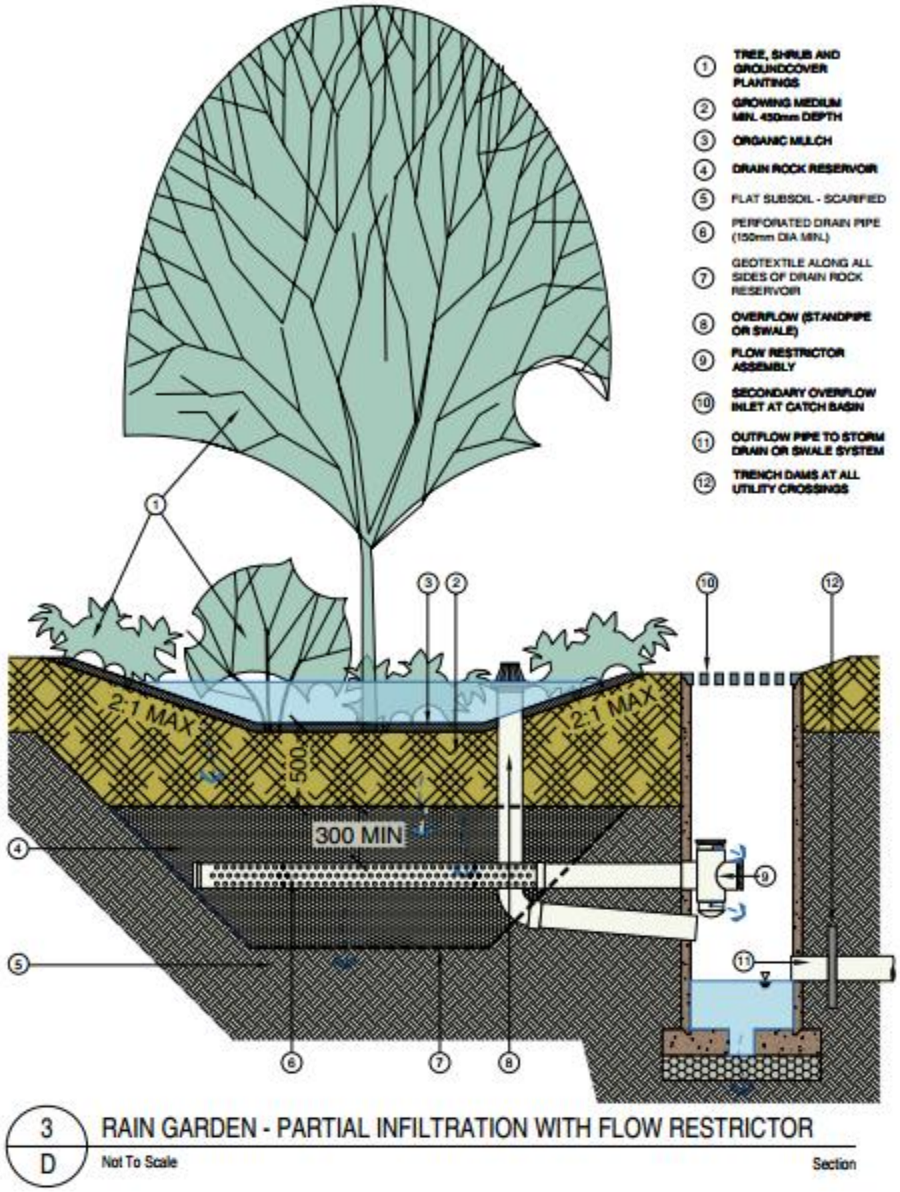

Fig.2.2 - 2 rain garden-partial infiltration with flow restrictor (Greater Vancouver Sewerage and Drainage District Sewer Use Bylaw No. 299, 2007. Retrieved April 1, 2013, Retrieved from http://www.metrovancouver.org/boards/bylaws/Bylaws/GVSDD_Bylaw_299.pdf)

Based on the topography of Wesbrook Village and UBC Farm, several locations of rain garden are suggested. It can be located at the Nobel Park near UBC Farm, at the area of the pond proposed in option 1, or anywhere in Wesbrook Village while being splitted into several small rain gardens. There is a tank underneath the Nobel Park which is currently not being used. Thus, if rain garden is located at Wesbrook Village or it is allowed to replace the traditional garden at the Nobel Park with rain garden, overflow can be directly stored in this tank. During peak season, the flow of conserved water can be simply controlled by turning on the taps of the pipe system, and water will flow down to UBC Farm by gravity. On the other hand, if rain garden is located at the wetland in the Farm, a tank has to be built in UBC Farm, preferably under the Farm Centre which has a relatively higher altitude than the fields; conserved water will be flowing down by gravity as well.

Recent studies show that the area of the rain garden should be no less than 10-20% of upstream impervious area (Greater Vancouver Sewerage & Drainage District, 2007). The size of the rain garden is determined by the flow of runoff water, as well as the infiltration rate of the subsoil which also decides the structure of rain garden. It is preferable to use a 2-year 24-hour storm event by continuous flow modeling to precisely calculate the suitable size for the rain garden.

Previous study done by UBC students has shown that, for rain gardens located near UBC SUB with total area of 212.06m^2 and depth of 450-600mm, the minimum implementation cost will be $12,866 and average annual maintenance cost will be $2,500 (Lam et al., 2011). Thus, assuming the same soil structure, in order to construct a rain garden with similar depth near the UBC Farm, the minimum capital cost will be approximately \$61/m^2 and the maintenance fee will be \$12/m^2.

2.3 Rooftop Water Harvesting System

Rooftop Water Harvesting System is based on a 4-step water treatment which includes collection, filtration, disinfection and storage. Fig 2.3-1 shows a simple 4-step RHS for a house.

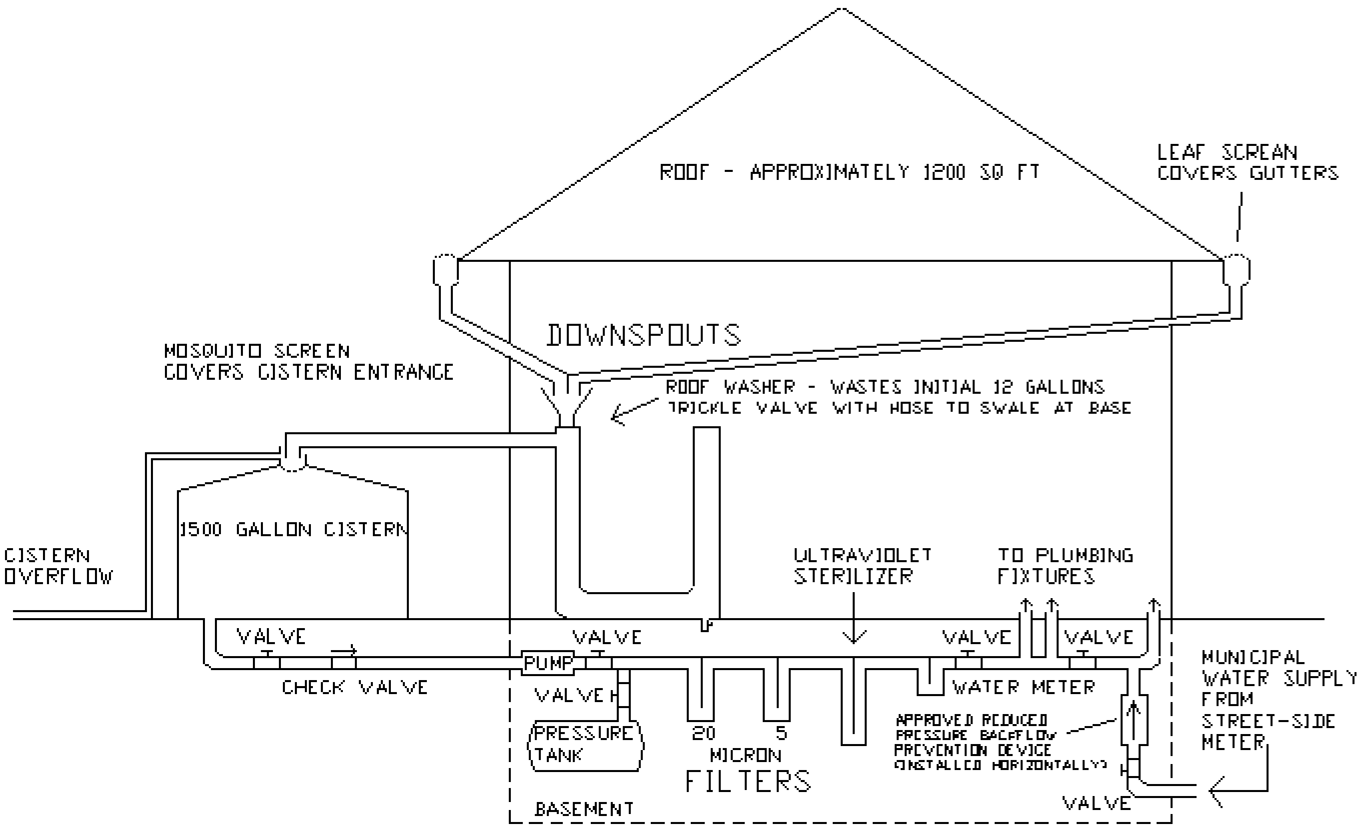

Fig 2.3-1 A Simple 4-step RHS for a House (Retrieved from rwh.in)

Rainwater is collected from the rooftop or any other top of a building, but the roof must be flat in order to have pools on the surface. All the water flows through gutters to enter the filtration system. The collecting system usually cost $1,500 per house. Since the major source of water is from stormwater in Wesbrook Village, the cost of having new collecting system can be saved.

In Fig 2.3-2 which demonstrates a typical filter, rainwater collected from rooftop goes through the Rainwater Inlet and thus becomes filtered water by passing through the Fine Mesh Filter, which in the end comes out from the Clean Rainwater Outlet. The trash part comes out from Stormwater Outlet and goes to waste. The stormwater filter can be built in city’s sewer system (vancouver.ca).

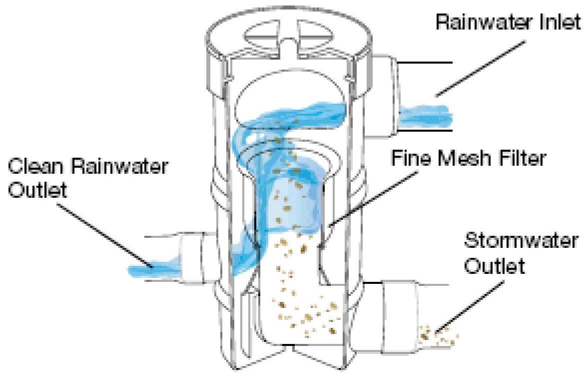

Fig 2.3-2 Diagram of the Filtration System (Retrieved from rainconcepts.com)

Next, the filtered water will be stored in a giant tank under the UBC Farm Center(example tank in Fig 2.3-4). During irrigation season, water stored in the tank will not be directly pumped to the field. It will pass through the disinfection system(Fig 2.3-3) from INLET port, and after being disinfected by UV light, it will be delivered to the user from OUTLET port. A typical UV disinfection product of water capacity 600 T/H costs $100,000 (from alibaba.com).

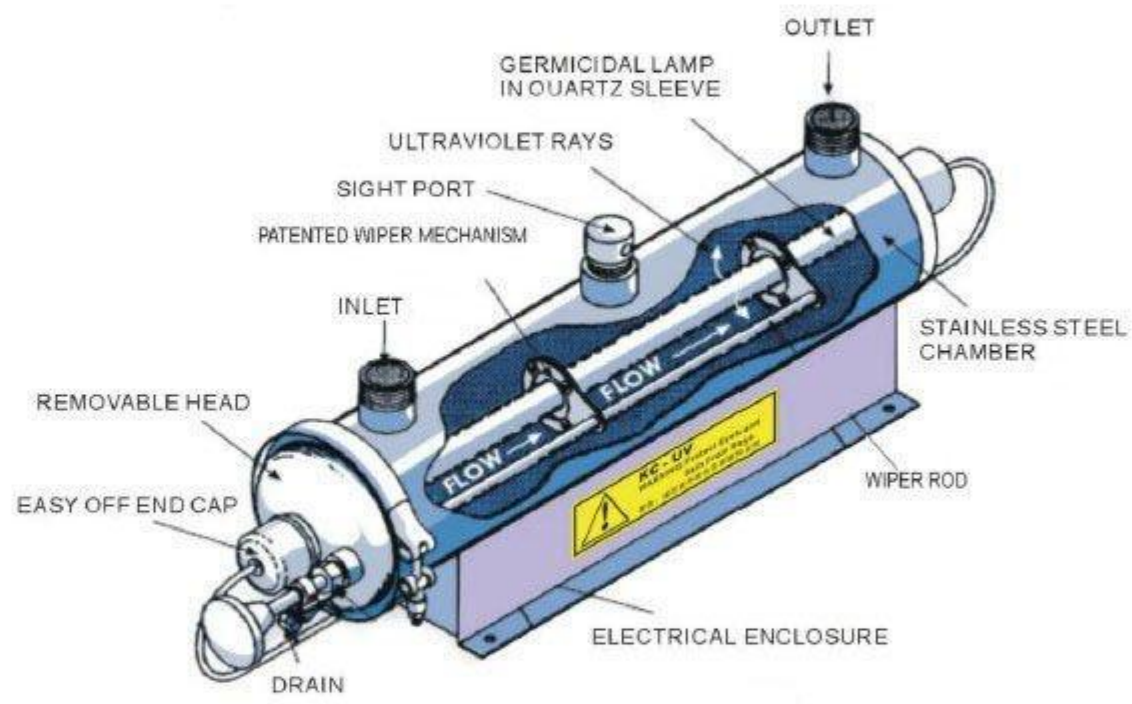

Fig 2.3-3 UV Disinfection System (Retrieved from alibaba.com)

Fig 2.3-4 Sample Storage Tank (Retrieved from capitolgreenroofs.groupsite.com)

Since the water consumption of UBC Farm between June and September is approximately 18221 cubic meter, we need a tank with minimum volume of 18,221 m^3 = 18,221,000 Liters. Since UBC Farm is going to construct a new Farm Centre, the constructing cost of tank will be combined with the new centre.

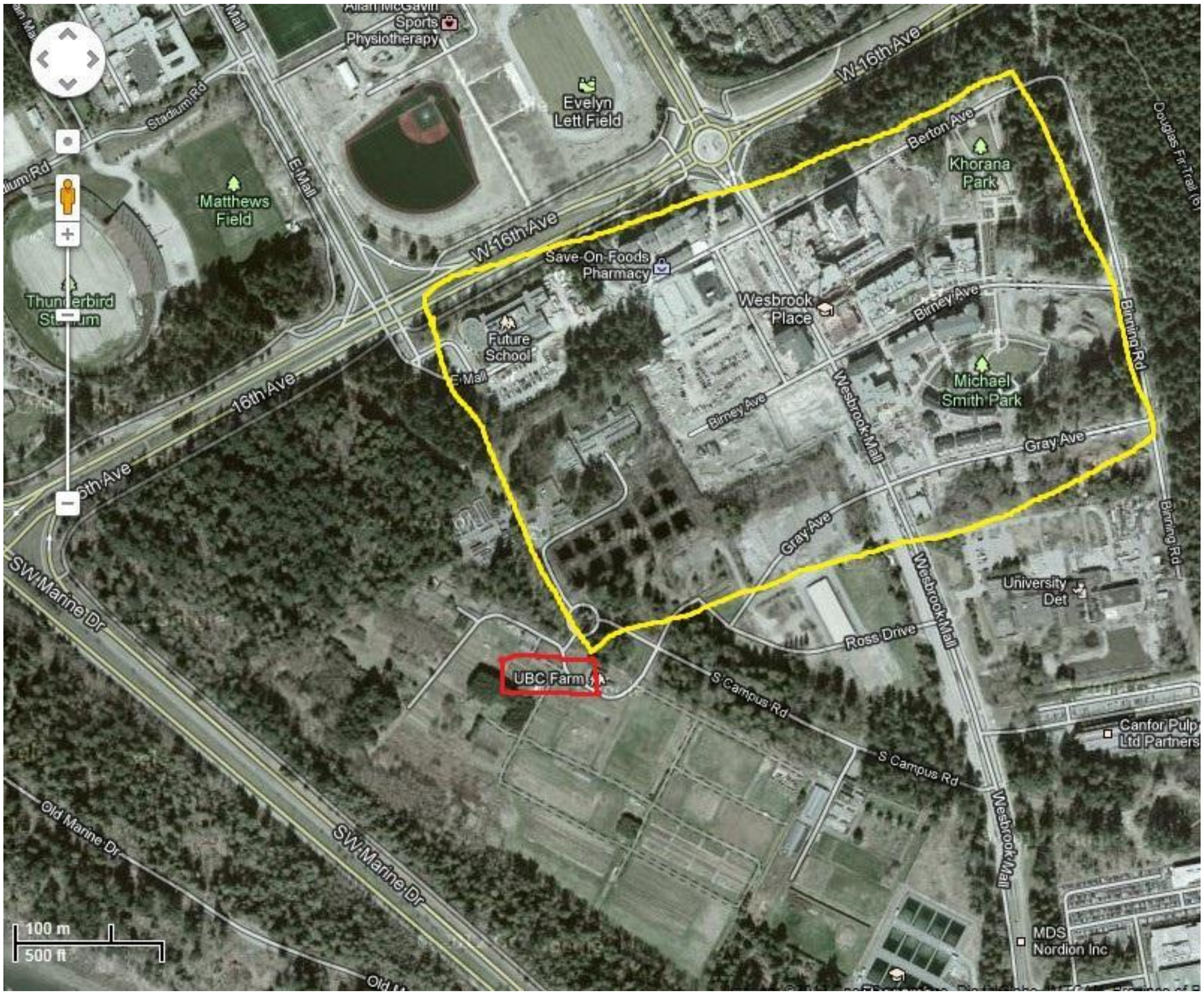

Fig 2.3-5 Maps of UBC South Campus (Retrieved from maps.google.ca)

Statistics shows that the average annual precipitation is 1166mm (Shown in Appendix 6.1). If the roof is flat, the area of rooftop needed to collect enough water will be approximately 15,627 square meter. According to Fig 2.3-5, the area of the Wesbrook Village is about 272,000 m^2. If RHS can be successfully implemented to the rooftop of the entire Wesbrook Village, the rainwater available for collection by RHS will be about 1166 L/m^2 * 272,000 m^2 = 317,152 m^3 per year, which is much more than the amount needed.

Thus, the cost for building a RHS with a tank of maximum capacity of 18,221,000 Liters is $1,822,100. A shipping and maintaining fee will also be added when the tank has been purchased.

3.0 Evaluation

In this part, in order to evaluate the level of overall sustainability of the three suggested solutions, each of them will be assessed in the following areas: economic, social, and ecological sustainability.

3.1 Economic Factors

By evaluating economic indicators, out of the 3 ideas, water pond is the most economically sustainable solution which will take 65 years to get the investment back. Due to the lower average capital cost per unit volume, with the same amount of money saved annually from water consumption for irrigation, the pond will give a shorter payback period and requires minimal maintenance cost during peak seasons. Rain garden is then ranked the second due to its limited capacity of storing water and the area restriction as compared to water pond. The cost of building a rain garden is also largely varied due to its undetermined size and location. In contrast, the RHS solution has the highest construction cost to store the amount of water required by UBC Farm. Even the cost of RHS only consists the cost of its tank (may be lower if the business is dealt with local company), pipe and UV sterilizer, the payback time is estimated to be 242 years. Moreover, the lifespan of the material is less than 100 years (Rainwater Harvesting 101). Thus, the cost for RHS is relatively expensive and unreasonable as compared to the other two. (Sample calculation of economic cost for the three solutions is attached in appendix.)

3.2 Social Factors

The implementation of stormwater catchment and filtration system demonstrates UBC's initiative and responsibility on achieving sustainability. Thus, it helps to raise community's awareness and to promote the idea of sustainability in the society. It also provides more research opportunities for staff and students to study how technology can be applied and improved to achieve better sustainability in the daily life. Furthermore, the implementation of the system helps to create potential students' job and volunteering opportunities for maintenance.

Among the three suggested options, rain garden obtains the highest ranking in social aspect, since both pond and rooftop harvesting system are bounded within UBC Farm and thus their social benefits are relatively minimal besides the ones being discussed above. Meanwhile for the rain garden solution, since it brings plantation to the area around UBC Farm, it creates a beautiful vegetated place for relaxation and enjoyment at Wesbrook Village, which helps to improve the standard of living of neighbourhood residence. However, due to the need of changing surface infrastructure and building construction at Wesbrook Village, UBC Farm has to seek formal approval from Wesbrook residence before the construction can be started. This will then be the drawback of the rain garden solution and if it is denied, the entire plan has to be stopped.

3.3 Ecological Factors

Out of the three systems, the ecological effect is more obvious in two of the systems: the water pond system and the rain garden system. Both systems use a lot of vegetation for the purpose of stabilization and filtration. In the pond, common pond plants are used at the shore because the complex roots can prevent runoff and disruption of the pond structure(Stevens, 2002). In addition, these roots act as a natural filtration system that filters out the possible toxic materials as stormwater flow from high elevation area (Sound Native Plants, 2001). However, the increased vegetation might alter the habitat of some local species, which will then be a negative impact of the system. A thorough survey of local habitat species and a habitat test should be taken before starting the project in order to avoid disturbing any endangered species. In contrast, the RHS has less direct effect to the ecosystem, because most operations were done by artificial devices near urban area or underground.

On the other hand, using these stormwater catchment systems also reduces the water consumption from Metro Vancouver. Efficiently collecting precipitation and runoff from the natural environment prevents wasting funding and resources. All the three systems achieve a 100% cost reduction on water consumption for irrigation during peak season.

4.0 Conclusion

Through investigating the triple bottom line assessment on the three systems, both positive and negative effects are clearly stated. The pond solution has the lowest cost and the shortest period of payback among the three, while the rain garden option gives the most social benefits but is also facing a high risk to be denied by Wesbrook community due to the huge construction required outside UBC Farm. The RHS solution requires relatively large amount of investment and an extremely long period of payback, fails to catch stormwater runoff but only rainwater directly from the sky, and has no significant benefits in social aspect. Thus, since the pond solution has outstanding feature in economic aspect and no significant drawbacks in social and ecological aspects, it is suggested that the implementation of a water pond at the wetland in UBC Farm and the use of ecosystem for filtration would be the best solution in this case. However, a habitat test has to be conducted prior to the start of construction, and in order to shorten the period of payback, additional funding such as university financial support and sponsorship is required.

5.0 Reference

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6.0 Appendix: SAMPLE CALCULATIONS

6.1 Precipitation

The annual average precipitation in Vancouver as shown in Fig 6.1-1:

Monthly Averages for
Vancouver, Canada
[English | Metric]

Monthly Averages | Table Display | Graph Display

Month	Avg. High	Avg. Low	Mean	Avg. Precip	Record High	Record Low
Jan	6°C	0°C	3°C	149.9 mm	N/A°C (N/A)	N/A°C (N/A)
Feb	8°C	1°C	4°C	124.5 mm	N/A°C (N/A)	N/A°C (N/A)
Mar	9°C	2°C	6°C	109.2 mm	N/A°C (N/A)	N/A°C (N/A)
Apr	12°C	4°C	9°C	76.2 mm	N/A°C (N/A)	N/A°C (N/A)
May	16°C	8°C	12°C	61.0 mm	N/A°C (N/A)	N/A°C (N/A)
Jun	19°C	11°C	15°C	45.7 mm	N/A°C (N/A)	N/A°C (N/A)
Jul	22°C	12°C	17°C	35.6 mm	N/A°C (N/A)	N/A°C (N/A)
Aug	22°C	13°C	17°C	38.1 mm	N/A°C (N/A)	N/A°C (N/A)
Sep	18°C	10°C	14°C	63.5 mm	N/A°C (N/A)	N/A°C (N/A)
Oct	13°C	6°C	10°C	114.3 mm	N/A°C (N/A)	N/A°C (N/A)
Nov	9°C	3°C	6°C	170.2 mm	N/A°C (N/A)	N/A°C (N/A)
Dec	6°C	1°C	3°C	177.8 mm	N/A°C (N/A)	N/A°C (N/A)

Vancouver, Canada Weather Facts

Fig 6.1-1: Monthly average precipitation (Monthly Weather for Vancouver, Canada., (2012). Retrieved from http://www.weather.com/weather/wxclimatology/monthly/CAXX0518)

149.9 mm + 124.5 mm +109.2 mm + 76.2 mm + 61.0mm + 45.7 mm + 35.6 mm +38.1mm +

+ 63.5 mm + 114.3 mm + 170.2 mm + 177.8 mm = 1166 mm

Unit conversion:

1 precipitation unit (mm) = 1 mm/(area measuring)

6.2 Wesbrook Village

Area:

~400 m x 680 m = 272,000 m^2

Stormwater available:

272,000 m^2 x 1166 mm = 317,152 m^3

6.3 Water Pond

Volume of water pond:

Area used: 100 m x 50 m = 5,000 m^2 (from Fig 2.1-1)

Designed depth: 4 m.

Total Volume of pond: 5,000 m^2 x 4 m = 20,000 m^3

Assume the pond holds precipitation and runoff water from the pond and the area of 30m around its radius.

The area holding stormwater will be (100 m + 30 m + 30 m) x (50 m +30 m +30 m)
= 176,000 m^2

The amount of water annually generated is:

176,000 m^2 x 1.166 m (precipitation) = 20,512.6 m^3/year

Total saving of water:

water generated by Water Pond 20,512.6 m^3 > 18,221 m^3 consumption by Farm during peak season. (The excess 2,000m^3 of water may be lost due to evaporation.)

Cost reduction = 100%

Construction cost:

\$53 /m^3 (Stormwater Management) x 20,000 m^3 = \$1,060,000

Payback years:

Construction cost / Annual saving = \$1,060,000 / \$16,344 per year ≅ 65 years

Approximated average capital cost = \$1,060,000 / 5,000 = \$212/m^2 with a depth of 4m

6.4 Rain Garden

From previous study done by UBC students,

estimated capital cost = \$61/m^2 with a depth of 450-600mm

estimated maintenance cost = \$12/m^2

Since the rain garden is planned to get stormwater runoff from the entire Wesbrook Village which has the area of 272,000 m^2, it should be able to provide enough water for irrigation during peak season. Thus, the cost reduction on water consumption should be 100% in this case.

6.5 Water Harvesting System

Tank price:

18,221,000 Liters x \$0.1/L (alibaba.com) = \$1,822,100

Tank after shipping:

\$1,822,100 x 2 (Rainwater Harvesting) = \$3,644,200

Cost for steel pipe size 3 (Stormwater Management):

Assuming needs 400m pipes, \$524(Stormwater Management)/m x 400 m = \$209,600

Total system cost:

\$3,644,200 + \$100,000 + \$209,600 = \$3,953,800

Energy cost(Stormwater Management):

Assume using a 10 Hp pump

Cost is approx. \$0.07/kWh (based off of BC Hydro Residential Rates)

10 [Hp]*746 [Watts/Hp]*0.001 [KW/W]*0.06 [\$/kWh] = ~\$0.5/hr

Cost reduction = 100%

Payback years:

Construction cost / Annual saving = \$3,953,800 / \$16344 ≅ 242 years