UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into South campus Storm Water Catchment and Filtration technology

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University of British Columbia

APSC 262

April 4, 2013

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Submitted April 4, 2013
APSC 262
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Abstract

The aim of the sustainability project is to introduce new practices, ideas, or designs, or to modify existing ones, with the end goal of creating a more sustainable campus environment. Our team is working on the implementation of a south campus storm water catchment and filtration technology on UBC campus; its main use would be to recycle storm water from Wesbrook Village for use in crop irrigation at the UBC farm.

Storm water is a term used to define water that originates from precipitation. Though plentiful in many developed nations, water is still a valuable commodity, and its proper use and management is fundamental in sustainable practice. As the scope of the project is large, we have decided to focus our attention towards filtration systems – three types in particular. To determine the potential risks and benefits of implementing a filtration technology, we use a triple-bottom-line analysis to investigate the social, environmental, and economic impacts of the three systems studied: Centre for Interactive Research on Sustainability (CIRS) water filtration unit, bioretention areas, and constructed wetlands.

There are three categories of storm water treatment systems – decentralized, semi-centralized, and centralized – differentiated by where filtration occurs after storm water catchment. Fully centralized systems filter the water at one main site, whereas decentralized systems filter immediately after catchment; semi-centralized systems are a mix of the two, and each of the filtration systems studied could be altered to fit into any one of these three categories.

The standard, technology-based water filtration unit at CIRS is the first system investigated. It has a relatively small footprint and has the least amount of social concerns among the systems studied – most of the concerns stem from people's misconception of storm water as waste water. The system at present is not economic given the low cost of water in the Lower Mainland, though another analysis may be done in the future given the current rising price of water. Overall, however, the system shows potential for use at the farm.

The second and third systems studied are bioretention areas and constructed wetlands respectively; both of these systems utilize natural means of filtration by using

environmental conditions, soil, and vegetation. Because of the use and construction of natural vegetation or habitats, minimal environmental disturbance is produced – the systems could also potentially improve environmental conditions by providing food and shelter for certain organisms. People have expressed concerns about the use of these natural systems, though; one downside would be the build-up of pollutants which are visible to the public. Having stated that, cost is another issue faced with these types of systems, given their inherently dynamic and situation-dependent nature. In documents from 2009, it was discovered that UBC already had plans to build natural filtration systems – CK Choi was the first building to do so. Thus, it is possible that the proper infrastructure is already in place. Ultimately, the use of natural filtration fits with the university's image of sustainability and advancement, so further research on these systems is recommended.

Having examined three different treatment systems and using the information we have obtained, we could conclude that a centralized system would be the best choice as the infrastructure for water catchment is already in place in Wesbrook. Though the CIRS system had greater social acceptance, natural filtration is likely more environmentally sustainable in the long-term. All three systems studied have their benefits and drawbacks, and no single system was deemed to be significantly better than the others. We recommend that further studies be done in the future to reach a conclusive decision on the most appropriate filtration system for crop irrigation at the UBC farm.

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2 Introduction

The UBC farm has requested that a feasibility study be conducted to determine if a water catchment and filtration system could be used to capture and treat the storm water currently sent to sewer in Wesbrook Village for use as irrigation at the farm. Our group has undertaken a feasibility study of three different filtration methods that will each use the Wesbrook Village storm water sewer infrastructure as a catchment system. A triple bottom line assessment of the CIRS storm water system, Bioretention areas and Construction Wetlands has been conducted in order to gain a strong understanding of the positive and negative implications of using these various types of filtration methods. The following report outlines the result of our analysis.

List of Illustrations

Glossary

coliform:	bacterial family whose presence in water indicates fecal pollution.
filtration:	removal of solid pollutants (chemical, particulate, organic) by passing a fluid through a medium or membrane. This can be a forced or natural process.
hydrocarbons:	organic compound found mostly in petroleum products (crude oil).
living laboratory:	a UBC initiative to use the UBC campus as a testing-ground for new environmental, social and economic practices or technologies.
storm water:	rain water that has flowed across impervious urban surfaces and been collected into a holding or transportation system. Generally, stormwater has a lower pollutant load than wastewater. A more general description exists, but the given definition is used for this report.
sustainability:	ability to persevere indefinitely in time without major change (eg: in resource consumption).
triple bottom line analysis:	project analysis involving assessments of the economic, environmental and social impacts the project may have.
waste water:	water that has been previously used (by humans) for some purpose, for example bath or toilet water.

List of Abbreviations

UBC: University of British Columbia

CIRS: Center for Advanced Research on Sustainability

MSR: Municipal Sewage Regulation

UV: Ultraviolet

3 Introduction to Storm Water Treatment Systems

3.1 Types of Storm Water Treatment Systems

This section will consider three general types of storm water treatment systems: decentralized, semi-centralized and centralized storm water treatment systems. These treatment systems specifically correspond to compact systems, filter systems and sedimentation systems respectively. Each of these types of systems is examined based on their suitability for this project. By conducting a triple bottom line assessment of their feasibilities in Wesbrook Village, we evaluate their respective economic, environmental and social impacts. Specific examples of these systems are discussed in subsequent sections of the report.

3.2 Background

Decentralized, semi-centralized and centralized storm water treatment systems do not describe a particular treatment processes but rather differentiate themselves through the location of the filtration device within the overall discharge system. A decentralized system consists of immediate filtration as soon as water enters the system. Typical examples of decentralized systems include gutter systems and shaft systems. Semi-centralized systems consist of drainage pipes that collect water discharge and direct it through a common treatment system, while taking care to isolate polluted sources from unpolluted sources. Examples of semi-centralized systems include water drainage from road surfaces. Centralized systems channel all water flow to a common water treatment system regardless of their source. Centralized systems may consist of a mixed sewage and storm water system but this is not the case in Wesbrook Village.

Depending on the purpose of the treated storm water, one system may be more favorable than the others. Many storm water treatment systems are centralized systems by nature. Because centralized systems simply divert all flow towards a shared processing unit, the liability of treating water rests solely on the single filtration device. Such systems usually have more sophisticated designs, which remove a diverse range of pollutants. Alternatively, decentralized systems may be favored in cases where there is a need to separate treatable storm water from waste water such as sewage. A truly decentralized system would require a micro treatment system at every intake point. This reduces the need for a single complicated treatment process at the end. On the other hand, semi-centralized systems exhibit a balance between decentralized and centralized systems.

3.3 Economic Analysis

Using figures from Stantec's 2012 report on UBC Irrigation, UBC paid \$0.68 - \$0.85 dollars/M^3 of water from Metro Vancouver. The current model of irrigation at UBC requires UBC Utilities to purchase 4 million cubic meters of water, supplied from the Capilano Reservoir in North Vancouver. Since the climate along the Southern BC Coast is fairly rainy apart from the summer, irrigation requirements are only at about 15-30 cm per year.

In 2012, the UBC Farm consumed a total of $22794 m^3$ of water. At the mean water cost of $\$0.765/m^3$, this translates into an annual cost of \$17437.41. While the consumption levels per year will vary, this provides a good estimate of current irrigation costs.

The installation of any treatment system will incur an upfront cost and a maintenance cost. Installation of a decentralized system could cost between \$10000 and \$20000, with construction costs ranging from \$10000 to \$50000. Once installed, the operating costs would be between \$2000 and \$3000 per year.

3.4 Environmental Impacts

The current model of irrigation at UBC Farm carries a significant footprint. Water must be first transported from Capilano Reservoir in North Vancouver to campus, before it is redistributed. Any waste water, including storm water, is channeled to the Iona Regional Wastewater Treatment Plant in Richmond.

With a storm water treatment system established, locally collected storm water can be directly processed and used for irrigation to sustain a local farm. With a circuitous transport problem resolved, the environment impact of such a system lies within the treatment system itself.

3.5 Social Impacts

UBC Farm currently consumes potable water for irrigation. While reclaimed storm water may not need to meet the same standard, it does have to abide by the minimal safety regulations in place. Under the provincial Environmental Management Act – Municipal Sewage Regulation (MSR) in Appendix A, there are two categories of irrigable water: Category 1 for Unrestricted Public Access and Category 2 for Restricted Public Access. Category 1 includes the use of reclaimed water to irrigate food crops that are eaten raw, crop cooling and orchards. Category 2 covers irrigation for commercially processed food crops, fodder and fibre. The UBC Farm will probably require Category 1 water. This means that there must be secondary treatment, chemical addition, filtration, disinfection and emergency storage. The pH of the water must fall strictly between 6 and 9. pH levels can be corrected by adding trace levels of calcium hydroxide (lime) or carbon dioxide. Additionally, there must be less than 10mg/L biochemical oxygen demand and less than 2.2/100mL concentration of coliform.

The establishment of a storm water treatment process in Wesbrook Village to irrigate the UBC Farm will bring about social impacts on two main parties: the Wesbrook Village residents and the regular patrons of the UBC Farm.

To inquire more about reaction from Wesbrook Village residents, our team interviewed Ralph Wells, the Sustainability Manager of Wesbrook Place. Mr. Wells noted that neighbourhood residents have been active in voicing their opinion in the past when new projects had taken place nearby. Some of the most concerning issues include higher noise levels and negative visual impacts, which may affect their livability. At the same time, Wesbrook Village residents understand the importance of sustainability and will support measures to improve it if their concerns are properly addressed.

Our team also gathered feedback from patrons of the UBC Farm to determine whether or not they will support a storm water irrigation system. This involved hosting a short survey, in which we investigated consumer response to such an initiative. The results of the survey indicates that 65% of respondents recognized the environmental benefits of the project while 60% of respondents will continue to buy the farm's produce, knowing that the filtered storm water will meet agricultural regulations.

4 CIRS Storm Water Filtration Unit

4.1 Background

UBC's Center For Interactive Research on Sustainability (CIRS) building on campus is an excellent sustainability practice model with many state of the art technologies used to ensure the building is both environmentally and socially sustainable. The CIRS building is equipped with a centralized water catchment and filtration system that provides both usable wastewater as well as drinkable quality water to the building. A triple bottom line assessment of this filtration system has been conducted to assess its suitability for use at the UBC Farm. In order to gain greater understanding of the CIRS water filtration and catchment system our team consulted Scott Yonkman, a Technical Specialist at the CIRS building. Mr. Yonkman gave us a detailed analysis of the systems triple bottom line impact.

4.2 System overview

The CIRS water catchment and filtration system consists of a rainfall catchment compatible roof that funnels the rainwater that falls onto the roof into a raw water tank that has been called the CISTERN. From the CISTERN the water is injected into a sand filter then through both a 5 Micron Filter and an Activated Carbon Filter. These filters remove the solid particulate (Biological and Non- Biological) from the storm water. After the solid filtration process the water is pumped through a UV Disinfection Unit used to purify the water then a small amount of Chlorine (0.2-4.0 mg/L) is added to further ensure drinking water quality. Sodium Hypochlorite is also injected into the water to adjust the alkalinity as rainwater PH is around 4 and water regulations indicated drinking water must be between 6 and 9. The Filtration system at CIRS is designed to accommodate a water demand of 2,200 L/day. Maximum storage capacity for treated water is 80,000L with a building code minimum of 50,000 L available for fire suppression. Full System blue print is available in Appendix B.

4.3 Environmental Assessment

The filtration system itself has a relatively small footprint and is located under the CIRS building. Mr.Yonkman was not able to show the filtration system itself but he has indicated that the sand filter, which is one of the larger components, has an approximate area of 60cm X 90cm. The system emits negligible vibration and sound while being run. Possible negative environmental impacts of the system are the systems 80,000L tank must be dumped for cleaning semi-annually which may strain the sewer system immediately adjacent to the systems location and waste 160,000 L of recovered water annually. Also Chlorine and Sodium Hypochlorite may be stored on site and must be properly contained to ensure it does not pose a risk of contaminating nearby areas. Sighting the interview with Mr. Yonkman it can be concluded that the negative environmental impact of this filtration system is minimal. The positive environmental impact of this system is it's ability to eliminate the water dependence of the building as it provides 2200 drinkable liters of recycled water per day (S.Yonkman, Personal Communication, March 13, 2013).

4.4 Social Assessment

The CIRS catchment and filtration system services potable water to the entire building including The Loop Café, which prepares sustainable and healthy food options for UBC students and visitors. The filtration system at CIRS was not yet operational at the time of this study so it is impossible to know how CIRS patrons will react to the water quality (taste, smell, etc) although by all accounts it is expected to be of the highest quality. During a visit to the CIRS building each patron of The Loop Café was interviewed to investigate how the general public felt about eating food prepared from recycled water as well as consuming recycled water. All thirty-two individuals that where interviewed had no negative comments in regards to consuming recycled storm water although almost all patrons wanted confirmation that storm water was not the same as sewage. An employee at The Loop Café was also interview and explained that even as prices are set slightly higher for the sustainable goods they offer patrons will purchase them without hesitation. From this study it can be concluded that the general public is receptive to the use of recycled storm water for consumption. The public was concerned about the use of recycled sewage for consumption and it appears that the term "storm water" must be clearly advertised as waste rainwater to avoid confusion that could lead to a social disinterest in drinkable recycled water. It must also be noted that many of the patrons of the CIRS building and The Loop Café that were interviewed are enrolled in courses that have increased there awareness and understanding of environmentally sustainable practice, this education may have led to a higher number of people having a positive outlook on recycled storm water. Patrons with less understanding of the environmental and social benefits of recycled water may be more hesitant to adopt a new water source as they are used to the municipal water system and trust how its quality is regulated.

4.5 Economic Assessment

The water rate quoted by Stantec is expected to increase to between 1.088 – 1.36 dollars per M^3 of water by 2014. At the current peak season water cost the CIRS water catchment and filtration infrastructure saves 682.55 dollars per year and at the 2014 peak season water price it will save 1092.08 dollars in utility cost per year. Table 1.1 shows the increase in cost savings per year through 2100, assuming a water cost increase of 0.17 cents per M^3. This linear cost increase is considered to be very conservative.

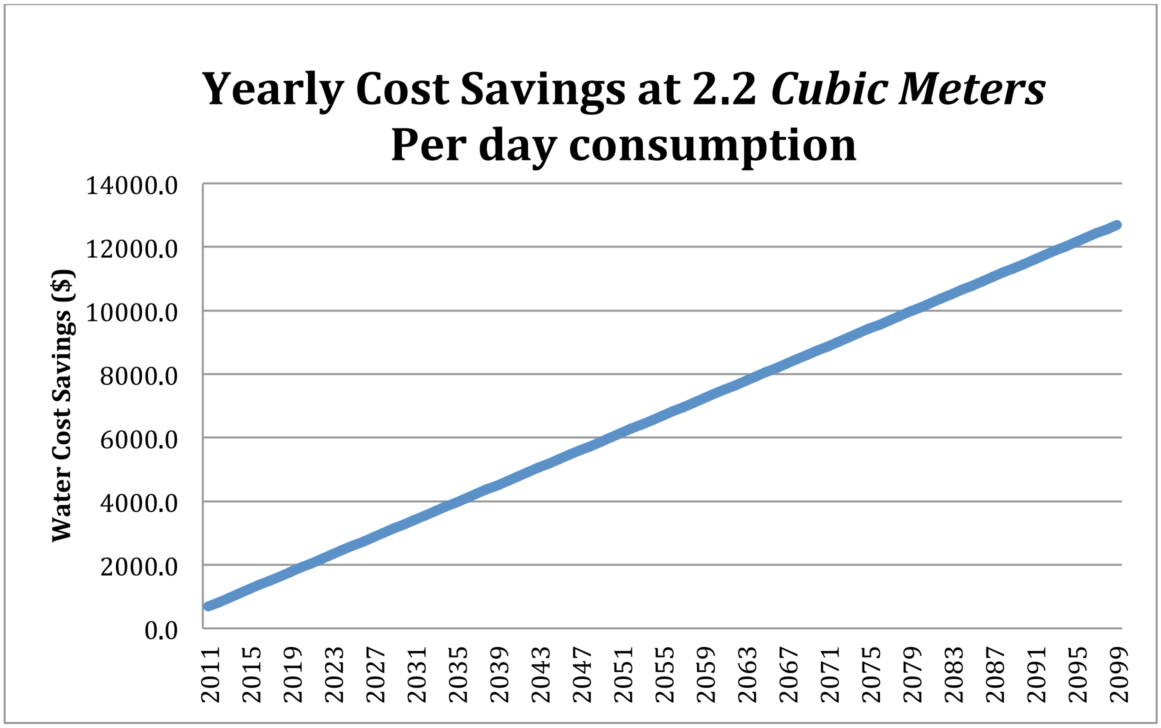

Figure 1 Yearly cost savings at 2.2 cubic meters per day

Mr.Yonkman explained that there would be significant maintenance costs for the system, as it requires multiple services and cleanings each year.

He estimates that due to this maintenance cost the system will not be economic in an area such as Vancouver due to the low cost of water. The calculations in this report suggest that due to increasing water costs this system may be economic in the distant future. The system has not yet been serviced as it is still in the testing and commissioning stages so service cost estimates were unavailable at the time of this report. No public domain information outlining the cost of the CIRS catchment and filtration system was available at the time of this report so a payback period could not be calculated.

4.6 Suitability for Use at The UBC Farm

Based on the triple bottom line assessment of the CIRS Catchment and filtration system and the expertise of Mr. Yonkman it has been concluded that the filtration system is suitable for use at the UBC Farm. The system has negligible negative environmental effect as it takes up very little space and is noise free. This system can also be scaled to support higher water volume need without increasing the footprint size substantially. If the water was to be used for the sole purpose of irrigation the use of Chlorine could be eliminated although Sodium Hypochlorite should still be used to control the water alkalinity. If category 1 water is required at the farm the system should include Chlorine. Based on the study of individual acceptance to the use of recycled water it appears that the UBC community is overwhelmingly in favor of recycled storm water as an alternative to the municipal water supply. The use of this system at the UBC Farm would help strengthen the farm's reputation as a sustainable and eco-friendly facility. It was found that patrons of The Loop Café where willing to pay a higher price for goods sold knowing that they were baked using sustainable methods. It may be feasible to increase the cost of goods grown at the farm without losing customers by advertising that a sustainable irrigation method was being employed. An increase in price could be put towards offsetting the initial capital cost of the filtration system. It is however unlikely that a filtration system at the farm will result in a cost savings as water prices at UBC are very low. (S.Yonkman, Personal Communication, March 13, 2013).

5 Natural Filtration

5.1 Background

To keep in line with UBC's 'living laboratory' approach to research and the Farm's aspirations to integrate ecological systems into sustainable communities, an investigate into a more natural filtration methods: the Constructed Wetland and the Bioretention Area was undertaken. A natural filtration system is a man-made geological feature that uses natural processes to purify water. Some of these processes include the sedimentation of particulates, the chemical decomposition of organic compounds (eg: certain pesticides), the sequestration of organic matter and hydrocarbons by plants and the removal of pathogens from the water ("Constructed Wetlands to Treat Wastewater," n.d.).

Realizing that another part of the issue of catching and filtering storm water run-off was the storage of filtered water the possibility of combining a Natural filtration method with an aquifer transfer and recharge strategy was considered. This experimental system has been used in Australia and involves the pumping of pre-filtered water into the aquifer below the filtration site. The injected water is then simultaneously stored for future retrieval and continued to be purified ("Recharge: turning stormwater," 2011). Upon consulting Dr. Roger Beckie of the department of earth, ocean and atmospheric sciences, we concluded that the neither of the two aquifers at UBC would be suitable for this purpose: the upper aquifer would leak water toward the UBC bluffs, and the lower one is likely too salty. Though there may be ways to make this technology work with the UBC campus geology, due to the risk of speculation the focus of this section will be natural filtration systems namely: Constructed Wetlands and Bioretention Areas.

5.2 Constructed Wetlands

5.2.1 System Overview

There are two types of constructed wetland. These two types are surface flow and subsurface flow wetlands. A surface flow wetland is perhaps what first springs to mind when one thinks of a wetland: a hybrid marsh-pond in which the water is directly in contact with the open atmosphere (see figure 2). A subsurface flow wetland, on the other hand, is one in which the water flows under some cover, usually a layer of rocks, and is not directly visible. This type of wetland generally does not need to be as large as a surface flow wetland, and though it prevents mosquito breeding it also loses the advantages of being exposed to sunlight ("Constructed Wetlands to Treat Wastewater," n.d.).

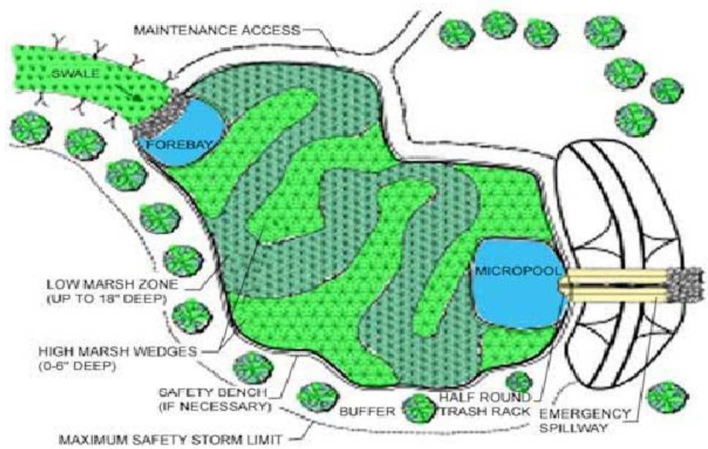

Figure 2 Example layout of a surface flow wetland

Vermont Department of Environmental Conservation,
http://www.vtwaterquality.org/stormwater/htm/sw_ConstructedWetland.htm

Both types of wetlands have similar filtration processes, namely biological, chemical and physical processes. The report "Constructed Wetlands to Treat Wastewater" describes each of these processes. Which are summarized in the following section. The biological processes rely on plants and microorganisms to break-up and remove nitrogen and carbon derivatives, and store these in the plant root systems. Chemically, organic compounds and certain pathogens can be neutralized by exposure to light and atmospheric constituents, and factors such as the pH of the water can affect the occurrence of many reactions. The most important physical processes are sedimentation and filtration, in which particulates suspended in the water succumb to gravity or are trapped when flowing through a medium like sand. Important to note is the fact that the effectiveness of these processes to clean the water is highly dependent on the time the water is retained in the wetland. Pollutant removal rates are generally high in a wetland, with very high removal rates of oil/grease and suspended solids ("Constructed Wetlands," n.d.). Since the removal efficiency of different pollutants depends on the size and type of wetland, as well as the water retention time, a more detailed analysis should be conducted when these parameters are chosen.

Like most, filtration systems a constructed wetland requires maintenance to function at its maximum potential. The wetland plants and animals should be kept healthy and floating garbage should be removed occasionally. Also with prolonged sedimentation the ponds may lose depth, affecting treatment volume and efficiency. For this reason, potentially major maintenance (large removal of sediment) may sometimes be required.

Due to the almost infinitely customizable nature of a constructed wetland, it is very difficult to judge the costs and impacts one would have. For the purposes of this investigation, averages of values from various reports are used. If no values were found, a general indication is given so as to avoid complete misinformation.

5.2.2 Economic Assessment

Due to the endless possibilities of construction, it is difficult to determine the costs associated with the set-up and maintenance of a wetland. One estimate we have found has indicated costs of $100,000-240,000 per hectare (on average) of surface wetland created, and around $1,500 per hectare per year for maintenance ("Constructed Wetlands," n.d.). For the purposes of this investigation, the wetland is assumed to be 1 hectare in area (~2.47 acres) and capital investment assumed to be $170,000, the mean of the quoted values, though the actual cost may be higher or lower depending on size and location geology. Generally around UBC there exists a relatively thick, impermeable layer of glacial till below the topsoil (*Integrated Stormwater Management Review*, n.d.). Depending on the soil thickness at the chosen location, this could reduce construction costs as there would be no need to engineer a lining to prevent water leakage and infiltration into the aquifer.

In addition to the maintenance costs associated with keeping the wetland functional, there are major costs associated with meeting regulatory requirements: the water must be tested daily for Coliform during irrigation if the crops are to be eaten raw. The cost for this and other testing is estimated at $12,400 per year assuming a four month yearly irrigation period (Paderewski, n.d.).

Another potentially significant expenditure is purchasing and placing the vegetation to be used in the wetland. No clear estimate of this cost can be given without knowledge of the desired vegetation type and density, though the investment required could be reduced by growing plants locally (perhaps on the Farm or by the UBC Botanical Garden) both avoiding purchasing and transportation costs. Other costs include the decreased filtering efficiency and need for major maintenance as well as the loss of arable land.

With the costs outlined above in mind, and using the mean municipal water price of $\$0.765/m^3$ and average farm water consumption of 22794 m^3/yr, we have calculated a crude estimated payback period of approximately 48 years, assuming no major maintenance is required within that period.

$$\$170000 + \left(\frac{13900\$}{yr}\right)\times t = \left(22794\frac{m^3}{yr}\right)\left(\frac{0.765\$}{m^3}\right)\times t \quad , \quad t = 48.05\ years$$

Perhaps a more useful figure is the expected annual return of $3540 per year in water savings. Though this amount may appear non-negligible, it is a very rough estimate made on the only information available. The average maintenance costs could be significantly higher than those used here.

$$\left(22794\frac{m^3}{yr}\right)\left(\frac{0.765\$}{m^3}\right) - \left(\frac{13900\$}{yr}\right) \cong \frac{3537\$}{yr}$$

5.2.3 Suitability for Use at the UBC Farm

Overall, a constructed wetland is a viable option for stormwater filtration at the UBC Farm. Through the assessment outlined above, this option has been determined to be capable of producing considerable advantages with respect to the triple bottom line. Due to the lack of truly relevant information, however, both the positive and negative impacts in all categories can only be listed as 'potential' and cannot be accurately quantified.

We think that though the wetland can significantly improve the quality of polluted water, it is likely that additional filtration be needed to bring the water to irrigation quality standards. We are unsure as to how quickly pathogens in particular die out, and think that a final filtration step may be necessary to remove harmful organisms. Further research and field tests could however demonstrate this as unnecessary.

We believe that a combination of surface and subsurface wetlands should be used as each type offers different removal efficiencies for different pollutants. In addition to maximizing the removal rates of all pollutants, we feel this would help with aesthetics and social integration as the water could pass through preliminary filtration before becoming visible to the public. This means that the public would not witness the polluted entrance flow, nor would they see the project as polluting the environment: a wetland covered by a film of oil is unlikely to garner public support.

A small wetland already intermittently exists on the Farm. This indicates that its location is already appropriate for surface water storage and that building there could decrease construction costs. Other important aspects in determining the location of the wetland could include access and safety, filtered water storage, as well as the pre-existing irrigation infrastructure. The importance of each of these can be judged in a later investigation if interest in the constructed wetland filtration system continues.

5.3 Bioretention Area

5.3.1 System Overview

Another possible filtration technology we are investigating would be the use of bioretention areas (sustainabletechnologies), which could be easily incorporated into the existing structure and landscape of the many different planted areas throughout campus. They consist of shallow excavated areas filled with mulch, soil, and selected native vegetation. During large downpours, the water would flow towards the depression in the ground and be filtered through the mix of mulch, soil, and plant roots. Though the gathered water could be filtered once more by using treatment facilities, bioretention areas could function as standalone filters for some applications; in many cases, the water could be used for crop irrigation without requiring further treatment. Their ability to be seamlessly integrated into areas of vegetation would result in less disruption to the local residents and students, many of whom would probably not notice any changes to the existing structures after the system is implemented. Some might even find additional vegetation to be aesthetically appealing. Another option would be to implement a similar, but larger scale and more deliberate version of bioretention areas: rain gardens.

The use of natural foliage promotes greater harmony with nature and provides local wildlife with more living areas; the inclusion of vegetation along with local wildlife offers a visual glimpse of sustainability and could help promote and increase awareness of sustainable practices, thereby affecting social perception.

As suggested by (ene), vegetated filter strips and ponds could also be considered as design alternatives.

Though there are distinct differences, all of the systems mentioned are aesthetically pleasing and unobtrusive, and could be used to filter and/or redirect the flow of storm water, both of which are important aspects in a proper water catchment and filtration technology.

5.3.2 Economic Assessment

Many of the costs associated with a more synthetic filter have already been discussed in the section pertaining to the CIRS complex. The total cost of the chosen system, including capital, operating, maintenance, engineering, and contingency costs, could be vast and should be considered before any design is to be implemented (ene). All of these costs are dependent not only on the system chosen, but also on the scope of implementation. Questions which need to be asked to determine costs include the required water cleanliness and the size and location of the storm water vegetation areas. As our project group lacks all of the necessary information, values listed here are assumptions and approximations to be used as a general guideline.

Table 7.3 in Appendix C provides early 2000 cost estimates for capital construction. Table 7-2 and 7-3 in (environ) provides 1996 cost estimates for capital construction and maintenance respectively. Though the costs are outdated and are based on values in the other provinces of Canada, they are still valid as general guidelines for cost estimates.

Wesbrook Village is a hundred acres in size and possesses a storm water catchment system. From a 2009 document provided by the project stakeholder, UBC has plans to create two ponds and integrate bioretention areas into the South Campus area's streets. No information could be obtained as to whether or not these natural filtration areas have already been implemented, but if so, the basic infrastructure would be already in place. Therefore, assuming that these areas are planning to undergo, currently in, or have finished development, the costs to build and maintain these areas would already have been predicted beforehand. Thus, no additional costs are required for construction or maintenance provided that no additional bioretention areas are to be constructed (or pre-existing ones modified). To determine if the water quality is suitable for crop irrigation, regular water tests are required – the quality of water that is collected depends on the types of vegetation used, the volume of the water collected in a single area, and the state of the area where the water is collected. If the water quality is not suitable for use on the farm at UBC, then another filtration system would have to be set-up after the water has been collected – the filtration system used by the CIRS building is one option.

5.3.3 Suitability for Use at the UBC Farm

Natural filtrations have many benefits and could be integrated into the streets and landscapes. In order to determine how viable they are for crop irrigation at UBC, a triple bottom line analysis had been done. However, given the lack of information, no concrete decision could be reached in determining the best filtration system. However, assuming that the infrastructure is already in place or being planned for construction, it is likely that UBC has already planned out many of the required things for their construction and upkeep. In order to determine if the water collected is usable, regular water tests would be required. Should the water be unsuitable another filtration system could be used, such as the filtration system used in CIRS.

5.4 Environmental Assessment

The use of a Constructed Wetland or Bioretention Areas as a storm-water filtration system has several obvious environmental benefits when compared to other systems. Perhaps the most important of these benefits is that it is a largely natural solution which requires no injection of potentially harmful substances into the contaminated water. This means that in addition to the lower operating costs (no chemicals needed), the effective waste that must be removed from the system will contain fewer unnatural substances and might be more easily disposable, or even reusable. Another benefit is the possibility of leaving the surrounding environment in a better state than it was originally. New wildlife habitat could be created, enabling the (re)introduction of native species of plants and possibly animals to the region. It is difficult to accurately judge the volume of water filtered and amount of waste removed by the wetland as these largely depend on the size and type of wetland.

One possible negative impact on the environment is that heavy machinery and intensive resource consumption may be necessary during the construction and large maintenance operations performed on the wetland and Bioretention areas, the impacts of these operations can be mitigated by reducing the transportation of materials to and from the site. One method of doing this is to source local components, such as soil and plants, and locally rid wastes or reuse them. Another possible impact is the deforestation of a piece of the UBC Farm to create the space needed to construct the wetland. Like many of those considered in this section of the report though, the extent of this impact remains incalculable as it depends on the size and location of the natural filtration device.

5.5 Social Assessment

For the purpose of brevity, the public's perception of the use of storm-water will not be discussed in this section as it is very similar to that described for the CIRS filtration unit given that the quality standards are the same. In addition to the impacts of direct consumption and favourable opinion regarding the use of storm-water for irrigation purposes, the Constructed Wetland and Bioretention Areas provide numerous other social benefits. One of these benefits is that it would provide UBC and the Farm with another example of the living lab mentality and demonstrates their commitment toward their goals of sustainability. This could support the existing image of UBC as a progressive establishment and affirm the fact that the Farm is an integral part of the university and the community. Tied to this are the education opportunities that having a “natural” filtration device could bring forth. Farm programs such as plant-tours and bird-watching might be boosted by the increase in flora and fauna, while academic research on wetland ecosystems and Bioretention technology as well as the use of these as water filtration systems could be done on campus rather than elsewhere. Image and education aside, the use of natural filtration systems could simply be a unique feature on campus capable of serving as an attraction to the local population. This could increase awareness and community involvement in the Farm, and increase clientele or swell the ranks of volunteers.

One of the major drawbacks of having an open wetland is the concern with safety, particularly with children. Without appropriate barriers to prevent people from accidentally falling into the water, the public may see the wetland as a danger of drowning or otherwise injuring oneself. This danger does not exist with Bioretention Areas, as they do not host open water. Another drawback of the wetland could be that people would be put-off by areas of the wetland that look polluted, namely the flow entrance. Though the above issues do have solutions, they are worth considering and the costs for their solutions should be included in the budget for this project should a natural filtration method be considered as the filtration system.

6 Conclusion

This report has discussed the possibility of creating a stormwater catchment and filtration system around Wesbrook Village and the UBC Farm. Due to the large scope of such a project, the report has been limited to examining its filtration aspects. To do this, a general description of three filtration systems was given. It was found that a centralized system would likely be the most effective solution since much of the necessary transportation infrastructure already exists to support such a system. A triple bottom line assessment was then performed on each of the three filtration systems chosen: the CIRS system, the constructed wetland and the bio-retention areas. Keeping in consideration that little data was available from which to draw conclusions, it was found that no one system significantly outperformed the others. This was to be expected as any option for any project inherently has both positive and negative aspects. Generally, it was determined that the CIRS system had the upper hand in terms of social acceptance, as people felt more confident in the cleaning abilities of a purpose-built filter than that of natural systems. Environmentally, however, the natural systems seemed advantageous as they required no added chemicals and could even improve the surrounding landscape by providing new vegetation and animal habitat. No type of system could definitively be said to be more economically viable than the others as very little data relevant to the UBC Farm could be found.

As a result of a lack of data and varying strengths of different systems, we cannot recommend any filtration system in particular. We have outlined the potential social, environmental and economic impacts each system could have, and leave it to the reader to determine the one that best fits his/her needs and constraints. We recommend that more targeted research be done when a better idea of the desired system is known, and that professionals in the related fields be consulted as they have the necessary resources and connections to give information relevant to this specific project. Given that no option seems entirely economically viable at the moment and that there seems to be no urgent need for a stormwater filtration system, we also suggest pausing future project development to examine the true impacts of the CIRS system when it is finally running, or the filtering potential of wetlands and bio-retention areas if these are later developed by UBC.

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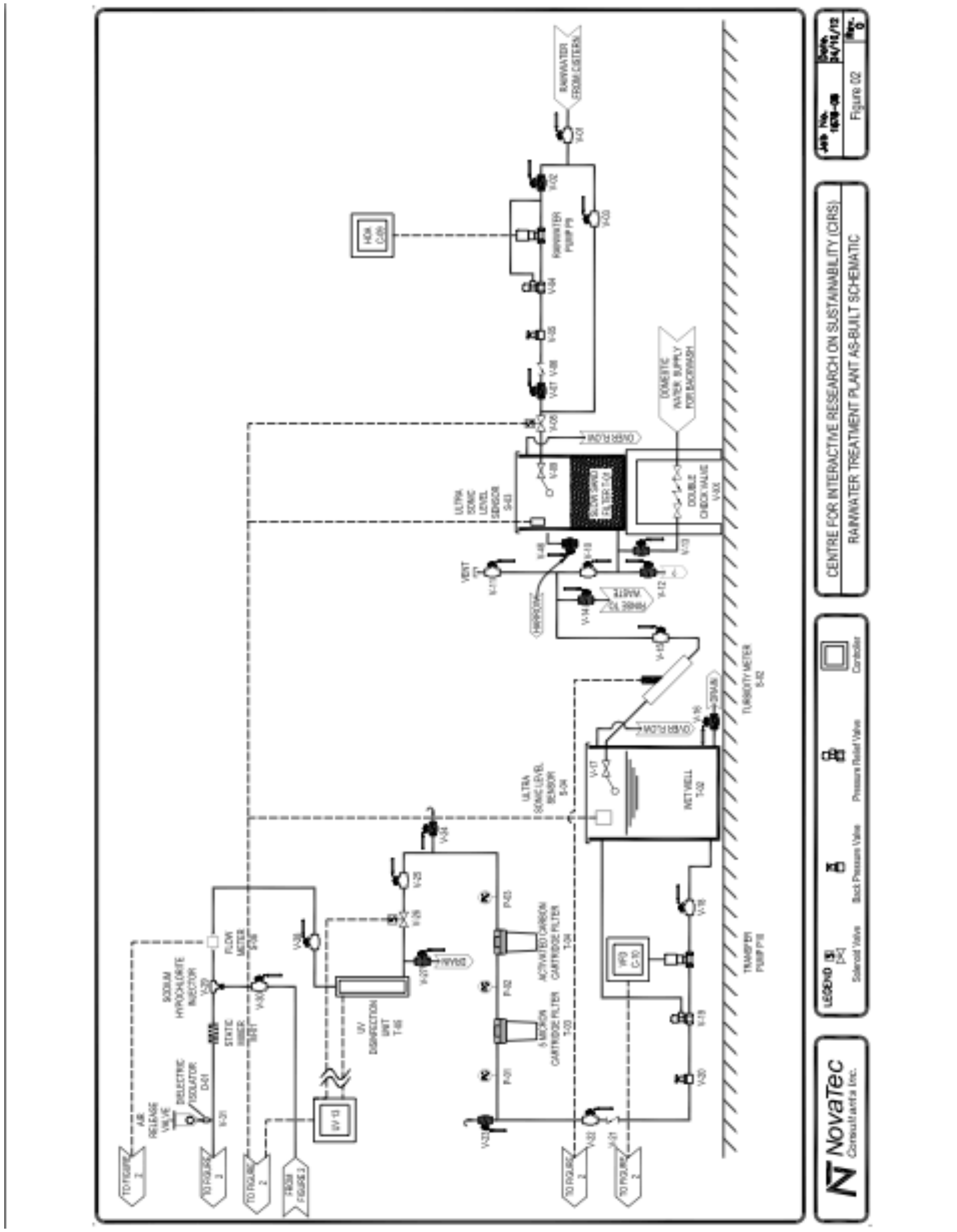
Appendix A

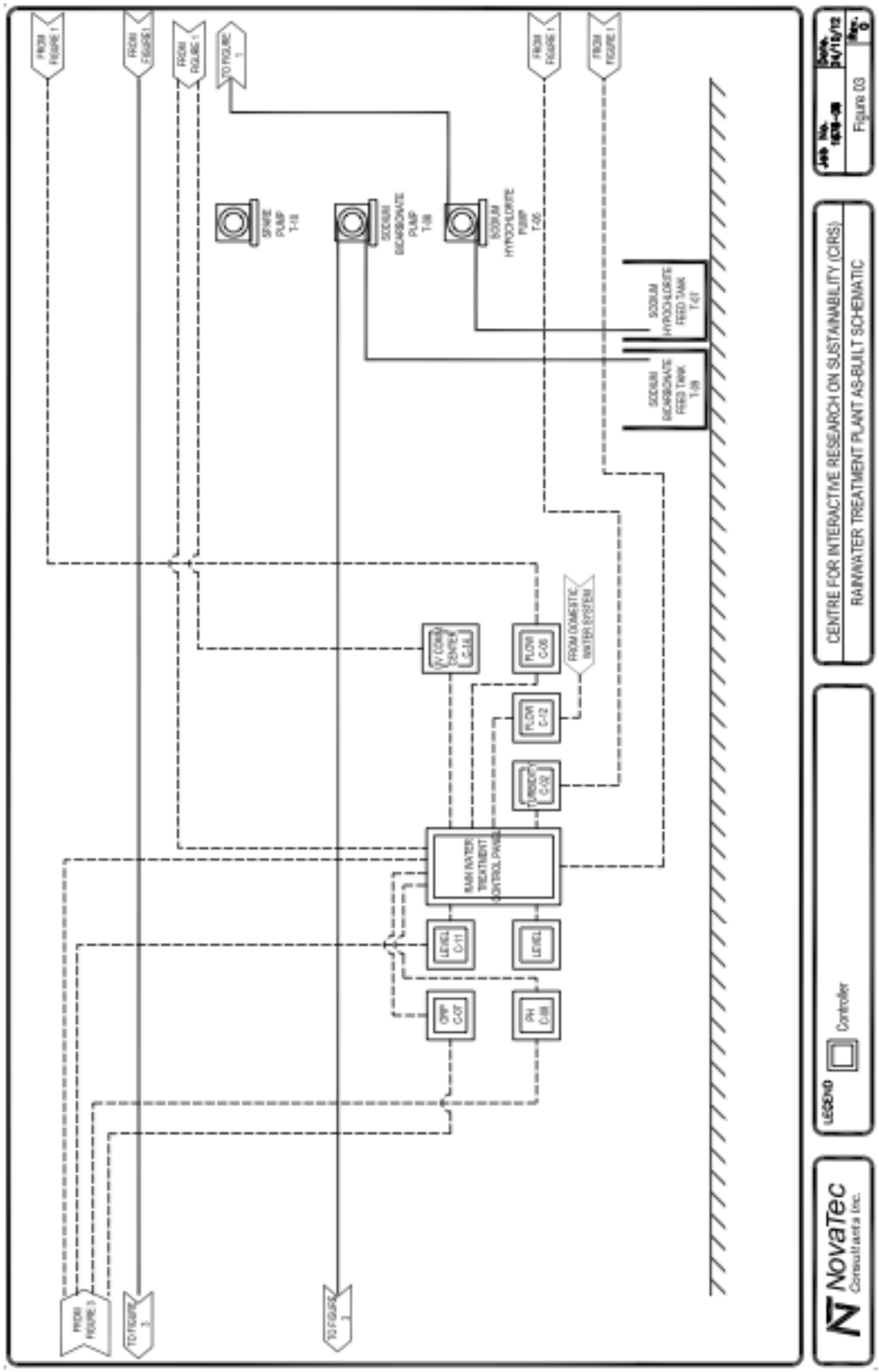
Table 1. Permitted uses for irrigation with reclaimed water

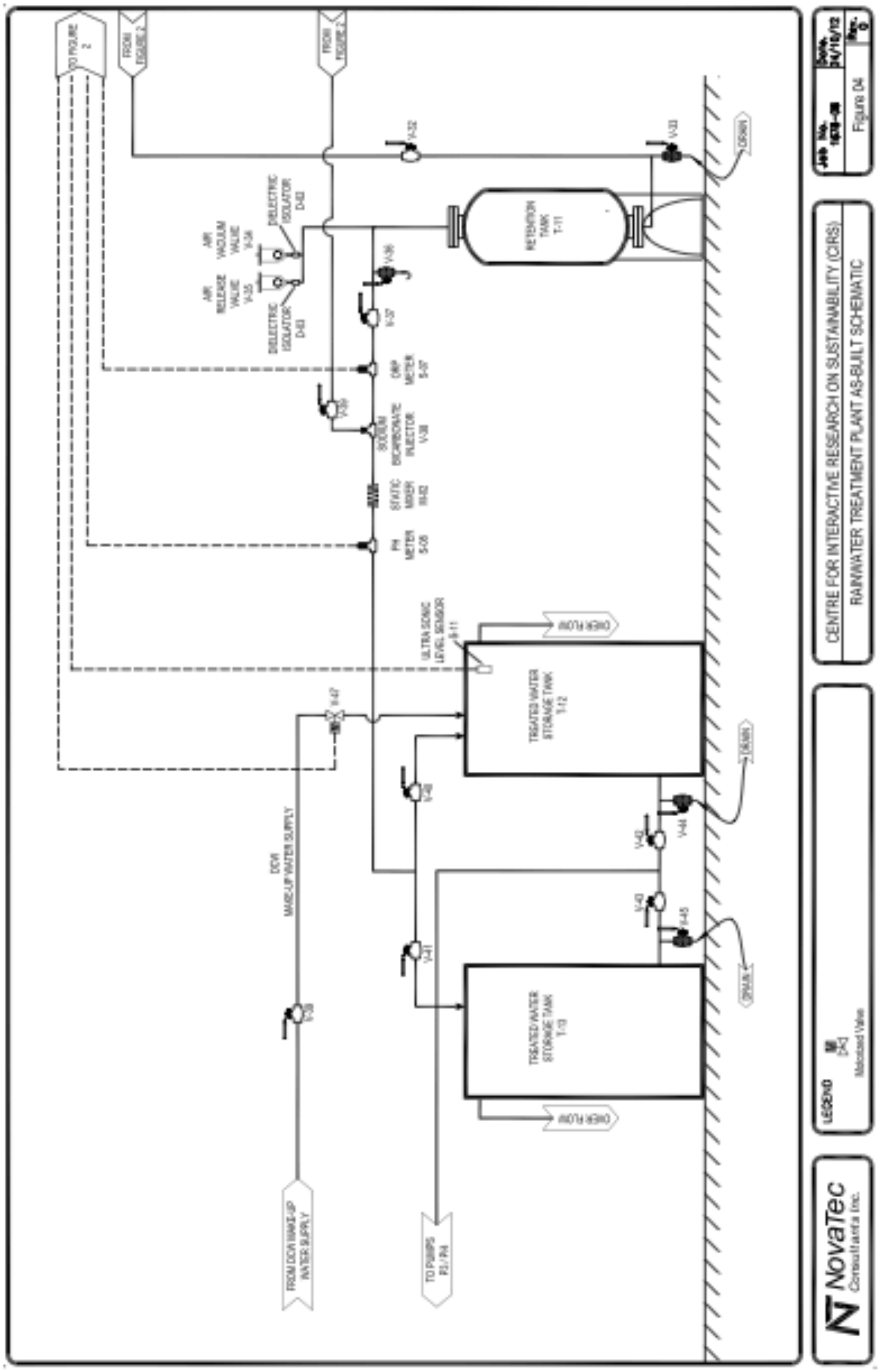
Category 1 – Unrestricted Public Access			
Permitted Uses for Irrigation	**Treatment Requirements**	**Effluent Quality Requirements**	**Monitoring Requirements**
Agriculture Food crops eaten raw Orchards and vineyards Seed crops Frost protection Crop cooling Pasture (no lag time for animal grazing) **Urban and Landscape** Parks Playgrounds Cemeteries Golf courses Road right of ways School grounds Residential lawns Landscape around buildings Greenbelts	Secondary Chemical Addition Filtration Disinfection Emergency Storage	pH = 6 – 9 $\leq$ 10 mg/L BOD_5 $\leq$ 2 NTU Number of fecal coliform organisms $\leq$ 2.2/100ml Provider must demonstrate that reclaimed water does not contain pathogens or parasites at levels that are of concern to health authorities. Levels for metal and nutrient concentrations are governed by crop limitations at various growth stages where applicable	pH – weekly BOD – weekly Turbidity – continuous Coliform – daily
Category 2 – Restricted Public Access			
Permitted Uses for Irrigation	**Treatment Requirements**	**Effluent Quality Requirements**	**Monitoring Requirements**
Agriculture Commercially processed food crops Trickle/drip for orchards and vineyards Fodder and fibre Nursery and sod farms Silviculture Pasture (with a 6 day lag time for milking animals and 3 days for other cattle grazing) Spring frost protection **Urban and Landscape** Parks Golf courses School grounds	Secondary Disinfection	pH = 6 – 9 $\leq$ 45 mg/L BOD_5 $\leq$ 45 mg/L TSS Number of fecal coliform organisms $\leq$ 200/100ml Levels for metal and nutrient concentrations are governed by crop limitations at various growth stages where applicable Setback from a potable well must be > 30 m. Spray drift must not exceed boundaries of property where reclaimed water is being applied and drift must not reach areas that are accessible to the public.	pH – weekly BOD – weekly TSS – daily Coliform – weekly

Water Use	Maximum Induced Turbidity - NTU or % of background	Maximum Induced Suspended Sediments - mg/L or % of background	Streambed Substrate Composition
Drinking Water - raw untreated	1 NTU when background is less than or equal to 5	No Guideline	No Guideline
Drinking Water - raw treated	5 NTU when background is less than or equal to 50 —— 10% when background is greater than 50	No Guideline	No Guideline
Recreation and Aesthetics	Maximum 50 NTU —— secchi disc visible at 1.2 m	No Guideline	No Guideline
Aquatic Life - fresh - marine - estuarine	8 NTU in 24 hours when background is less than or equal to 8 —— mean of 2 NTU in 30 days when background is less than or equal to 8	25 mg/L in 24 hours when background is less than or equal to 25 —— mean of 5 mg/L in 30 days when background is less than or equal to 25	fines not to exceed - 10% as less than 2mm - 19% as less than 3mm - 25% as less than 6.35mm - at salmonid spawning sites
Aquatic Life - fresh - marine - estuarine	8 NTU when background is between 8 and 80 —— 10% when background is greater than or equal to 80	25 mg/L when background is between 25 and 250 —— 10% when background is greater than or equal to 250	Geometric mean diameter not less than 12mm —— Fredle number not less than 5mm
Terrestrial Life - wildlife - livestock water - Irrigation Industrial	10 NTU when background is less than or equal to 50 —— 20% when background is greater than or equal to 50	20 mg/L when background is less than or equal to 100 —— 20% when background is greater than or equal to 100	No Guideline

Appendix B


CENTRE FOR INTERACTIVE RESEARCH ON SUSTAINABILITY (CIRS)
RAINWATER TREATMENT PLANT AS-BUILT SCHEMATIC
Figure 02
NovaTec
Consultants Inc.


CENTRE FOR INTERACTIVE RESEARCH ON SUSTAINABILITY (CIRS)
RAINWATER TREATMENT PLANT AS-BUILT SCHEMATIC
Figure 03
LEGEND
Controller
NovaTec
Consultants Inc.
SODIUM BICARBONATE FEED TANK
SODIUM HYPOCHLORITE FEED TANK
SPARE PUMP
RAIN WATER TREATMENT CONTROL PANEL
FROM DOMESTIC WATER SYSTEM


TO FIGURE 2
FROM FIGURE 2
FROM FIGURE 2
FROM DCW MAKE-UP WATER SUPPLY
DCW MAKE-UP WATER SUPPLY
TO PUMPS P3 / P4
AIR RELEASE VALVE V-35
AIR VACUUM VALVE V-34
DIELECTRIC ISOLATOR D-03
DIELECTRIC ISOLATOR D-02
PH METER S-06
STATIC MIXER
SODIUM BICARBONATE INJECTOR
DRP METER S-07
ULTRA SONIC LEVEL SENSOR
TREATED WATER STORAGE TANK T-13
TREATED WATER STORAGE TANK T-12
RETENTION TANK T-11
OVER FLOW
OVER FLOW
DRAIN
DRAIN
DRAIN
V-47
V-41
V-43
V-45
V-44
V-37
V-36
V-32
V-33
NovaTec Consultants Inc.
LEGEND
Motorized Valve
CENTRE FOR INTERACTIVE RESEARCH ON SUSTAINABILITY (CIRS)
RAINWATER TREATMENT PLANT AS-BUILT SCHEMATIC
Figure 04

Appendix C

Table 7-2 Typical Unit Costs for Capital Construction (1996)		
Type of Construction or Material	**Unit**	**Price**
Excavation (offsite disposal)	m^3	$10
Earthwork (cut and fill onsite)	m^3	$3
Erosion block/stone	m^2	$50
Concrete Outlet Structure	each	$5,500
Concrete Outlet Pipe (300 mm/600 mm/900 mm	m	$70/$170/$300
Observation Well (100 mm PVC)	each	$15
Riprap (450 mm)	m^2	$50
Perforated Pipe (100 mm, plastic)	m	$10
Perforated Riser Outlet Pipe (300 mm, plastic)	m	$90
Perforated Riser Outlet Trash Rack (400 CMP)	m	$100
Temporary Fencing (post and wire)	m	$15
Concrete (poured)	m^3	$600
Trash Rack (metal)	m^2	$100
Inverted Elbow Pipe	each	$300
Outlet Gate Valves (300 mm/600 mm)	each	$1,200/$4,800
Outlet Sluice Gates (300 mm/600 mm/900 mm)	each	$5,500/$8,000/$11,500
Clear Stone (gravel, 25 mm - 50 mm)	m^3	$35

Table 7-2 Typical Unit Costs for Capital Construction (1996)		
Type of Construction or Material	**Unit**	**Price**
Filter cloth	m^2	$1
Filter Material (sand)	m^3	$15
Structures	each	$50,000/facility
Monitoring Equipment	each	$20,000/facility
Sub-drainage System	ha	$25,000
Irrigation System	m^2	$2
Geomembrane Liner	m^2	$10 (dependent upon soil conditions
Seed and Topsoil	m^2	$2.50
Grass Sod and Topsoil	m^2	$4.50
Emergent and Submergent Fringe Vegetation	m^2	$12
Shoreline Fringe and Flood Fringe Vegetation	m^2	$12
Upland Vegetation	m^2	$5
Trees (Wooded Filter Strips)	m^2	$25

Table 7.3
Typical Unit Costs for Operations and Maintenance

Type of Maintenance	Unit	Ontario		City of Edmonton	
		Price	Maintenance Interval	Price	Maintenance Interval
Litter Removal	ha	$2,000	Every year	-	-
Grass Cutting	ha	$250	***	-	-
Weed Control	ha	$2,500	Every year	$2,400	1 to 3 times per year
Vegetation Maintenance (Aquatic/Shoreline Fringe)	ha	$3,500	Every 5 years	-	-
Vegetation Maintenance (Upland/Flood Fringe)	ha	$1,000	Every 5 years	-	-
Sediment Removal (front end loader)	m^3	$15	*	-	-
Sediment Removal (vacuum truck - catch basin, filter strip, grassed swale)	m^3	$120	*	-	-
Sediment Removal (manual - oil/grit separator, sand filter)	m^3	$120	*	-	-
Sediment testing (lab tests for quality)	each	$265	*	-	-
Sediment Disposal (off-site landfill)	m^3	$300	*	-	-
Sediment Disposal and Landscaping (on-site)	m^3	$5	*	-	-
Inspection (inlet/outlet etc.)	each	$100	Every year	-	Early spring and every visit to pond
Pervious Pipe Cleanout (flushing)	m	$1	Every 5 years	-	-
Pervious Pipe Cleaning (Radial Washing)	m	$2	Every 5 years	-	-
Seasonal Operation of Infiltration System By-pass	**	$100	Twice per year	-	-
Infiltration Basin Floor Tilling and Re-vegetation	ha	$2,800	Every 2 years	-	-
Water Sampling	each	-	-	-	Monthly (Spring to Fall only)
Remove Shoreline Debris	each	-	-	-	Twice per month
Remove Floating Debris	each	-	-	-	As required
Check Depth of Sediment	each	-	-	-	Every 2 to 5 years
Routine Maintenance	each	-	-	$3,800	-
Vegetation Harvesting	ha	-	-	-	Once per year (Late Fall)

* frequency of sediment removal depends on SWMP type and volume
** dependent on filtration facility (based on centralized facility) Seasonal operation of a system with many inlets (ie pervious pipe system) would be more expensive
*** no grass cutting or minimal frequency of grass cutting (once or twice per year)

Source: Ontario Ministry of Environment and Energy; SWMP Planning and Design Manual, 1994
Personal correspondence from City of Edmonton, 1996