UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Wastewater Treatment at the University of British Columbia

Final Synthesis Report

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WASTEWATER TREATMENT AT THE UNIVERSITY OF BRITISH COLUMBIA
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INTRODUCTION

The University of British Columbia Point Grey Campus operates as a small municipality, servicing approximately 40 000 students, 20 000 staff members, and a permanent resident population expected to grow to 18 000 by 2020. Approximately 85% of the total water delivered to campus leaves as wastewater via the sanitary sewer, whether it is potable water, sewage water, or rainwater runoff (1). Presently, UBC produces about 3.85 billion litres each year (2). Sewage at UBC is collected and discharged through two connection points to the Greater Vancouver Sewerage and Drainage District sanitary sewer system of Iona Island Wastewater Treatment Plant (3). The wastewater undergoes primary treatment at Iona and is then discharged through a 7.5 km deep sea outfall into the Strait of Georgia (4).

The current water system is inefficient and not adept to handle projected future population growth on campus (5). Environmentally, the distribution system requires significant energy to transport water to and from the campus. Economically, there are substantial costs to purchasing potable water from Metro Vancouver, paying for its disposal, and implementing infrastructure upgrades, all of which could be avoided through more a sustainable wastewater system. Currently, UBC pays about $0.40 per cubic meter or around $2 million annually for Iona to take in their sewage (2). Although this may not appear to be a high cost compared to the procurement costs, it could easily be decreased if UBC reduced its amount of sewage water.

Furthermore, the current system does not facilitate progress on UBC's long-term vision to achieve a net positive water system for the campus (1). New, innovative approaches to water management are needed if UBC is to support its future growth and function as living laboratory for campus sustainability. Advanced technologies currently exist that would allow UBC to improve the environmental, economic, and social sustainability of the campus. Implementing a localized scale wastewater treatment facility on campus will allow UBC to realize many of its sustainability objectives, including:

- Reduce energy use, improve operational efficiency, and further self-sufficiency by reducing reliance on the municipal system
- Develop a closed loop system for integrated resource recovery
- Meet Climate Action Plan targets
- Capitalize on cost saving opportunities

- Ensure long-term economic sustainability through investments and partnerships
- Create a university community in which living, working, and learning can flourish in an integrated, sustainable environment
- Become a leader in campus sustainability and an agent of change within the greater community
- Function as "living laboratory" in which students, operations, and academia to work together to further campus sustainability

The purpose of the options study, assessment tool, and feasibility study developed for this report is to minimize the risks inherent in implementing novel wastewater technologies on a university campus scale. By ensuring the options are compatible with UBC objectives and meeting the indicators developed in the criteria matrix, we are able to recommend the wastewater treatment option that is the most environmentally sustainable, economically viable, and socially beneficial. Furthermore, the proposed option will support the development of a broader sustainability framework at UBC.

WASTEWATER OPTIONS

1. PRIMARY TREATMENT + CONSTRUCTED WETLANDS

Overview of the Technology

Step 1: Primary Sedimentation Tank

- Sewage water is screened to remove all large objects like cans, rags, sticks, plastic packets and carried in the sewage stream
- Sewage flows through large tanks, called "primary sedimentation tanks." The tanks are used to settle sludge while grease and oils rise to the surface and are skimmed off (6)
- Sewage sludge accumulated in the primary wastewater treatment process must be treated and disposed of in a safe and effective manner, acceptable options for treatment include anaerobic digestion, composting or sending the sludge to Iona.
- Effluent created in this process is sent to the constructed wetlands for further treatment

Step 2: Secondary Treatment with Constructed Wetlands

- Subsurface flow constructed wetlands consist of saturated substrates, wetland plants, and microbial communities (7)
- As water flows through the wetlands it contacts the plants, root, and soil microzones which absorb and transform nutrients and potential contaminants (7)
- Through the plant and bacterial metabolism, processes such as denitrification, ammonia assimilation, and reduction of the biological and chemical oxygen demand can occur (7)

- Effluent coming out of constructed wetlands can be directly transferred to the UBC Farm to be stored and used immediately
- Water that cannot be stored could be released through the stormwater piping at UBC

Cost Implications

Primary Treatment Tank

- Building Cost: $115 000
- Operating Costs: $43 000 (8)

Constructed Wetlands

The following costs are based on the Cannon Beach wooded wetlands treatment system in Oregon:

- Building cost: approximately $1.5 million US
- Operational costs: approximately $72 000 US per year
- Operating costs: $170 to $410 per m^3/day (7)
- Revenue: Commercial profits from calla lilies, mushrooms, and fish from aquaculture operations have all been economically viable (7)
- Savings: $5.67 million on potable water that would have been used for irrigation (5)

Potential Sites on UBC Campus

The wetlands typically consist of a series of lanes or cells with dimensions of 2m by 20m, requiring a total area of 60 000m^2 or 14.83 hectares (9). Since a long narrow design is optimal for maintaining a constant flow rate, wetlands are often constructed in a serpentine path to minimize the total ground area needed (9). A possible location for the constructed wetland is in the south campus area. There are already sustainable land use strategies in place such as the stormwater management systems into which the wetlands could be integrated.

Advantages

Primary Treatment

- Reduces the impact on municipal infrastructure, decreases the overall water demand on campus, and lowers sewage connection fees (10)
- Significant energy and cost savings due to reduced transportation distances
- Sludge created can be used in the form of fertilizer or could be used to create electricity energy on site from biogas (6)

Secondary Treatment

- Numerous positive ecosystem impacts including the production of clean, safe water, reduced nutrient loading, nutrient recovery, habitat for wildlife, and increased biodiversity (6)
- Low maintenance requirements, operational costs, and energy requirements
- 31. 5 million cubic feet of potable water used for irrigation would be saved because of effluent reuse (2)
- Potential reuse applications of the effluent including irrigation of the UBC Farm and green spaces on campus, flushing toilets, groundwater recharge, and discharge to wetlands and creeks to increase biodiversity and restoration of fish populations (11)

- Virtually self-sustaining and can be in continual use for more than 30 years, thereby becoming an integrated and vital green space for UBC (7)

Disadvantages

Primary Treatment

- Sludge treatment produces a large amount of heat and GHG emissions.
- Sludge accumulation could lead to outbreak and contamination if not properly stored or used for energy purposes

Secondary Treatment

- There is a need for a preliminary treatment before the wastewaters treated by the constructed wetlands system
- Production of methane from decomposing in the constructed wetlands contributing to UBC's GHG emissions
- Space limitation may make this option is not feasible for UBC or limit the potential scale of the constructed wetlands
- May not be able to withstand shock loadings and volume changes coming from the treatment tanks while maintaining a consistent discharge quality
- Need for longer retention time of wastewater than a conventional system
- Potential increase in insects and odors

Teaching and Learning Opportunities at UBC

- Serve as a valuable educational tool for UBC students and provides research opportunities for faculty to explores issues of wastewater, wetland ecology, microbiology, and plant dynamics
- SEEDs projects by students to determine the feasibility of CW on campus

Community Response/Involvement

- Provides aesthetic, commercial, habitat, and recreational value to the communities they exist in
- Participatory processes that engage community members, identify concerns, and satisfy different stakeholder perspectives

2. SOLAR AQUATICS

Overview of the Technology

- Solar Aquatics (SA) is a bioremediation process that replicates and optimizes natural wetland functions to treat wastewater
- Raw sewage flows through a series of tanks, engineered streams, and constructed marshes where contaminants are metabolized by algae, rooted aquatic plants, bacteria, clams, snails, and fish that purify the water (12)
- Built components of the solar aquatics system include primary settling tanks, blending tanks, aerobic tanks, clarifiers, sand filters, constructed wetlands, and a solar greenhouse containing all the components
- Solids remaining at the end of the system are settled out by gravity and pumped to the front of the system or to the sludge digester to be aerobically stabilized (13)

- The waste stream flows through a sand medium where remaining solids are filtered before entering the constructed wetlands. The stabilized solids are transferred to a phragmites reed bed for passive composting and the resulting biomass can be used as a soil amendment (13)
- The final effluent is stored in a process water tank and flows by gravity or pump to reuse applications on campus (13)

Cost Implications

- SA systems offer a treatment process that produces high-quality water at a low cost. The total cost of SA is in most cases is less than the cost of conventional technology (13)
- Systems vary in cost based on treatment level, climate, and special client requirements

This report draws upon several case studies to extrapolate information for the UBC context: Bear River Solar Aquatics Wastewater Treatment Facility located in Nova Scotia, Errington Solar Aquatics Facility in British Columbia, and the "Living Machine" Advanced Ecological Engineering System located in Maryland.

- Capacity to treat: 56 775 -151 400 L of sewage per day (9)
- Capital cost: $300 000-$450 000 (9)
- Operating and maintenance costs: $14 000-$50 000 per year (13).
- Revenue: $2 400 per year from the sale of plants grown in the system's marsh component (9)
- Savings: $5.67 million on potable water that would have been used for irrigation (5)

Potential Sites on UBC Campus

SA can be designed at any scale and size, including a phased, modular system decentralized over larger communities (13). A complete system, including all the components would require an area of approximately 210-750m^2 or 0.075 hectares. An area near the south campus research reserve and the UBC Farm would be an ideal location.

Advantages

- SA systems produce tertiary quality effluent within two to four days (12)
- Lifecycle energy requirements are very low: sunlight provides the primary source of energy and wastes generated by the inhabitants of one vessel become the food for inhabitants of another
- Reduced transportation distances resulting in significant savings in energy and GHG emissions
- Reduces the impact on municipal infrastructure, helps conserve water through reuse, and lowers sewage connection fees (10)
- Heat recovery from the effluent after treatment if UBC deems thermal energy to be a valuable resource
- Positive ecosystem impacts include pathogen reduction, denitrification, and reduced nutrient loading, and the production of clean, safe water
- Resource recovery products such as aquatic pond plants, ornamental plants, hydroponic herbs and flowers, compost fertilizer, and ornamental fish and snails (13)
- Potential reuse applications of the effluent

Disadvantages

- Some energy will be required if the collection system relies on pumping to transport the wastewater to treatment facility
- The decomposition processes of CW produce methane gas, which would contribute to UBC's GHG emissions

Teaching and Learning Opportunities at UBC

- Serve as a valuable educational tool and learning center for UBC students and provides research opportunities for faculty to explores issues of wastewater, wetland ecology, microbiology, and plant dynamics
- SEEDs projects by students to determine the feasibility of SA on campus

Community Response/Involvement

- SA systems are free of unpleasant odours and unsightly equipment, and are generally viewed as an asset to a community
- Participatory processes can take place that engage community members, identify concerns, and satisfy different stakeholder perspectives
- SA systems can be designed and adapted to meet the specific needs of the UBC community
- If developed and run jointly with the Musqueam band, the facility could generate job opportunities for band members (11)

OVERVIEW OF ASSESSMENT TOOL

I. Purpose

The criteria matrix includes three main objectives focused on environmental, economic, and social factors. Focusing on the three dimensions of sustainability ensures that the indicator set is a representative sample. Both the type of wastewater options considered and the UBC context informed the selection of objectives, criteria, and indicators in the matrix. Indicators that were specific, measurable, achievable, realistic, and time-bounded were selected whenever possible. Indicators are also designed to support the development of a broader sustainability framework at UBC and are in line with the UBC objectives outlined on page three.

The environmental objective for the project is a sustainable, localized scale wastewater treatment system. Environmental indicators were selected to support UBC objectives to develop a closed loop system for integrated resource recovery, reduce energy use, improve operational efficiency, further self-sufficiency, and meet Climate Action Plan targets. The economic objective for the project is a system that is financially affordable and economically viable for UBC. Economic indicators are designed to highlight systems that have potential for cost savings, creating revenue, partnerships, and investment. These indicators help mitigate financial risk by ensuring the project will be an attractive investment and economically sustainable over the long-term. The social objective for the project is a net positive impact on the UBC community. Social indicators were selected to reflect the option that allows UBC to be both a leader in campus sustainability and an agent of change within the greater community through teaching, learning, and research. For further details on the criteria matrix, please consult the Appendices on page 13 of the report.

II. Approach

The assessment tool set uses quantitative and qualitative indicators, such as yes or no and rating 1-3 scales. The availability of data was central in determining whether we used a quantitative or qualitative indicator. Overall, the criteria matrix was designed as an objective assessment approach, rather than one specifically tailored to our goals or options, to ensure that it could be used in future wastewater studies. The evaluation process involved running each option through the indicator set independently, and then comparing the outcomes to the status quo and to each other. Points were aggregated equally between the environmental, economic, and social objectives in the criteria matrix, with no additional ranking system. Each objective (environmental, economic, social) was given equal weight and each indicator was worth one point. The outcome for each objective was determined by tallying the total points. Although each objective and indicator was ranked equally, certain indicators were identified as being more important or potential deal-breakers. The indicators that were most influential in determining the final outcome included land requirements, energy requirements, GHG emissions, operating costs, by-product revenue streams, and acceptance by the UBC community.

FINDINGS AND RECOMMENDATIONS

Below is a discussion of conclusions drawn from the feasibility study. For an indicator-by-indicator explanation of the results, please consult the feasibility study results in the Appendices on page 15 of the report.

Conclusions from Environment Indicators – Best option: SA

- Both of the options offer wastewater treatment that is more environmentally beneficial than the status quo primary treatment system.

    - The SA option offers tertiary level treatment, while the CW provides secondary treatment.
    - In both options, the effluent produced is of much higher quality than the status quo and is safe for reuse applications, such as irrigation, building uses (ie. toilets, sinks), recreational uses, and groundwater recharge, all which would allow UBC to meet its goal integrated resource recovery and self-sufficiency.
    - Overall the quality of effluent produced from SA is superior to what is produced in the CW. For this reason, SA ranks higher than CW in terms of effluent reuse and quality.
- Since the amount of land available on campus is very limited, land requirement was one of most influential environmental indicators in determining the outcome.
    - The SA option requires less than 1 hectare of land, which is significantly less than the primary treatment + CW option, which requires almost 14 hectares.
- Both options rank equally in terms of meeting UBC's vision to become a closed loop system and reduce dependence on the municipal system.
- The exact GHG emissions are unknown, but both options contain a CW component in which methane is produced, which will increase GHG emissions.
    - There is a significant reduction of transportation-related GHG emissions in both off options, since the wastewater is treated and reused on campus
    - Overall, SA produces less GHG emissions that the CW due to its efficient and compact design.
    - These emission reductions are in line with UBC's Climate Action Plan targets.
- SA also requires almost zero energy and could potentially become net positive.
    - The primary treatment tanks of the constructed wetlands option use energy to run the tanks, although energy could be recovered in the form of biogas from sludge produced.
    - The constructed wetlands process does not require energy to facilitate it. Although both systems require considerably less energy than the current status quo system, the SA option ranks higher than the CW, as it uses less energy overall.

Conclusions from Economic Indicators – Best option: SA

- Both options are economically viable for UBC and are better than the status quo.
- The feasibility study found that both systems require a relatively low capital investment, provide large cost savings in terms operating costs, and have a potential to create new revenue streams.
    - Both options are fairly low risk investments with a short pay off period of within three years.
    - SA has the potential to create new revenue streams through the sale of reclaimed water, composted biomass, and aquatic plants.
    - CW has the potential to recover energy through biogas production and reusing the effluent for irrigation.
    - For both options, the reuse of the effluent for irrigation would allow UBC to save $5.6 million per year which is the amount currently spent on purchasing potable water for that purpose.
- Overall, the results from the economic indicators were surprising, as we expected primary treatment plant + CW to be less economically attractive because it requires two systems and has a higher operating cost than SA.
    - The capital investment for SA ranged from $400 000 to $1.4 million (9) and this was only slightly lower than CW which valued at around $1.6 million (8).
    - The operating cost for SA was around $14 000 (9) and for primary treatment plant + CW it was around $104 000 (8, 13).
    - Ultimately, operating costs are a long-term liability, while capital investment is a one-time cost. Thus, we placed greater importance on operating costs, making the SA more attractive option.
- Overall, the results indicated that SA is the most financially affordable and economically viable option for UBC.
    - The lower capital and operating costs combined with a greater potential for new revenue streams of SA demonstrate that it is more likely to be economically sustainable for UBC over the long-term.

Conclusions from Social Indicators - Best option: SA

- Both the SA system and primary treatment + CW option will achieve the project's social sustainability objective of a net positive impact on the UBC community.
  - In terms of the educational value criterion, both options will provide significant research and development potential and serve as a model for decentralized wastewater treatment in the region, thereby allowing UBC to carry out its mandate to be an agent of change within the greater regional and global community.
  - In terms of the impact on the UBC community criterion, both options are likely to create new jobs and be accepted by the community and will contribute to UBC's vision for a university community in which living, working, and learning can flourish in an integrated, sustainable environment.
  - However, the CW option may pose greater visual or sensory disturbance than SA. For this reason, SA ranks slightly higher than CW.
- Participatory planning processes that engage community members, identify concerns, and satisfy different stakeholder perspectives will be vital to success of either system.

LIMITATIONS

In our approach to sustainability assessment, the largest limitation was the availability of data. Most of the data was obtained from research on existing projects. However, these projects differ from UBC in terms of geographical location, climate, scale, and capacity. Due to these differences, the data used in our project may not be accurate when applied to the UBC context. As well, there were several items that we simply could not find the information for. In this case, we had to make assumptions and change our indicators from quantitative to qualitative measures.

Another major analysis limitation was lack of capacity within the group. With no previous knowledge on wastewater treatment, group members struggled with the technical material. The iterative nature of the project was also challenging, as were we constantly learning new information and continually making changes to our options and evaluation tool. If we had a higher level of expertise and access to more concrete data and information, it would have resulted in more detailed option studies, a more comprehensive criteria matrix and indicator set, and more accurate analysis of results and final recommendations.

REFLECTIONS

Course structure

The theoretical component of the course (lectures, academic readings, seminar discussions) did not compliment the project component. The academic papers were not explored enough in depth to justify the amount of time spent reading them. It was frustrating to have to spend hours reading a paper or preparing the written assignment, and then only discuss it very briefly in the seminar. Furthermore, the papers were not particularly helpful in informing our projects. Some of the lectures were not particularly interesting or engaging, and only a few of the lectures facilitated engaging debates among students and faculty. In the future, putting the course onto the Vista website would be more convenient for students and encourage more class discussion and collaboration on projects topics.

In terms of the project component, students need more foundational knowledge and information on their respective topics. We would like to recommend that a large portion of the earlier lectures, readings, and seminar discussions be dedicated to providing the basic information that will be required to complete the project (ex: how wastewater treatment works, how to conduct sustainability research and assessment, what indicators are, how to develop evaluation tools). It would have been helpful to have more reliable, accessible information sources, including a summary of essential facts, where to find the necessary data, as well as more focused presentations or meetings with UBC faculty or staff (opposed to unstructured question and answer sessions). Clearer expectations regarding the criteria matrix evaluation tool, indicators, and whether projects should even involve data would have been helpful in guiding the project process.

Overall, we think it would be more effective to break the course into two components: (1) theoretical sustainability (involving lectures, readings, and discussions of sustainability concepts) and (2) practical sustainability (focusing the project process, including *how* to develop sustainability projects, sustainability research, evaluation tools and indicators, and feasibility studies). Focusing on these components separately and more in depth will allow more effective sustainability education.

<u>APPENDICES</u>

Authorship Statement

Throughout each of the assignments group work was split evenly. Correspondence was done through emails in which the assignments were worked on and sent to the group. The background brief was written as a compilation of research by each of the members. For the options study, Sara was responsible for researching and writing the about Solar Aquatics, Roshni was responsible for researching and writing about the Primary Treatment and Constructed Wetlands option, and Diana was responsible for researching and writing about the Reclaimed Water Treatment Plant. For the criteria matrix and feasibility study, Roshni was responsible the environmental indicators, Sara was responsible for the social indicators, and Diana was responsible for the economic indicators. In all assignments, group members actively edited and reviewed the assignment.

Reflections on the Group Process

Since we were a small group, we were able to hold most of our discussions online and work on the assignments over email. This approach was very efficient, since it allowed group members to work on the project when it best suited their schedule. Clear communication and providing each other with feedback was crucial to the success of our project. All group members deserve top marks for their dedication, diligence, reliability, and commitment to the project. However, we would have benefited from more meetings in-person to discuss the overall direction of our project, clarify the purpose of the assignments, and clarify specific content we did not understand. Our biggest challenges resulted when group members were not on the same page and had a different understanding of the assignments' expectations. These difficulties could have avoided through more in-person meetings to discuss our different perspectives and roles.

Criteria Matrix

Objective(s)/Goals	Criteria	Indicator	Justification
ENVIRONMENTAL: A sustainable, localized scale wastewater treatment system	Effluent reuse	Potential for effluent reuse: (Y/N)	In line with UBC objectives to develop a closed loop system for integrated resource recovery & to further self-sufficiency.
	Environmental Impact	Land requirements (m^2)	Facility must fit within the limited amount of space UBC has.
		Total energy requirements (taking into account both energy consumed and energy recovered/produced onsite) (rate 1-3): 1 – Net positive 2 – Zero or very minimal 3 – Lower than status quo 4 – Equal to or higher than status quo	In line with UBC objectives to develop a closed loop system for integrated resource recovery, reduce energy use, improve operational efficiency, & further self-sufficiency.
		GHG emissions in transportation and treatment (rate 1-3): 1 – Reduction 2 – Remain the same 3 – Increase	In line with UBC's Climate Action Plan targets.
		Potential to decrease dependence on municipal infrastructure: (Y/N)	In line with UBC's vision of university community that is sustainable and integrated with nature and to develop a closed loop system for integrated wastewater treatment & to further self-sufficiency.
	Health and Safety	Effluent quality (ex: pathogen level, secondary/tertiary)	Meet effluent standards currently being used to ensure that the waste is at a safe level.
ECONOMIC: A system that is financially affordable and economically viable for UBC	Capital investment	Capital investment required for project	UBC will more likely invest in a project that has a low capital investment as it makes the project less risky. It should also be in line with UBC's current infrastructure investment: - $48 million in water distribution infrastructure including pipes, valves, fire hydrants, and building water meters (UBC Utilities, 2010) - $88 million stormwater and $33 million in sanitary collection infrastructure (UBC Utilities, 2010)
	Operating Costs	Treatment costs per litre	It is easier to make a large investment in capital if there is some sort of payback or cost savings measure. UBC will look towards a system that can create cost savings (similar to the UBC EcoTrek project (UBC Sustainability, 2011).

	Recovery of costs	Potential to recover costs through new revenue streams or cost saving measures	Systems that have the potential to create revenue (eg. from the sale of recovered resources, composted biomass, and plants) or cost saving potential (eg. Lower energy costs) will be more economically sustainable over the long-term and be a more attractive investment.
	Pay off Period	Amount of years required to pay off capital investment given any savings or new potential revenue that may occur	A shorter pay off period is a more attractive investment and less risky as there is a lower liability associated with it.
	Partnership potential	Potential for partnerships with industry, academic institutions and government agencies: (Y/N)	Allows UBC to contribute to community capital & the regional economy. Partnerships also reduce the financial risk associated with a project.
SOCIAL: Net positive impact on the UBC community	Impact on UBC community	Acceptance by UBC community (low or no impact in terms of any visual or sensory disturbance): (Y/N)	In line with UBC's vision for a university community in which living, working, and learning can flourish in an integrated, sustainable environment.
		Potential of new jobs for local citizens & students: (Y/N)	
	Educational value	Research and development potential (rate 1-3): 1 – Will advance the university as an academic leader in this field 2 – Research connections exist or have potential to be established 3 – No foreseeable research potential	Allows UBC to carry out its mandate to be an agent of change within the greater regional and global community. Raises awareness, promotes community engagement, and stimulates sustainable behaviour change.
		Potential to serve as a model for decentralized wastewater treatment in the region: (Y/N)	
		Provides opportunities for public education & engagement (facility tours, recreation): (Y/N)	

Feasibility Study Results

Environmental

Potential for effluent reuse: (Y/N)
There is potential for effluent reuse in both of the systems. The option of the primary treatment + Constructed Wetlands (CW) produced secondary effluent while the Solar Aquatics (SA) produces tertiary effluent which is cleaner and better for the environment. Both types of effluent can be stored and used for irrigation and further use.
Results: SA > CW

Land requirements (m^2)
The primary treatment tank + CW option uses a large area of land, estimated to be almost 14 hectares of land. SA uses much less land comparatively, about 1 hectare of land. SA treatment plants are much smaller than traditional wastewater treatment plants, so they can be placed in tight, urban areas. Both systems would need to be located close to the UBC Farm in south campus in order to make effluent reuse possible.
Results: SA > CW

GHG emissions in transportation and treatment (rate 1-3):
1 – Reduction 2 – Remain the same 3 – Increase
Primary treatment + CW rates as 1 – reduction in GHG emissions. Primary treatment requires a significant amount of energy and produces GHG emissions equal to what is being produced currently. The CW for sewage treatment is a significant source of methane and GHG emissions, much more than what is produced in natural wetland (Tail et al., 2002). Transport emissions caused by the transfer of wastewater from UBC campus to the Iona Treatment Plant would be reduced to zero emissions. There would be minimal transportation emissions on campus. The overall emissions would be lower than the status quo in this system. SA rates as 1 – reduction in GHG emissions. The constructed wetlands component of SA would produce moderate methane emissions. There would no transport GHG emissions to Iona and reduced transportation emissions on campus. Overall, SA would produce less GHG emissions than status quo and the CW option.
Results: SA > CW

Potential to decrease dependence on municipal infrastructure: (Y/N)
Both systems reduce UBC's dependency on municipal infrastructure. Both systems would reduce their usage of pipes that run from the campus to the Iona Treatment plant if treatment centers were placed on campus.
Results: SA = CW

Effluent quality (ex: pathogen level, secondary/tertiary)
CW produces secondary quality effluent. The secondary treatment system provides further processing of the effluent from primary system to remove the residual organics and suspended solids. It involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes. SA produces tertiary quality effluent. Specific wastewater constituents which cannot be removed by secondary treatment are removed through this system.

Individual treatment processes remove nitrogen, phosphorus, additional suspended solids, refractory organics, heavy metals, and dissolved solids, resulting in a higher effluent quality.
Results: SA > CW

Total energy requirements (taking into account both energy consumed and energy recovered/produced onsite) (rate 1-3):
SA rates as either 1 – net positive or 2 – zero or very minimal in terms of energy requirements. Since sunlight provides the primary source of energy in SA, the lifecycle energy requirements are very low. Some energy will be required if the collection system relies on pumping to transport the wastewater. However, gravity may be sufficient in the UBC context. Energy recovery is beyond the scope of this report, but heat could be extracted from the effluent after treatment and biogas could be recovered to generate fuel. Thus, SA has the potential to be net positive in energy requirements. Primary treatment + CW rates as 3 – lower than status quo. Primary sludge treatment requires a significant amount of energy. However, sunlight provides the primary source of energy in CW, therefore the energy demands are very low. Again, energy will be required if the collection system relies on pumping to transport the wastewater, but gravity may be sufficient in the UBC context. In addition, a significant amount of electrical energy can be generated onsite from the biogas produced from sewage sludge. Thus, this option offers significant energy savings from the status quo.
Results: SA > CW

Economic

Capital investment required for project
For the SA system, capital investments range from as little as $150 000 (EcoTek, 2011) to $400 000 (Grant et al., 2002) to $1.4 million for a system that includes heat recovery, solar water heating, seasonal earth heat and a storage system (EcoTek, 2011). This was based off a similar project developed in Yarrow Ecovillage on Vancouver Island and Cynthia, Alberta in 2009 (EcoTek, 2011). To be conservative, we will use the $1.4 million cost. In order to build a CW, UBC will also need to invest in a primary treatment tank first. A simple settling tank can cost upwards of $115 000 based on a settling tank proposed in Thailand (Suwanayuen & Bhumiratana, 2008). The CW itself can cost approximately $1.5 million US for a 14 hectare one (CAAWT, 2011). The total cost for a CW system on UBC will be about $1.6 million. In terms of capital investment, the SA is the cheaper option but by an almost negligible amount.
Results: SA > CW

Treatment costs per litre
UBC pays around $2 million annually to Iona for wastewater disposal. We will like to invest in a project that has lower operating costs. For the SA, operating and maintenance costs range around $13 000 - $14 000 per year (Grant et al., 2002). For the CW, it ranges around $71 000 operation costs per year and for a primary treatment facility, the operating costs are around $43 000 per year.
Results: SA > CW

Potential to recover costs through new revenue streams or cost saving measures
The SA system has the potential for heat and resource recovery (EcoTek, 2011), and reuse application (Öberg, 2010). For the CW, there is a potential recovery of energy through biogas and reuse application such as for irrigation. Reusing the water for irrigation can help UBC save about $5.6 million from having to buy potable water for that purpose.
Results: SA = CW

Partnership Potential
UBC strives to create partnerships with other academic institutions, industry, and government agencies to gain the fullest potential from a project. These partnerships are not only research based but provide monetary support for the projects as well. Both the SA and CW have partnership potential. There are several BC and Canadian based firms that are highly interested in both wastewater techniques. As well, government agencies may be interested in investing in such projects.
Results: SA = CW

Amount of years required to pay off capital investment given any savings or new potential revenue that may occur
A less risky project will require a lower pay off period meaning that UBC will have less debt obligations. For the SA system, UBC can save about $1.1 million (Current costs subtracted from SA operating costs) in wastewater treatment costs by not having to pay Iona. In terms of this saving, the project can be paid off within 3 years given a $1.4 million capital investment and other costs that may incur (eg. Materials, labour and contingency). For the CW, the project can be paid off sooner than the SA as its capital investment is around $215 000.
Results: CW > SA

<u>Social</u>
Acceptance by UBC community (low or no impact in terms of any visual or sensory disturbance): (Y/N)
SA systems are free of unpleasant odours and unsightly equipment, and are generally viewed as an asset to a community. The primary treatment tank may pose a visual and sensory disturbance to the UBC community. CW may potentially increase insects and odours onsite, but will also provide aesthetic, habitat, and recreational value to the UBC community. Overall, SA will pose less disturbances than primary treatment + CW.
Results: SA > CW

Potential of new jobs for local citizens & students: (Y/N)
Both options can be designed and adapted to meet the specific needs of the UBC community, including the creation of new jobs. Jobs will arise from the operation and maintenance of the facilities, as well as managing and marketing by-products, such as recovered resources, composted biomass, and aquatic plants. These jobs could include both permanent, full-time positions for local citizens and seasonal, temporary, part-time positions for UBC students.
Results: SA = CW

Research and development potential (rate 1-3):
Both options rate as 1 – will advance the university as an academic leader in this field. Both SA and primary treatment + CW will serve as a valuable educational tool for UBC students and provide research opportunities for faculty to explores issues of wastewater, wetland ecology, microbiology, and plant dynamics.
Results: SA = CW

Potential to serve as a model for decentralized wastewater treatment in the region: (Y/N)
Both options have potential to serve as a model for decentralized wastewater treatment in the region. Through showcasing novel wastewater treatment technologies at a university campus/municipality scale, UBC will raise awareness and stimulate sustainable development at other universities, thereby carrying out its mandate to be an agent of change within the greater global community.
Results: SA = CW

Overall Tally:

SA – 8 CW – 1 = SA > CW

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