UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Wastewater Treatment at UBC Point Grey Campus

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Phase 5: Synthesis Report

Solar Aquatic System in Bear River, Nova Scotia

(Source: http://www.collectionscanada.gc.ca/eppp-archive/100/200/301/ic/can_digital_collections/west_nova/bearriver.html)

Constructed Wetlands in Shanghai, China

(Source: http://www.pflanzenklaeranlagen.de/englisch/index.html)

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INTRODUCTION

UBC as a "Living Laboratory" for Sustainability

The University of British Columbia (UBC) is a renowned academic institute, acknowledged for its excellence in research, education, and forward thought. Located west of Vancouver, UBC is situated on the Point Grey Peninsula surrounded by ocean and forest parkland. Recently sustainability has come to the forefront at UBC, and has been recognized in UBC's new 2010 strategic plan "Place and Promise". Therefore, UBC has taken a new approach and incorporated sustainability by linking "academic, research and operational sustainability to become a "Living Laboratory" (The UBC plan) and as a result have taken sustainability to a whole new level.

The new "Living Laboratory" concept involves "cost-neutral ways to include sustainability teaching and learning in and across all disciplines, and encouraging students, staff, and faculty to carry daily sustainability practices out beyond the gates" (The UBC Plan) Utilizing UBC as a "Living Laboratory" can be influential to the community, and displays the campus as a role model to the world for its actions as a living and learning experiment.

UBC currently supports a community of approximately 60,000 individuals, and as the population grows, the University must uncover innovative ways of providing utility services without compromising the ambitious sustainable aims of the campus (Pair UBC, 2008). By utilizing UBC as a "Living Laboratory," innovative technologies for utility services can be practiced. Wastewater management, the focus of this report, is a logical step for UBC to embark on because we believe it will help the university remain a leader in sustainability education and practice.

Overview of Current Wastewater Management

UBC receives its potable water from Metro Vancouver's water system. It is delivered from the Capilano and Seymour reservoirs through thousands of kilometers of pipes and water mains (Metro Vancouver Source and Supply, 2011). In 2010, the GVWD (Greater Vancouver Water District) was charging member municipalities a summer season rate of $0.56 per cubic meter and an off-peak season rate of $0.45 per cubic meter. UBC Utilities is responsible for $48 million in water distribution infrastructure on campus and purchases over 4 million cubic meters of water from Metro Vancouver (via University Endowment Lands) on an annual basis. Some of these costs would be potentially avoidable if UBC were to manage its own wastewater.

UBC produces 3.85 billion liters of wastewater annually. Wastewater is sent to the Iona Island Wastewater Treatment Plant (IIWWTP) where it is treated before being pumped through a 7.5km-long pipe and discharged into the Strait of Georgia as effluent. Sewer outflow at UBC amounted to approximately four thousand cubic meters on average from 2001 to 2009 (Öberg, 2011). Currently UBC relies heavily on Metro Vancouver for its wastewater management needs and a new system could decrease dependence on GVRD, make UBC fully accountable for its waste, and provide the foundation for a more sustainable future.

Sustainability can be measured via social, environmental, and economic areas, and we can see that the current wastewater treatment system can be improved upon in all three of these areas. Socially, the UBC community could be much more integrated into the wastewater system through testing and research. Also, since UBC doesn't have full control over its entire water cycle, there will always be certain social barriers regarding the dependence on GVRD for wastewater disposal. Environmentally, there are many negative impacts that need to be taken into consideration, such as how effluent affects local ecology after it is released into the ocean, or the amount of greenhouse gases that are released into the atmosphere when the remaining sludge begins to decay. Economically, as was mentioned above, the current system of wastewater treatment for UBC has proven to be very costly when buying the treated potable water in the first place, and then paying again to have it treated at the IIWWTP. Overall, if UBC wants to operate a truly sustainable wastewater treatment cycle at the Point Grey campus, it must address these issues in detail.

Objective

Residents within British Columbia, including individuals at UBC have the luxury of consuming large amounts of water. However, water is an essential resource that is becoming increasingly scarce and must be sustained. It has been globally recognized that sustainable water and wastewater management is a necessary component to a functioning community (Grant et al, 2002). Therefore, we can not only benefit economically by conserving water, but also increase the campus's sustainability through proper wastewater management. Our main objective is to increase sustainability at UBC by recommending an alternative wastewater management option.

At first, we considered several wastewater treatment options. However, Solar Aquatic Systems and Constructed Wetlands seemed more advantageous than the others because they both have the potential to increase independence from GVRD, make UBC more sustainable, and provide research opportunities. To make a final recommendation for an appropriate wastewater treatment option, our second objective was to create a framework to evaluate and compare the overall sustainability of the two options. To the best of our abilities, a criteria and indicators matrix was developed to compare the overall sustainability of the two wastewater treatment options. Our third objective was to make a final recommendation for a wastewater management system. This recommendation was based upon the developed multi-criteria analysis tool, catered specifically for assessing wastewater management options for increasing sustainability at the University of British Columbia.

There are many options available for treating wastewater at the UBC campus. However, for this project, we decided to focus on two options: a Solar Aquatics System, and Constructed Wetlands. The options are being considered as potential alternatives for wastewater treatment because they take advantage of and mimic natural ecosystem processes. We believe that this will improve the sustainability of the current system at UBC. An overview of each option is described below.

OPTIONS

Option 1: Solar Aquatics

Overview

The Solar Aquatic System (SAS) is a wastewater treatment system first developed by John Todd, (Rink, 2008). It is a wastewater treatment process that is centered in a green house, and uses a series of aerated tanks that host an ecosystem, which digests and purifies wastewater (Grant et al, 2002). The ecosystem consists of a variety of plants, bacteria, algae, snails, and fish. SAS is able to treat effluent to secondary and tertiary standards (Solar Aquatics, 2000).

Cost Implications

In Cynthia, Alberta, the capital cost for a 2000 sq. ft. facility was $1.4 Million, with a $14,000 per year operational cost (EcoTek, 2009). In order to treat the entirety of wastewater at UBC, a facility 155 times larger would be needed. Based upon this example, a facility would cost approximately $217 Million, if we assume cost will not be minimized by overlap in facility infrastructure or increased efficiency created by a larger facility. Additionally, cost will depend on treatment level, climate, and spatial requirements, which will differ for each individual project.

Potential Sites

The greenhouse portion of the system requires 2.0 m^2 per 1.0 cubic meter/day (m^3/d) of wastewater based on a tertiary treatment level. Systems can be built in units as small as 50 m^3/day and decentralized over large communities (EcoTek, 2009). This gives the potential for various sites to be located throughout the Point Grey campus. Otherwise, an area such as a plot near the UBC Farm may be ideal for a large facility.

Environmental Impact

SAS produce approximately 50% less sludge than conventional systems. There is no use of chemicals in treatment process (EcoTek, 2009), and it eliminates harmful outfall to natural water bodies. Energy requirements will be dependent on the amount of aeration and pumping required for the treatment process. However, they could be significant in Vancouver because of heating requirements in the winter months, due cold temperatures and lack of solar radiation.

Community Co-benefits

The SAS has the potential to create revenue activities from the sale of reclaimed water, composted biomass, and a diverse range of plants (EcoTek, 2009). The facility at UBC could also serve as a demonstration project. A facility in Bear River Nova Scotia receives almost 2,000 annual visitors (Grant et al, 2002); therefore by building a facility at UBC at a much larger scale, there would also be a high demonstration potential through opportunities in advertising, as well as public tours.

Research and Academic Opportunities

There is a high potential for this project to feed into research and academic programs at UBC because SAS are relatively unstudied in detail. Tools for these systems are only limited by the biodiversity found in nature. Thus, through research and academic programs involving this type of technology, the combinations of different species and their capabilities are potentially limitless.

Potential Community Response

SAS are an aesthetically-pleasing treatment system because they mimic a natural environment. Also, they are often used to educate people about waste and wastewater and therefore, as stated above, can be a demonstration site at UBC. There are rarely odors or other sensory nuisances because the space is enclosed. Systems are labeled “green” compared to conventional wastewater treatment systems; therefore, we predict that community response could be very positive, as people will see the potential in having a natural system treat their wastewater.

Option 2: Constructed Wetlands

Overview

Constructed Wetlands (CW) are specialized areas built to treat contaminated water. Typical wetland ecosystems consists of five 'compartments': macrophytes, algae, water, organic sediments, and microbes. The components function collectively to treat wastewater as an integrated system. They consist of a gravel bed planted with a variety of wetland species. The wetland treats the wastewater that flows laterally through the system by oxidizing the organic matter (Grant et al, 2002). CW's rely on self-regulating and self-maintaining biological processes; therefore their big advantage over other options is that they accomplish the same tasks without requiring energy (NSI, n.d.).

Cost Implications

CW have low capital cost. Based on estimates from Natural Systems International (NSI, n.d.), cost are $72,000 to $100,000 per acre. To treat the entirety of wastewater at UBC, the estimated land area needed for a CW would be roughly 14.6 hectares. This would approximate capital costs to be $2.6 to $3.6 Million.

Potential Sites

The estimate of 14.6 hectares above is based on UBC's wastewater treatment needs of 4 billion liters of wastewater per year (UBC, 2009; Solano, 2004). The UBC farm is roughly 14 hectares, and could be a potential site for a CW, though this would most likely not receive much support.

Environmental Impact

Negative impact: The vegetation from CW will absorb significant amounts of CO2, but will also produce and release methane to the atmosphere. As Teiter and Mander (2005) point out, if all global domestic wastewater were treated by wetlands, their share of the trace gas emission budget would be less than 1%. Although CW's release GHG emissions, the amount is quite minor. CW may also be a potential breeding ground for mosquitoes.

Positive impact: CW's have the potential to treat wastewater while supporting wildlife habitats. These systems have the ability to integrate wastewater treatment and resource enhancement.

Community Co-benefits

In Queensland, Australia, there is growing interest to use CW as a low cost, environmentally friendly alternative to the conventional wastewater treatment process, and as such, there are currently two University/local government wetlands there (Greenway and Woolley, 1999). Through building a CW at UBC, community members can use this development as a demonstration project by providing educational information about natural wastewater treatment, and through giving public tours.

Research and Academic Opportunities

There is a moderate potential for research opportunities. Although the CW technology is relatively mature, we believe there are still research gaps within this area. UBC could help to fill these gaps and use the proposed CW as an academic test site of field research for this technology.

Potential Community Response

The potential community response could be poor because of the presence of different sensory nuisances that are associated with a CW. This is due to the high concentration of suspended solids, which may cause the filtration bed to clog, creating unpleasant odors (Vymazal, 2002). Also, as briefly mentioned above, CW can provide the breeding habitat for mosquitoes, which are capable of acting as a vector for different pathogens, causing disease in humans and animals (Russell, 1999). However, CW can increase the aesthetics of the site by enhancing the landscape with a water feature. They also add diversity to the landscape and naturally create a visually-appealing feature.

Overview of Assessment Tool

Purpose

In order to provide the wastewater management solution most suitable for UBC, and along with the guidelines for the course, we developed a method of assessment based on a matrix of sustainable criteria and indicators, which we planned to use as an assessment tool to choose the best option. We first considered the potential impacts of a wastewater management system, and then asked ourselves how the project would affect UBC throughout its lifetime, including both detrimental and beneficial effects.

Next, we examined UBC's sustainability goals for the future, both implicit and explicit. UBC has publicly stated its goals to reduce greenhouse gas (GHG) emissions for the future, but we also wanted to emphasize the fact that UBC is a place of learning, so we asked ourselves how a wastewater management project could benefit the community academically. At this point we realized that it was also important to consider what we thought UBC *should* have as its goals, instead of only what it has already. We came up with five categories of criteria, including economic, environmental, social, technical, and educational. (See Appendix 1 for a complete list)

Approach

For each criterion, we came up with one or more indicator. We began by considering the SMART guidelines for indicators: Specific, Measurable, Achievable, Realistic, and Time-bound. In our case, given the lack of concrete information and a plethora of unknown variables in our analysis, coming up with indicators that were realistic shaped our final results. For example, the performance of CW as a wastewater management solution is very subjective to climate effects such as sunlight and daily precipitation. With this in mind, we took a bit of a short cut for some indicators, and 'measured' them based on previous studies and research articles.

While developing our criteria matrix, we kept in mind its purpose: to compare and assess wastewater management systems at UBC. It became clear that some criteria and indicators should be given more weight than others, because they were more in line with UBC's goals, or simply more indicative of whether or not an option would be realistic. We focused more on the practical side at the beginning because we wanted to eliminate any projects that were obviously impossible to implement at UBC. In this way, we were using the assessment tool as a screen to filter the options.

Next, we used indicators that could provide a measure of how the project fits with UBC's sustainability goals. Potential to reduce GHG emissions, energy consumption, or to reduce potable water consumption were some of the indicators for this stage. Towards the end of developing our assessment tool, we realized that it is important for a project to integrate well with the UBC community, and to be used as an educational aid. Indicators including potential to be a demonstration project, and potential to create research opportunities on campus were used. We believed that it is not only important for UBC to be sustainable and integrate sustainability in its curricular activities, but also to provide education in its extra-curricular projects. It was a combination of these indicators that led us to eliminate several potential wastewater management options.

During our work in developing a criteria matrix, we realized that our assignment had a secondary goal, which was potentially more important than a wastewater management solution. The assessment tool, and our process in developing it, could be used at UBC for future projects. An important aspect of this process is that it took several steps to develop. We first came up with as many indicators as we could, and categorized them into criteria. We then did research and tried to gather results to use the indicators to assess our options, and realized the importance of choosing the correct indicators for the project.

We also found some that didn't represent the situation very well, such as visual appeal, and number of people employed. Some indicators would be impossible to know before the project is implemented, such as reduction in Biochemical Oxygen Demand (BOD) and social acceptance. We found ourselves cutting out indicators that couldn't be used to compare our options, and using a multi-step iterative process. In the end we focused on two similar options, constructed wetlands and solar aquatics. We eventually ended up with a list of criteria and indicators that were specially tailored to compare and assess their sustainability and practicality at UBC.

FINDINGS/ RECOMMENDATIONS

Discussion of Findings

Based on the outlined criteria and indicators, the Solar Aquatics System (SAS) is favorable in terms of social and environmental aspects since it is relatively odorless and the potential risk of spreading pathogens can be eliminated with UV treatment. Nevertheless, the SAS is rather inconvenient regarding the economic indicators we chose to rate it against. We found that capital construction cost of infrastructure and monthly operational costs for UBC would be very high.

On the contrary, CW would offer UBC relatively low capital and operational costs, as well as a low energy cost by comparison to the SAS (but higher CO_2 equivalencies, discussed below). However, we cannot recommend CW as an appropriate solution for UBC, specifically because of the enormous amount of land that would need to be displaced. Also, CW are more subject to local weather conditions, which can often be very unpredictable, making it difficult to depend on as a wastewater management solution for the UBC campus.

The SAS greenhouse component would require additional heating in the winter months in Vancouver in order to sustain the organisms, which results in greater operational costs during these months. Although CW would not require heat during the Vancouver winter, it is subject to decreased efficiency with temperature, meaning that it is less reliable, and needs to be over-engineered to achieve the same capacity as SAS. To offset these energy/heating costs, there is potential for revenue collection through water reclamation in the SAS, and through the sale of a variety of plants and composted biomass (i.e. nutrient-rich soil). The potential for revenue from this option increases the economic feasibility, therefore increasing the overall sustainability of this project. Also, reclaimed water from the process could be used for irrigation, therefore decreasing external source reliance.

Moreover, the SAS is superior to CW in terms of reducing CO_2 equivalencies- something that UBC as an institution is trying to achieve through its sustainable campus goals. Since both options use plants and microbial digestion, they both will release methane (CH_4) – a GHG known to be 30 times more harmful than CO_2. Yet, the SAS has the potential to collect and burn this CH_4 before releasing it into the atmosphere, thus equally reducing GHG emissions in the process, and helping UBC achieve its goal of decreasing the amount of GHG's it emits.

Recommendations

As explained in the discussion above, we used our designed evaluation matrix to assess our two chosen options based on the outlined criteria and indicators. We have determined that, for a number of reasons, the SAS rates higher on overall sustainability, and could be considered a practical and viable option for the UBC campus when compared to CW (see Appendix 2 for Matrix Results).

Although SAS is more expensive to construct, it uses much less land, has a greater potential to recover heat from wastewater, and has a longer overall lifetime for its facility than CW- all of which are important reasons for the UBC context, where available land and finances are strong decision-making factors. Additionally, SAS is a closed system meaning that it is not dependent on weather or climate, since it is in a greenhouse. In a climate such as the one we exhibit in Vancouver, the SAS is a much more reliable option.

As a direct result of this exercise in options assessment, we realized that it is worth spending the extra effort needed to create an evaluation matrix to assess multiple options before implementing a sustainable project at UBC. For example, initially, one option might seem much more viable than all the others, say in terms of financial cost. However, we know that there are other important factors such as the environment, and social considerations that need to be taken into account before a truly ‘sustainable’ decision can be made and the best option put into use. Therefore, we recommend spending time to develop a method of assessment for each individual project that is proposed at UBC.

Obviously, priorities will be dependent on the situation, and the stakeholders involved. For instance, for a location/client other than the UBC campus, which may have more available land to use, and a more appropriate climate, we may find that CW is the more viable option. It’s important to evaluate options against individual contexts and situations in order to make the best decision. In the future, as the population of UBC increases, technologies change, and the economy fluctuates, sustainability will constantly be a moving target that UBC will be working towards. Often the overall effectiveness of indicators isn’t realized until they are actually applied to the project. Thus, we believe that all projects need to be assessed in a similar manner for adequate comparison. We acknowledge the importance of this, and recommend an iterative approach to the decision making here on campus- for wastewater initiatives, and for all sustainable projects in general.

LIMITATIONS

While this project was a valuable exercise and demonstration of sustainable assessment, its extent was somewhat limited. As mentioned above, the process of developing an assessment tool led to the rejection of several indicators, and the modification of others in order to accurately represent and measure our criteria. In some cases however, we were forced by constraints to choose indicators that didn't actually measure anything, but rather indicated the value of a project through other means. We chose some that indicated potential for a project to have an effect, and not how much of an affect it would have. For example, we rated a potential to reduce GHG emissions on a scale from 1-3, because of our limited knowledge and time to research the concept. Ideally, we would have been able to provide an estimate of how much the project would reduce or produce greenhouse gases.

Moreover, we often settled with indicators that were a 'yes-or-no' measure. Rather than indicate how much energy a project would use in operation, we tried to estimate if there would be significant energy use at all. Aside from choosing simplistic indicators, there was also an issue in coming up with accurate results for our quantitative measures. The capital costs of construction for the project were based on smaller projects implemented in different climates, and simply scaled up to the size that would be sufficient to treat a yearly average flow of wastewater at UBC. It is impossible to know if the system will be more or less efficient in our climate, or if there is any way to significantly cut down on construction costs.

It's also important to note that daily flow is much more representative of capacity than yearly flow, since the amount of effluent at UBC depends on the time of year, and even day of the week. Ideally, we would have an idea of peak daily flow at UBC, and peak capacity of the wastewater system. Another indicator with similar issues was the land requirement of the project. However, we realized towards the end of the project that even with these limitations, we were able to provide a good comparison between two different options. Even without concrete data, the important differences became quite clear.

A valuable lesson that we gained from these limitations is that it is important to know how significant they are, and when an indicator is actually good enough to compare between options, rather than to just provide a quantitative measure.

REFLECTION

Towards the beginning of our project on wastewater management, the scope and direction was not fully clear in terms of how our group was going to come up with options, assess them and then provide overall recommendations to UBC. The ongoing weekly seminars provided a more concrete framework for our assignment. The major part of our project was the construction of goals, objectives, indicators and criteria. There is a lot of overlap between these terms, and many involve value judgments.

Aside from this, it seemed that we were hard pressed with a lack of data and time. I think we would all agree that it would be interesting to pursue this project to completion, and work on it exclusively. Once our criteria indicator list was established, the rest of the project of comparing our options fell quickly into place, and was a smoother transition.

One suggestion we have to the students of next year, would be to start the phases as early as possible, because group coordination can take time to establish efficiency and a good flow that works within your own group dynamics. Starting early also means more time to think about the project and gives adequate time for any necessary changes.

Overall, we are impressed with the knowledge we gained, and feel we are walking away from this project with a well-developed foundation in sustainability, as well as a fresh perspective on sustainable development at UBC.

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APPENDICES

Appendix 1: Final Evaluation Matrix

Type	Criteria	Indicator(s)	Objective(s)	Justification
Economic	Cost	Capital construction cost ($)	To estimate the amount of money that UBC would spend on this project. This would most likely be money that could otherwise be spent on other sustainability initiatives.	The amount of money that UBC would need to spend on construction is a key factor in any decision. Often decisions are made entirely based on cost.
		Approx. monthly cost ($/month)	To provide an estimate of how much UBC will designate to this project per month throughout its lifetime.	Operational cost will provide an indication of how much the project will cost throughout its entire life cycle.
		Approximate value of land displaced by system (rate 1-3) Low Medium High	Approximates the value of land displaced by a full scale system on UBC campus. Any land used for treatment could be used for other purposes, so the market value must be considered in the life cycle	This will give an indication of the impact of the system, and is an alternative representation of total land used.

			analysis for the system	
	Revenue	Operational revenue from potential sale of by-products (rate 1-3) Low Medium High	A relative estimate of the amount of money the project could generate monthly based on the value of any by-products, such as methane, fertilizer, and biomass.	Any economic gain from a system will deem it more feasible. If the system generates revenue that surpasses monthly operational cost, then it has the potential to pay for itself.
Environmental	Energy use	Significant energy consumption? (Y/N)	To provide an estimate of how dependent the system is on external sources of energy, and of how much it would affect UBC's overall energy consumption.	If a system depends on significant amounts of energy, it may require backup generators, which would complicate the system (provided it does not produce energy)
	GHG emissions	Potential for CO2 equivalent reduction (rate 1-3) Reduce emissions Neutral Increase emissions	This criterion is intended to provide insight into the project's effect on overall GHG emissions at UBC.	It is important to consider whether a system generates GHG emissions, or reduces them. In reality, the amount of GHG emissions should be measured in quantifiable numbers, such as kilograms CO2 equivalent. However, for the sake of simplicity, we've used a scale of 1-3.
	Fresh water/	Potential to reduce annual	With this criterion, we're	It is important to view any sustainability

	Potable water use by campus	potable water consumption on campus Reduce water Neutral Increase water	trying to assess how the project will affect the consumption of fresh water at UBC.	initiative from a broad perspective, and in our case, we aim to consider the entire water system as a whole. If a project has potential to both treat wastewater and reduce our overall consumption of fresh water, it could be very valuable. On the other hand, a treatment system could use a significant amount of fresh water in the process, thus reducing its efficiency.
Technical	Technical feasibility	Rate the age of maturity: Young (0-10 yrs) Medium (10-20) Mature (20+)	In order to assess how successful a project will be, we consider the age of the core technology.	A technology that is less mature may lead to higher economic risk, and may deviate significantly from other approximations.
		Can the technology operate year round? (Y/N)	In order to assess how effective a technology will be, we need to know if it can operate throughout the entire year.	If a system cannot operate throughout the entire year, then UBC will still be dependent on external treatment, and the technology will be less attractive. A wastewater management solution must be dependable.
		Approximate space requirement (Hectares)	An approximation of the space required by a project will determine how acceptable its construction will be at UBC.	At UBC, no matter what the cost of the project is, there is only a finite amount of land available for development. If land requirement is too large, the project will simply not happen.
		Approximate project lifetime (Years)	To estimate the overall value of a project as an investment.	At the end of the life cycle, a project must be reconstructed to proper working order. This

				will give weight to the capital construction costs as an investment spread over time.
	Degree of Effluent Treatment	Is the effluent treated to the same degree as Iona WWTP? (Y/N)	We're trying to indicate if a project can potentially take the place of Iona WWTP as UBC's wastewater treatment solution.	If alternative treatment is required to supplement this project, then it may have little or no value to UBC. If a project can take Iona's place, then UBC can potentially have full control over its ecological impact.
Educational	Educational value	Potential to be a demonstration project (Y/N)	We're attempting to measure the capacity of this project to educate the public about wastewater management, and sustainability in general.	If this project is unique to our city, it could lead to future partnerships, as UBC and Metro Vancouver have similar sustainability goals.
		Research potential (rate 1-3) Will advance the university as an academic leader Research connections exist or have potential to be established No foreseeable research	This is a measure of how much UBC's current academic community can benefit from the project.	Even if a project is not economically attractive, its value in research could be extremely attractive to certain academic groups on campus, and could ultimately determine the feasibility of the project.
Social	Potential community response / opposition	Presence of sensory nuisances (Y/N)	The presence of sensory nuisances gives us an overall indication of how acceptable the project will be to the community because it	We predict that this project could be constructed incrementally, and that the fate of future expansion depends on community support.

		indicates most of the direct impacts that will affect people nearby.	
	Is there potential risk for spread of pathogens? (Y/N)	The risk of potential spread of pathogens is a general indication of how a project will affect community health.	If a project will have a negative impact on community health, then it will not be politically feasible to construct.

Appendix 2: Matrix Evaluation Results

Indicator	Constructed Wetlands	Solar Aquatic System (SAS)
Capital construction cost ($)	$72,000 to $100,000 per acre * 2.47 acres/hectare * 14.612 Hectares = **$2.6 to $3.6 M** (NSI).	For the 2000 sq. ft. facility in Cynthia, Alberta, capital cost for construction was $1.4 M (EcoTek, 2009). UBC would need a total size of 155 times that, therefore costing ~ **$217 M** (assuming cost cannot be minimized by some overlap in facility infrastructure efficiency by making it larger).
Approx. monthly cost ($/month)	$32/day / (123 m3/day) * 0.25 m3/ha * 14.612 ha * 30 day/month = **$28.51/month** (Vanier, 2001) (NSI).	$14,000 annual cost (EcoTek, 2009) / 12 months = average **$1167/month**
Approximate value of land displaced by system (rate 1-3) **Low** **Medium** **High**	**3. High** value of land displaced (for 14.612 Ha) 1 Hectare = 107,639 sq. ft. 107,639 sq. ft * 3.5 ha * $362 = $569,361,227 Approximately **$570 M** of property value based on $362 per square foot point grey land values of 2009 (Basra, et. al., 2009)	**2. Medium** value of land displaced (for 3.5 Ha) 1 Hectare = 107,639 sq. ft. 107,639 sq. ft * 3.5 ha * $362 = $136,378,613 Approximately **$137 M** of property value based on $362 per square foot point grey land values of 2009 (Basra, et. al., 2009)
Operational revenue from potential sale of by-products (rate 1-3) **Low** **Medium** **High**	**2. Medium** It is possible to harvest 22 tons dry biomass per hectare per year if the system is using cattails as the major plant species. Methane harvesting is not typically done (Solano, 2004).	**3. High** From the sale of reclaimed water, composted biomass, and a diverse range of plants (EcoTek, 2009)

Significant energy consumption? (Y/N)	**No** But there may be minor pumping required	**Yes** Energy will be needed for heating in the winter months to sustain plants and organisms? Extract waste heat? Justified compared to wetlands.
Potential for CO2 equivalent reduction (rate 1-3) **Reduce emissions** **Neutral** **Increase emissions**	**2. Increase** The vegetation from constructed wetlands will absorb significant amounts of CO2, but will also produce and release methane to the atmosphere. Even if all global domestic wastewater were treated by wetlands, their share of the trace gas emission budget would be less than 1% (Teiter and Mander, 2005); however this is still an increase.	**1. Reduce emissions** Greenhouse gas mitigation through aeration and plants. Reduction of CO2 and methane through potential recapture (EcoTek 2009).
Potential to reduce annual potable water consumption on campus **Increase water** **Neutral** **Reduce water**	**2. Neutral** If properly designed, the system will be able to treat effluent for stream discharge, but we haven't found any sources that say it is acceptable for use in toilets and/or irrigation.	**3. Reduce water consumption** Treated water from facility can be re-used in toilets and fields for irrigation, reducing potable water consumption
Rate the age of maturity: **Young (0-10 yrs)** **Medium (10-20)** **Mature (20+)**	**3. Mature** Constructed wetlands were discussed as far back as the 1950s (USEPA, 2000).	**3. Mature** Founded in 1989 by Dr. John Todd (Rink 2008)
Can the technology operate year round? (Y/N)	**Yes** The efficiency of the technology will be reduced in	**Yes** Because it is in a greenhouse, with sufficient heating

	lower temperatures, but it can still operate.	in lower temperatures, it will still work.
Approximate space requirement (Hectares)	**14.612 hectares** 1 hectare of CW can treat enough wastewater for 3000 people producing 250 litres per day each, meaning that it could treat 3000*250*365 litres per year. UBC releases about 4 billion litres of wastewater per year, meaning we could need 14.612 hectares of constructed wetlands to treat all of UBC's wastewater (UBC, 2009) (Solano, 2004).	**3.5 Hectares** (possibly decentralized) "The facility at Bear River is 2400 square feet and…is currently configured to process 15,000 imperial gallons of wastewater per day or over four million imperial gallons a year (Bear River Solar Aquatics, 1997). 1 Imperial gallon = 4.54609188 L, therefore 2400 sq. ft. can treat 24.9 million L / yr. It would need to be ~155 times larger to treat UBC's effluent. (2400 sq. ft. x 155 = 372, 000 sq. feet). So, effectively, UBC would need just under 3.5 Hectares of land to treat its current level (3.85 billion L / yr) of effluent.
Approximate project lifetime (years)	**15-20 years** (Heathcote) (Vrhovsek, 1996).	**50+ years** Infinite with proper maintenance and monitoring
Is the effluent treated to the same degree as Iona WWTP? (Y/N)	**Yes** Can also treat to secondary and tertiary levels.	**Yes** Can also treat to secondary and tertiary levels.
Potential to be a demonstration project (Y/N)	**Yes** In Queensland, Australia, there is growing interest to use CW as a low cost, environmentally friendly alternative to conventional wastewater treatment process, and there are also two University/Local government CW's there (Greenway, and Woolley, 1999).	**Yes** The Bear River facility in Nova Scotia gets almost 2,000 annual visitors. UBC, an educational institution providing a much larger scale of SAS, could greatly increase this potential by advertising and providing public tours (Green River, 2001).

Research potential (rate 1-3) **No foreseeable research** **Research connections exist or have potential to be established** **Will advance the University as an academic leader**	**2. Research potential to be established** There is a moderate potential for research opportunities. Although the technology is relatively old, we believe there are many interesting things that are still unknown.	**3. Will advance the University** There is a high potential for this project to feed into research and academic programs at UBC because SAS are a mature technology that hasn't been researched enough in practice yet.
Presence of sensory nuisances (Y/N)	**Yes** (Smell) because high concentration of suspended soils may cause the filtration bed clogging and subsequent surface flow. Pretreatment in small systems designed for a single household consists of a septic tank. For larger sources of municipal or domestic wastewater it usually consists of an Imhoff tank. (Vymazal, 2002)	**No** Bear River, Nova Scotia's sewage treatment plant is relatively odorless (Green River, 2001).
Is there potential risk for spread of pathogens? (Y/N)	**Yes** Constructed wetlands can provide habitats for mosquitoes that are capable of acting as vectors of pathogens of various types, such as protozoa (e.g. Malaria), nematodes (filaria) and viruses (arboviruses: a blend of arthropod borne virus), which can cause disease in humans and other animals (Russell, 1999).	**No** Ultraviolet light can be used instead of toxic chemicals to purify and kill any pathogenic bacteria (Wong, 2009)

Appendix 3: Authorship Statement

Overall Group Dynamics

During this project, each team members in our group got along well, there was no personality clash or heated, unresolved disputes. We recognized the need to divide up and first tried circulating our portion through the use of Google documents. However, the troublesome of editing and compiling the final draft of phase one through Google documents posed challenging, thus Teresa suggested the use of Dropbox. By making use of Dropbox system, we were able to circulate files and reference resources, which made dividing up work easier

Group Contributions

Bruce: Contribution to all prior phases as mentioned before; Overview of Assessment Tool, and Limitations; as well as multiple edits of the document

Derek: Contribution to all prior phases as mentioned before; Introduction, Works Cited, Authorship Statement, and general editing.

Hong: Contribution to all prior phases as mentioned before; Introduction, Options, multiple edits, and general compilation of the final document.

Teresa: Contribution to all prior phases as mentioned before; findings, recommendations, and works cited for this phase; multiple structural and detail edits; group communication and organization.