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Report #EWW 10-06

REPORT TO CORE AREA LIQUID WASTE MANAGEMENT COMMITTEE
MEETING OF WEDNESDAY 27 JANUARY 2010

<u>SUBJECT</u> **RESOURCE RECOVERY STUDIES, UNIVERSITY OF VICTORIA AND JAMES BAY/DOWNTOWN – CORE AREA WASTEWATER TREATMENT PROGRAM**

PURPOSE

To provide information on the detailed resource recovery studies conducted in the University of Victoria (UVic) area and the James Bay/downtown area.

BACKGROUND

At its meeting of 02 June 2009, the Core Area Liquid Waste Management Committee approved Option 1 of the distributed treatment model which included recommendations to undertake detailed assessments of wastewater heat recovery systems and delivery mechanisms in James Bay/downtown and to investigate opportunities for heat recovery and water reuse with the University of Victoria.

James Bay / Downtown Victoria Study (Appendix A)

Stantec staff undertook a detailed heat availability and heat demand review, including the following tasks:

1. Identify potential buildings and facilities to be served by the system and assess the market for use of such heat. Review previous work completed by Kerr Wood Liedel. Identify potential major users. Estimate the heat demand for buildings in the proximity of James Bay on a unit-size basis or on available records of gas consumption and using the information developed by the previous consulting team.
2. Complete field visits to several case study buildings in the James Bay area to determine the issues associated with retrofitting existing buildings to accept heat from a district heating system.
3. Conceptualize opportunities for heat recovery from trunk sewer lines upstream of Macaulay/McLoughlin and from secondary effluent from a plant at Macaulay/McLoughlin.
4. Develop concepts for a district heat distribution system to transfer heat or hot water to potential market buildings.
5. Determine the feasibility for retrofitting buildings such as the Parliament buildings and major buildings such as hotels and office buildings to enable use of recovered heat. Prepare life cycle costs for construction of a district energy system from raw and treated wastewater.
6. Estimate revenue generation potential.
7. Calculate greenhouse gas offsets.
8. Conduct a triple bottom line analysis of options.
9. Prepare a technical report.

At the 2030 average day flow of 84.2 megalitres per day (ML/d) of treated effluent at McLoughlin Point, the consistent heat output would be approximately 23,000 kilowatts (kW).

With respect to demand, based on the case studies of numerous buildings in the downtown area, most boiler-heating systems operate at a temperature of 80°C or more. As a result, a district energy system would be required to supply heat at a temperature substantially higher than the temperature of the sewage effluent in the winter (12°C). The older government and legislative buildings are serviced by a high temperature steam plant. Steam heating systems operate on a closed loop at a much higher temperature and cannot utilize moderate temperature hot water which can be produced from recovered effluent heat. Three other buildings were investigated in the James Bay/downtown area and they use hot water heating systems and typically operate at temperatures of 82°C. The huge capital costs needed to lift the temperature for existing buildings with high temperature systems, along with the long conveyance system, does not make a good business case, with the payback period exceeding 50 years.

However, a smaller district energy system for the north portion of the downtown area where it is expected to see a redevelopment with new building construction would be much more feasible. New developments commonly use lower temperature, energy efficient boilers which could use the heat recovered from effluent. This smaller energy system could be integrated with the energy requirements of the biosolids facility located in the upper Victoria Harbour. Heat extracted from the effluent would be conveyed to the biosolids facility at ambient temperature (<25°C) thus eliminating heat losses along this line. The transmission line would go through Esquimalt and Victoria West eliminating the need to use the proposed tunnel under Victoria Harbour.

A district heating facility housing heat pumps could be located at the biosolids facility and hot water at a temperature of 60-65°C would be distributed to the biosolids process equipment and the nearby north portion of the downtown area. This system would be designed to take into account the lower operating temperature of newer heating systems. Also the system would only use two-thirds of the extractable heat to provide process heat to the biosolids facility and the north downtown area, therefore leaving a significant amount of energy for other developments in Victoria West and Esquimalt.

Therefore, the best option is to install a closed-loop distribution piping system through Victoria West between the wastewater liquid treatment plant at McLoughlin Point and the energy centre (if located in the upper Victoria Harbour). This would be the first phase and would allow reclaimed heat to be used for sludge and digester heating and plant building space heating. The second phase would be the installation of the separate District Energy System (DES) to service the north downtown area. As this area redevelops, new buildings could connect to the DES, allowing a more cost-effective development. There would also be the opportunity to extract heat and distribute it through separate local DES in Esquimalt or in Victoria West should other redevelopment opportunities arise. A critical component would be the requirement to reflect in the zoning of any redevelopment area the need for new buildings to connect to the DES.

It is recommended that further discussions be conducted with City of Victoria staff and potential DES providers.

University of Victoria Study (Appendix B)

The main work tasks for the UVic study included:

1. Undertake an inventory of major mechanical and heat demand systems at the university.
2. Review current water usage patterns within UVic and surrounding communities.
3. Review gas and power consumption records from UVic.
4. Review all existing mechanical and heating systems at the university.
5. Summarize treatment requirements for reuse by water use category and reuse standards and identification of required standards development. Consider recommendations of draft provincial position paper with respect to reclaimed water reuse.
6. Develop water reuse and heat recovery plans including capital and operating costs and potential revenues including carbon credits.

Water Reuse

The proposed Saanich East North Oak Bay (SENOB) treatment plant utilizing membrane bioreactor ultra-filtration would produce an effluent with low biochemical oxygen demand and turbidity that could be reclaimed for water reuse. The opportunity would largely be in the dry weather months when there is the need and the system can meet the alternative storage requirements under present provincial regulations.

Demand for reclaimed water opportunities include UVic irrigation and toilet flushing; golf course irrigation; and potentially other irrigation water users including municipal parks and adjacent schools in the UVic area.

Four options were analyzed by the consulting team and in each case, taking into account lost revenues from the sale of treated water, each option resulted in an overall loss. To avoid an operating loss the price of reclaimed water would have to be similar to the price of potable water. This analysis was done on the basis of the SENOB treatment plant at the Finnerty Arbutus site. While the two treatment sites on campus would reduce the conveyance piping by $1.5 million, there is an additional cost of $25-$30 million to locate the plant at the UVic sites, as a large pumping station and forcemain would be required to pump sewage from the Arbutus trunk sewer to UVic.

The best water reuse system is for UVic irrigation and possibly surrounding schools, with irrigation and purple pipe use in future new buildings. The cost of retrofitting plumbing systems in existing buildings to accept reclaimed water would be significant and is not considered feasible.

Heat Recovery

The existing average daily sewage flow at the proposed SENOB sewage plant would be 9.6 ML/d. This would increase to 16.6 ML/d for 2030 and 17.2ML/d by 2065. The plant could yield about 50% of the heat demand for UVic. Unfortunately the campus is currently served by a high temperature (115°C) natural gas fired district heating system. This system has been designed to operate at much higher temperatures than are available from effluent heat pumps. In addition, hourly variations in available heat from treated effluent must be considered and a storage tank would be needed to provide additional heat in the early morning when sewage flows are low and heat demands are high.

In order to deal with the limited heat supply, it is proposed to service only a portion of the campus with the effluent heat extraction system. This would include the Commons, Student Union Building, and the Craigdarroch and Lansdowne residences. In the summer, when space heating demand is low, the available heat from effluent would instead be used to provide domestic hot water heating.

Three systems to provide heat extraction were evaluated and a moderate temperature distribution system ranked the best.

Staff members at UVic are commencing an integrated energy study for the entire campus. The information provided in this study will be considered during that review to assess synergies and determine if further steps on this project are warranted.

<u>ALTERNATIVES</u>

1. That the CALWMC receive these reports and recommend that staff forward the final heat recovery study on the James Bay/downtown area to the City of Victoria and the District of Esquimalt for information and consideration; forward the final heat recovery study for the University of Victoria to university staff for consideration with their integrated energy study; and

meet with potential private-sector partners to explore mutual opportunities.

2. That the CALWMC refer the reports back to the consulting team with further recommendations.

FINANCIAL IMPLICATIONS

The cost of phase 1 of the downtown heat recovery system, $12.2 million, is included in the wastewater treatment program project costs. Phase 2, $17 million, would need to be covered by the DES project development budget. The estimated total cost of the James Bay/downtown heat recovery system is $29.2 million.

For the University of Victoria water reuse system, capital costs are estimated at $3.9 million, while the heat recovery system costs are estimated at $12.1 million, for a total cost of $15.9 million.

While the capital costs would be reduced by $1.5 million if the SENOB plant was built at the UVic field sites, there is an additional $25-$30 million to locate the plant at the UVic sites. Projected revenues, using an incentive pricing system, would only cover the annual operating and maintenance and the corresponding loss of revenues from the sale of treated water. The cost of the line from the plant to the campus ($3.5 million) is included in the wastewater treatment project budget. The additional $12.4 million would be subject to external sources for funding.

SUMMARY

The use of reclaimed water and recovered heat must be analyzed for every specific situation as conditions at different sites may vary dramatically; what is feasible in one location may not necessarily work at another location.

The estimated cost of the James Bay/downtown heat recovery system is $29.2 million. The system can be phased, with the cost of the first phase to transport heat from the liquid plant to the energy centre ($12.2 million) included in the wastewater treatment project capital budget. Phase 2, the north downtown district, is estimated at $17 million and would be constructed in conjunction with the establishment of a DES.

The capital costs of the reclaimed water system and heat recovery system for the University of Victoria are estimated at $15.9 million. The cost of the energy line from the Finnerty Arbutus site to the University ($3.5 million) is included in the wastewater treatment project budget. The additional costs of $12.4 million would require funding from sources outside of the core treatment project. Should there be interest in this project with the university, federal and provincial funding could be pursued.

RECOMMENDATIONS

That the Core Area Liquid Waste Management Committee recommend that staff:

1. Forward the final heat recovery study on the James Bay/downtown area to the City of Victoria consideration and further discussion with Capital Regional District staff;

2. Forward the final heat recovery study for the University of Victoria to university staff for consideration with the university's integrated energy study; and

3. Meet with potential private-sector partners to explore mutual opportunities.

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DK:jta
Attachments: 2

Capital Regional District

Core Area Wastewater Treatment Program
Feasibility Study for Heat Recovery for James Bay and Downtown Victoria

Executive Summary

The proposed secondary wastewater treatment facilities for the Core Area present an opportunity for the recovery of heat from raw wastewater or from treated effluent to provide heat for use in buildings and for process heat at the wastewater treatment facility. Previous studies have recommended that this option be examined in further detail to determine its technical and cost viability. In order to further examine this concept, a more detailed feasibility study on the recovery of heat for use for the James Bay and Downtown area was carried out.

Available Heat and Heat Demand

The existing average sewage flow during the fall and winter period (October 2008 to March 2009) at the proposed McLoughlin Point wastewater treatment plant is 83.4 ML/d. The projected average dry weather flows are 84.2 ML/day for 2030 and 87.5 ML/day for 2065. The amount of saleable heat is estimated at 70% of the available heat since space heating is not required for the summer months though domestic hot water, which often sources off end users boiler systems, is required year-round in the downtown core especially in the residential buildings and the hotels. Some of the available heat will also be used for process related functions such as digester heating and biosolids drying. The estimated saleable heat that can be extracted from the treated effluent at McLoughlin Point is summarized in Table E.1.

Table E.1 – Estimated Saleable Heat (GJ/yr)

Year	Total Annual Heat Available	Estimated Saleable Heat
2009	1,505,951	1,054,166
2030	1,521,516	1,065,061
2065	1,581,147	1,106,803

Figure E.1 shows the diurnal variations in sewage flows and extractable heat at the McLoughlin Point wastewater treatment assuming a wastewater temperature of 12C.. This figure also shows the hourly variations in winter heat demand for the Downtown and James Bay Areas based on the capacity of the existing hot water boiler in the James Bay and Downtown area.

At the 2030 average day flow of 84.2 ML/d, the consistent heat output from treated effluent would be approximately 23,000 KW. This is insufficient to meet the winter heat demand for the Downtown/James Bay areas. Early in the morning, the supply would satisfy less than 20% of the demand. This would rise in mid-day to approximately 50% of the winter demand.

In order to increase the supply of heat in the early morning, a cursory analysis of supplementing with heat extracted from sea water was carried out. However, because of the high cost, this was not retained for further analysis and the options for a District Energy System for the James Bay and Downtown area were sized on the basis of supplying 23,000 KW.

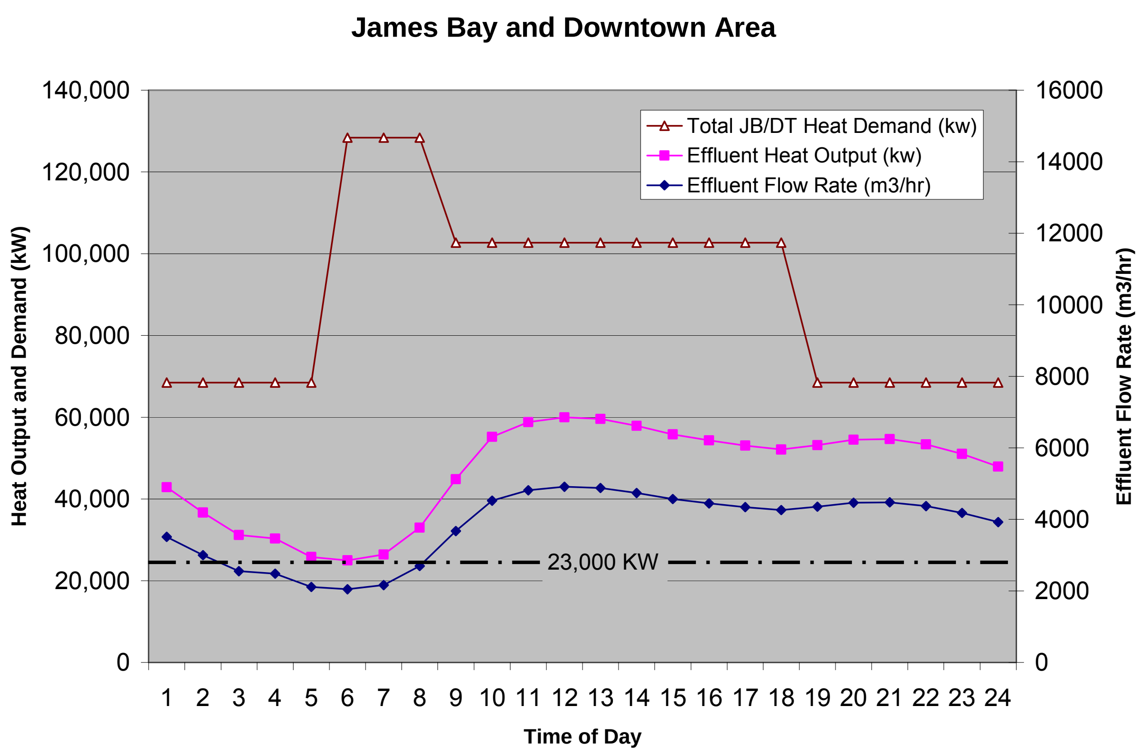

Figure E.1 – Hourly Variations in Heat Demand and Heat Available from Effluent

<u>Options for a District Energy System for James Bay and Downtown Area (Options 1 to 3)</u>

Based on the case studies carried out during the course of this project, it appears that most of the existing boiler systems in the James Bay and Downtown core are operating at design temperatures of 80^{0}C or more. Modern day systems are designed at lower temperatures of 60C to conserve energy. As a result, a District Energy System (DES) would be required to supply heat at this temperature in order to meet the peak winter demand of potential customers and still continue to use existing mechanical heating systems. Modern energy efficient boilers are now designed to operate at lower temperatures of 60^{0}C. There are three options on how this could be achieved for high temperature DES serving the James Bay and Downtown areas:

- Option 1 – Distribute the heat at ambient temperature (up to 20 ^{0}C) and install heat pumps at each point of use to boost the water temperature to 80^{0}C.

- Option 2 – Install dual system heat pumps at the wastewater treatment plant and distribute water heated to 80^0C.

- Option 3 – Install heat pumps at the wastewater treatment plant for the first lift in temperature, distribute the heat at 35^0C and install a second set of heat pumps at the point of use to lift the temperature to 80^0C.

In all cases, it would be necessary to install two sets of heat pumps. It is noted that a dual heat pump system to boost water temperature to 80^0Cconsumes significantly more power than a system with only one lift to a lower temperature such as 65^0C.. The first set of heat pumps would boost the temperature from 12 -14^0C to 35^0C. The second heat pump would lift temperature to 80^0C. Options 1, 2 and 3 would require the installation of a 6.5 km long dual pipe closed loop system from the proposed McLoughlin wastewater treatment plant to the biosolids treatment facility in the Upper Victoria Harbour. The cost associated with piping the heat over such a length would be very high at $14.9 million considering that excavation would be required in busy downtown streets, which already have a significant amount of underground utilities. There is also a concern that mechanical rooms in existing buildings may not have the available space to install the heat exchangers and heat pumps that would be needed to connect to the DES. A case study review of several buildings in the Downtown core indicated that this was indeed the case.

Option for a District Energy System for North Downtown (Option 4)

For the above reasons, a fourth option, referred to as Option 4 was identified. With Option 4, the service area would be reduced in scope to include only the biosolids handling facility located in the Upper Victoria Harbour and the north portion of the downtown area north of Pandora Street. This portion of the downtown area is not as developed as the area located further south and it is anticipated that that most of the customers of a DES would consist of new buildings instead of older buildings. These new buildings would be designed with modern more energy efficient boilers operating at a lower temperature of 60^0C. There would be no requirement for the significant retrofit costs as is the case in the downtown core with older buildings. This option would result in lower capital and operations costs.

Cost Summary

The capital cost, the annual operating and maintenance (O&M) cost and the estimated revenues for the four options are summarized in Table E.2. The capital costs include interim financing estimated at 4% of all direct and indirect costs. The O&M costs shown in Table E.2 do not include the annual debt servicing. However, it should be noted that based on interest rate at 6% and an amortization period of 25 years, the annual debt servicing would be at $54,000 for each $1 million of capital cost not covered by senior government grants. A triple bottom line analysis was carried out on all four options and is summarized in Table E.3.

Table E.2 – Summary of Costs and Revenues

	Option 1 - Ambient Temp. (<20^{0}C)	Option 2 -Moderate Temp. (80^{0}C)	Option 3 - Low Temp. (35^{0}C)	Option 4 - Hybrid North Downtown Only
	James Bay and Downtown			
Capital Cost	$54,410,000	$45,632,000	$50,737,000	$29,274,000
Annual O&M Cost (1) (3)	$4,078,000	$3,933,000	$4,017,000	$2,521,000
Annual Revenues (1)	$4,596,000	$4,228,000	$4,412,000	$3,018,000
Annual Net Revenues (1)	$518,000	$295,000	$395,000	$497,000
Annual Carbon Credit (2)	$495,000	$451,000	$473,000	$314,000

(1) Based on selling 90% of available heat. Initially it is anticipated that revenues will be much lower at start up, perhaps in the 25% range and will ramp up as new development occurs and energy prices increase. Green developments may also accelerate the demands for recovered heat.

(2) Based on selling 90% of available heat and assuming carbon credit at $25/tonne $C0_2$

(3) Annual debt servicing of $54,000 per $1 million of capital cost not covered by senior government grant is not included in the annual O&M cost.

Table E.3– Summary of Triple Bottom Line

	Option 1 - Ambient Temp. (<25^{0}C)	Option 2 -Moderate Temp. (80^{0}C)	Option 3 - Low Temp. (35^{0}C)	Option 4 - Hybrid North Downtown Only
	James Bay and Downtown Area			
Economic	49	62	51	88
Environmental	63	53	57	67
Social	36	70	45	70
Total	147	185	153	225

Analysis of Options for a Large DES System for James Bay and Downtown (Options 1 - 3)

The difference in capital and in O&M costs between the three options for a large District Energy System for James Bay and Downtown is not significant. The capital cost of Option 2 is the lowest of the three options for a large DES mainly because of the economies of scale resulting from having all equipment and the heat pumps at one location.

It appears that most existing boiler systems are operating at "legacy" temperatures of 80^0C or more. As a result, a DES would be required to supply heat at this temperature in order to meet the peak winter demand of potential customers. If the DES were to supply heat at a lower temperature, either ambient temperature or up to 60ºC, a combination of heat exchangers and heat pumps or a back-up-boiler would be needed on the customer's private property to increase temperatures. It appears, however that in most cases, the mechanical rooms in existing buildings would not be large enough to accommodate this equipment. For existing infrastructure areas such as James Bay and Downtown Victoria, it would be preferable for a DES to supply heat at a temperature of 80^0C.

The net revenues generated by the sale of heat to the existing buildings in James Bay and Downtown Victoria are low in comparison to the capital cost of $45 million that will be incurred for the extraction and distribution of this resource based on Option 2. When the value of the carbon credit is added, the annual net revenues would increase from $295,000 to $746,000. However, the payback period exceeds 50 year.

It is anticipated that these revenues will be realized given the Province's desire to move towards being carbon neutral but it will take some time before this occurs. A reasonable estimate is to assume initially that no more than 30% of the available heat will be used and this would include the heat used for heating of digesters which is estimated at 14 % of peak demand. There are several reasons why the capital, O&M costs and payback period are large for a district energy system serving the James Bay and Downtown area:

- The length and resulting cost of the heat transmission main from the WWTP to the most distant point of use which would be the digesters located in the Upper Harbour. This transmission main cannot be phased since the biosolids facility which would be connected to the heat recovery system is at the far end of the pipe. Also this pipeline is expensive to construct because the heat loop must be installed in developed roadways with a number of utilities, some of which will require relocation.

- The heat extracted from the effluent must be lifted twice from a temperature difference (potential) of 7ºC in winter (12ºC – 5ºC) to the required end user temperature of 80ºC. The size and cost of the equipment to accomplish these two lifts is significant. In addition, the electrical power consumption for the pumps and heat pumps is significant and increases operating costs substantially.

- The diurnal low flows early in the morning limit the amount of consistent available heat that can be extracted from the effluent. Since the peak demand occurs when flows are lowest and therefore the amount of heat that can be extracted, the net sales are limited. These low net sales adversely affect the payback on the significant capital costs for equipment.

- Cost of buildings to house the heat pumps either at the wastewater treatment plant for a moderate temperature heat distribution system or at each point of use for other options. In the case of ambient or low temperature distribution, it will be necessary to expand the mechanical rooms in many existing buildings to provide additional space for the heat pumps.

- Energy and carbon prices for heating with current energy sources are still too low to be able to charge more for a DES unit of energy. If energy prices were more in line with European prices, revenues would be higher and the payback period would be reduced. At some time in the future a DES may become more attractive if energy prices increase.

<u>Analysis of Option for a Smaller DES System (Option 4)</u>

Modern heating systems, primarily in the last decade or so, are designed using condensing boilers which operate at significantly lower temperatures of approximately 60^0C (140^0F). As well, the proposed digesters will be designed to operate at 55^0C (131^0F). These temperature levels align much better with the temperature-coefficient of performance (COP) constraints of modern high quality heat pumps. The COP at these temperatures would make the business case more favorable as factors like transmission heat loss, equipment size and needed electrical energy would be reduced. Since the potential customers of a DES in the north portion of the downtown core would likely consist of new development as opposed to retrofitting existing buildings, the temperature of the DES could be reduced to 60-65ºC making Option 4 more financially attractive.

<u>Conclusions</u>

The existing buildings in the James Bay and Downtown core are served by high temperature (>80^0C) or steam heating systems. It would be very challenging and cost prohibitive to implement a district energy system to service the James Bay and Downtown area. The huge capital cost needed to lift wastewater heat to 80ºC and convey it through a 13 km pipe loop does not make a good business case based current energy prices and carbon credit at $25/tonne. The payback period exceeds 50 years.

The business case and economics of construction favour construction of a smaller scale District Energy System to serve the north portion of the downtown core in close proximity to the proposed biosolids facility (Option 4). Consideration should be given to constructing a smaller energy system to service the north portion of the Downtown area. This smaller energy system could be integrated with the energy requirements of the biosolids facility located in the Upper Victoria Harbour.

Heat extracted from the effluent would be conveyed to the biosolids facility at ambient temperature (<20^0C) thus eliminating heat losses along this line. The transmission line would go through Esquimalt and Victoria West eliminating the need to include it in the tunnel under Victoria Harbour. The pipe could be attached to the Bay Street Bridge.

A district heating facility housing the heat pumps could be located at the biosolids facility and hot water at a temperature of 60-65^0C would be distributed to the biosolids process equipment and the nearby north portion of the downtown area. This system would be designed to take into account the lower operating temperature of newer heating systems.

The capital cost of this smaller DES system is estimated at $29,274,000. This system can be phased with the cost of the first phase estimated at $12,258,000. This amount includes the construction a non-insulated ambient temperature transmission line from the WWTP to the biosolids facility and sized for the needs of the biosolids facility and the north downtown area. This amount includes the heat exchangers and the heat pumps sized for the biosolids facility only. In a second phase, estimated at $17,016,000, a loop to serve the north downtown area with an insulated line to a temperature of 65^0C together with additional heat exchangers and heat pumps would be constructed.

Since it is proposed to use only two thirds of the extractable heat to provide process heat to the biosolids facility and the north Downtown area, a significant amount of energy would be available for other developments in Victoria West and Esquimalt.

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Section 1.0 Introduction

1.1 Introduction

The Capital Regional District (CRD) is planning the construction of a secondary wastewater treatment facility at McLoughlin Point. The proposed location for this plant is on a parcel of land owned by Imperial Oil and used as an oil delivery terminal. The site at McLoughlin Point is too small to accommodate the biosolids treatment portion of the plant. One of the options under consideration is to locate the digesters and the other solids handling processes at a separate site in the Upper Victoria Harbour.

The recovery of heat from raw sewage or from treated effluent to supply heat to large users is one of the areas where resources from wastewater can be recovered. Several earlier preliminary assessments have indicated that there may be an opportunity pending further investigation to use a significant amount of the heat generated from the wastewater. This may potentially be utilized by large users in the James Bay and Downtown area to meet some of their needs for space heating and domestic hot water., thereby offsetting the use of natural gas and reducing the carbon footprint of these buildings.

Heat recovery requires infrastructure to: (1) transfer the heat from the effluent to a clean heat transport liquid through heat exchangers, (2) lift the temperature of the clean liquid to a level that is usable by boiler systems through the use of heat pumps, (3) pumping of heated liquid, (4) distribution of the heated liquid through a network of pipe, and (5) connection to the customers.

This report examines various options and requirements for the various components of the infrastructure needed to deliver heat to potential users in the James Bay and Downtown areas.

1.2 Challenges and Opportunities

Perceptions of treated effluent as a waste material can affect the willingness of clients, public, potential customers and regulators to embrace the idea that treated effluent is a resource that can be utilized for heat or cooling. Open loop geo-exchange systems often rely on water from aquifers in the earth that is usually pumped from wells at approximately 12^0C, the very same expected lowest temperature of treated effluent water! Treated effluent represents an excellent source of water for operating heat pumps and when the effluent is between 12^0C and 25^0 C in summer and shoulder seasons, heat pumps operate even more efficiently than with 12^0 C source water. Heat pumps do however consume electricity for their operation and this power consumption can be significant.

Before options for a treated effluent utility are described in detail, the technical, regulatory and perception challenges of heat exchange from wastewater must be addressed. Previous effluent heat recovery projects and studies have identified the following challenges:

- The lowest treated effluent flows occur in the early hours of the morning when heating demands are generally the highest. Buildings typically experience a demand spike in the morning to heat up the building for user comfort. Effluent flow, and therefore heat supply typically lag demand by a few hours in the early morning. Treated effluent flows can also vary from season to season and even during certain weather conditions if inflow and infiltration into the sanitary sewer system are an issue. Therefore, the careful selection of design constraints that consider peak and lowest treated effluent flows is essential to a successful system.

- Total required heating power demand (KW) far exceeds the heat supply. This shortfall would have to be compensated by either reducing demand (e.g. reducing number of buildings connected) or increasing supply by employing an "energy source mix" from, for example, sea water, backup boiler possibly fired with bio-methane or natural gas, solar thermal and/or geothermal.

- Treated effluent can be corrosive and any metal components can corrode if proper materials are not specified. Entrained air is present in large quantities in treated effluent, thus making the design of high capacity air venting systems essential for any closed loop or circulating pipelines. The presence of available entrained air, and thus oxygen accelerates the corrosion of any metal components in the pipeline system.

- Secondary treated wastewater contains small amounts of suspended solids, thus the fouling of any heat transfer or heat exchange surface can be an ongoing concern reducing heat transfer efficiency. Treatments for this condition include online heat exchanger cleaning systems, spiral "tube in tube" heat exchangers similar to those used in the pulp and paper industry, and heat exchangers with a high internal scouring velocity in order to prevent fouling.

- Pipelines for conveyance of the treated effluent are costly and must have proper clearance from watermains and other utilities, in order to avoid cross contamination with domestic water utilities and satisfy regulatory requirements.

Ministry of Environment standards dictate the quality and temperature of discharged effluent, as well as the requirement to not contaminate the discharged effluent in any way. Usually, any treated effluent heat exchangers must be of the double wall type, adding cost and complexity to whatever heat recovery system is installed.

Section 2.0 Example of Existing Heat Recovery Installations

The following are examples of a district energy systems and /or heating system using heat extracted from treated effluent. Similar systems are in operation throughout North America and Europe.

Okanagan College

There are existing operating systems and projects that utilize treated effluent water as a source for heat pumps. One such example is Okanagan College's Clearwater system, designed by Stantec in 2002.

Okanagan College's KLO Campus is located in Kelowna, BC, and was retrofitted with a heat pump heating system that utilizes treated effluent water from the adjacent City of Kelowna Wastewater Treatment Facility. The "Clearwater" system was first operational in 2003/2004 and is used to provide about 40% of the peak heating demand for the campus.

The Clearwater system utilizes a small fraction of the available City of Kelowna wastewater flow. About 3.3 ML/d of treated effluent water are drawn from a pipeline that flows at approximately 71 ML/d, thus lowering the temperature of the discharged effluent by only 0.47°F. The heat pumps in the Clearwater system provide heat to approximately 3,500 m^2 of campus buildings, and distribute that heated water through existing underground insulated district heating piping.

Kelowna Wastewater Treatment Plant Maintenance Building

A second example of treated effluent heat recovery utilizing heat pump technology is the City of Kelowna's Wastewater Treatment Facility new Maintenance Building. The new building is targeting LEED™ Silver registration, and one of the main components of the facility's energy reduction system is the heating and cooling systems that utilize heat pumps connected to treated effluent water. The plant maintenance facility is located on the same site as the wastewater treatment plant.

Okanagan Centre for Learning

A third example of treated effluent heat recovery is Okanagan College's new Centre for Learning. This new facility is targeting LEED™ Gold registration, and incorporates a heat pump heating and cooling system that is connected to receive treated effluent water from the City of Kelowna's Wastewater Treatment Facility. The Centre for Learning building has been operating since mid 2009.

The Okanagan College Clearwater system is an example of an "ambient" temperature district heating system. The Clearwater system currently has two main usage points or customers. The main usage is through the College's Central Heating Plant Building that houses the heating boilers and heat pumps for the main campus, and the second usage is for the new Centre for Learning Building, where new heat pumps and treated effluent heat exchangers are installed.

The ambient distribution system utilizes purple pigmented ("purple pipe") non-potable AWWA C900 Class 150 PVC piping with push on bell and spigot joints. C900 piping is commonly utilized in municipal water works distribution piping, although it is coloured bright blue for that application. Piping for distribution of the treated effluent water is pigmented with purple dyes, and is marked "Non-potable" along the spine of the piping, with the spine turned upward in the trench during underground installation to ensure that it cannot be mistaken for potable water piping during later excavation.

The purple PVC piping is installed in the same manner as conventional water works piping, utilizing common excavation, installation and backfilling methods, and is installed below the frost level without external insulation.

The treated effluent water is piped to utility customers using the C900 piping, where a heat exchanger separates the treated effluent water from the customer's closed loop piping systems.

Whistler Athlete's Village

The Whistler Athlete's Village district energy system consists of a two pipe closed loop energy system operating at ambient temperature and using heat extracted from the Whistler WWTP as the primary source of energy. The secondary source of energy consists of natural gas boiler. The source of gas would be either the landfill or natural gas. The secondary source is required to maintain the capacity of the DES when the effluent flow and temperature are inadequate.

The district energy system is designed to provide 70% of the peak building load. Electric duct heaters are installed within the buildings to provide standby heat and will also be sized to meet approximately 70% of the peak building load. As such, the electric duct heaters would more than adequately supplement the DES to meet both peak demand and any upset operating conditions. The supplemental heat provided by the duct heaters will only be required for short periods during the coldest weather. The system also has back up natural gas fired boilers, which can be used to provide additional supplemental heat as necessary to the loop.

Saanich Peninsula STP Thermal Energy Recovery

The proposed district energy sharing system will be a closed loop system with the supply water temperature into the loop between 11^{0}C and 30^{0}C. Plate heat exchangers located at the sewage treatment plant will inject heat into the system. The effluent will be pumped through the primary side of the heat exchangers and the liquid will be circulated into the system using VFD controlled water pumps.

Each building that is connected to the system will require a heat pump to increase the water temperature. The heat pumps at each point of use will be located in separate enclosures within the building if the mechanical room is large enough. The heat pumps will be integrated with the existing systems so that, should the heat pump system fail, the existing mechanical systems within the buildings would keep operating effectively.

The main users for the recovered heat will be the Panorama Recreation Centre and the Saanich Peninsula sewage treatment plant. These will have externally located metal enclosures containing heat pumps. Pumping and controls will be arranged such that both heat sources complement each other. If the rink refrigeration system can produce warmer water than the effluent, then part of the DES will be allowed to rise in temperature to improve the efficiency of the nearby heat pumps. The system may be extended into residential areas at a later date.

Section 3.0 Heat Analysis

3.1 Available Heat

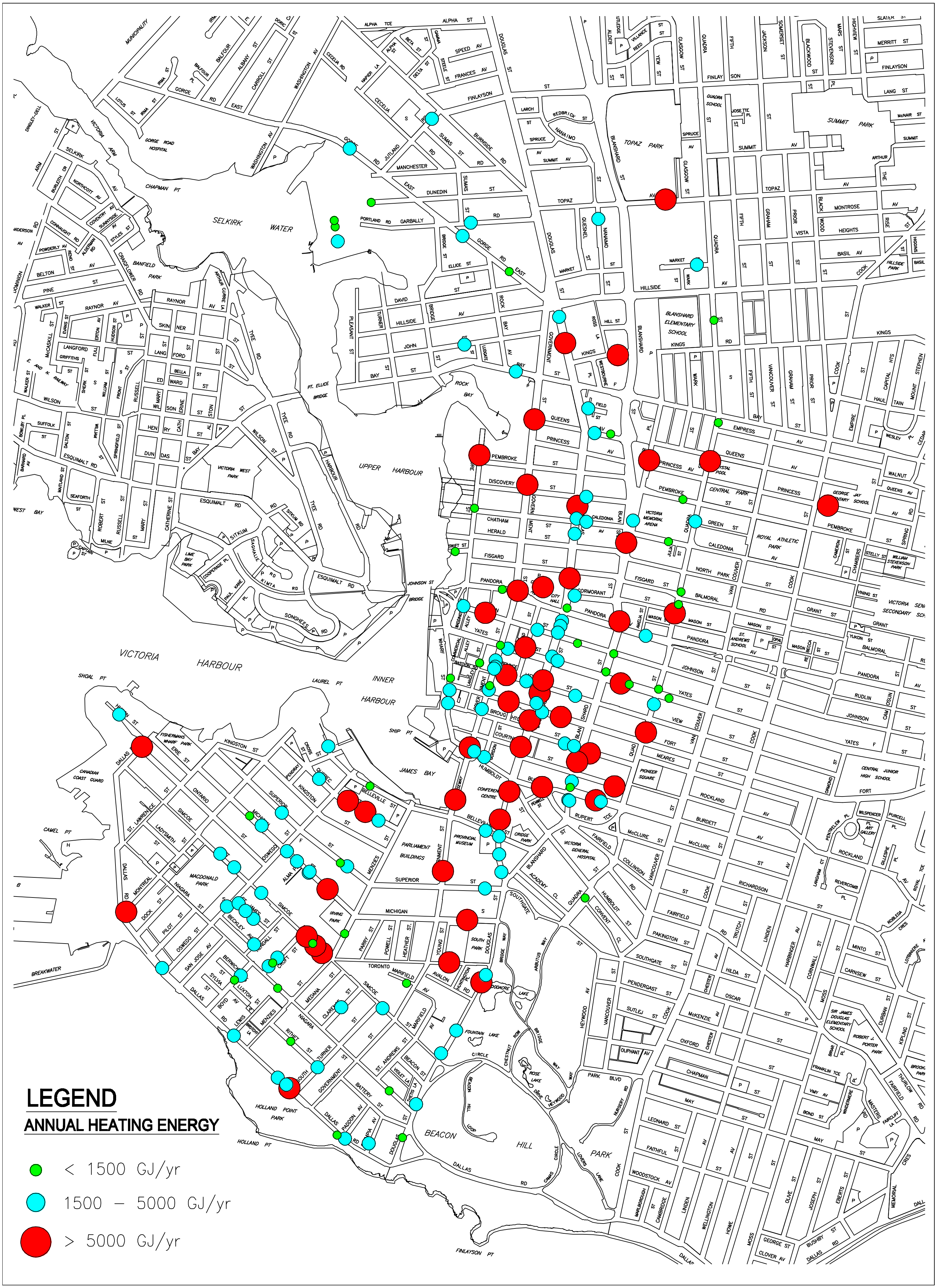
The existing average sewage flow at the proposed McLoughlin Point wastewater treatment plant during the winter months (MPWWTP) is estimated at 83.38 ML/d. This estimated existing flow has been calculated by summing the flow records at Clover Point and Macaulay Point outfalls and subtracting the estimated flow from the proposed Saanich East plant that will be diverted to the new Finnerty outfall. This flow includes the flow from the West Shore which will initially be serviced by the plant at McLoughlin Point. Based on this flow, the total annual heat available is 1,636,904 GJ/yr. Heat losses through a transmission system operating at 80^0C are estimated at 8% leaving 1,505,951 GJ of available heat for the entire year. The existing flows as calculated above are similar to the projected dry weather flow for the facility of 84.2 ML/day for 2030 and 87.5 ML/day for 2065. This increases the year-round available heat to 1,521,516 GJ and 1,581,147 GJ respectively. The amount of saleable heat is estimated at 70% of the available heat since space heating is not required for the summer months though domestic hot water, which often sources off end users boiler systems, is required year-round in the downtown core especially in the residential buildings of James Bay and in hotels.

Table 3.1 – Estimated Saleable Heat from MPSTP (GJ/yr)

Year	Total Annual Heat Available	Estimated Saleable Heat
2009	1,505,951	1,054,166
2030	1,521,516	1,065,061
2065	1,581,147	1,106,803

* Assuming status quo consumption practices and 1% per year compounded growth projections

The estimated heat available from treated effluent is based on the following assumptions: (1) temperature of treated effluent of 12 ºC, and (2) allowable minimum temperature of effluent of 5 ºC prior to ocean discharge. At first glance, it appears that the heat demand density in the downtown and James Bay areas would provide an excellent opportunity for the viability of a district heating system (DHS). For these areas, and along a corridor towards the proposed biosolids facility located in the Upper Victoria Harbour, installed boiler power data obtained from the BC Safety Authority indicates a demand of 223,162 GJ/year for James Bay and 859,155 GJ/year for the downtown area. Based on site visits at three installations in the James Bay and Downtown, it appears that the BCSA boiler data is not current. It should be noted that boilers west of Quadra Street and north of Gorge Avenue were not included as they were considered too remote and too small for connection to the DHS loop. Based on demand density, the best location for the DHS loop would be along Douglas Street. The BCSA data provides a good overview of current boiler installations in the James Bay and Downtown area. The boiler information is shown in Figure 3.1.



LEGEND
ANNUAL HEATING ENERGY
< 1500 GJ/yr
1500 – 5000 GJ/yr
> 5000 GJ/yr
VICTORIA HARBOUR
INNER HARBOUR
UPPER HARBOUR
SELKIRK WATER
JAMES BAY
BEACON HILL PARK

A more detailed analysis has been performed on the flow data at McLoughlin and "boiler power" demand for Downtown and James Bay. This was undertaken due to concerns over the significant variations in the amount of heat that may be available from wastewater throughout the day in the winter months. The hourly variations in sewage flow and therefore the available heat are shown in Figure 3.2. As can be seen, sewage flows from midnight until 8:00 am are low, with the lowest flow occurring around 5 am. This limits the supply of heat at a critical time early in the morning when most buildings begin to ramp up their heating systems to meet the occupied demand.

Figure 3.2 also shows the hourly variations in winter heat demand for the Downtown and James Bay Areas. The heating systems go into set-back mode between the hours of 8 pm - 5am. This is when demand is at its lowest. At approximately 5 – 6 am, there is a sharp spike in demand as the boilers ramp-up to heat the buildings for the occupants arriving between 7 am and 9 am. The system reaches a daytime equilibrium and then drops in the evening. Unfortunately, the morning peak heating demand occurs while the sewage flows are still low. This situation is the reverse to what would be optimal, where supply would lead demand.

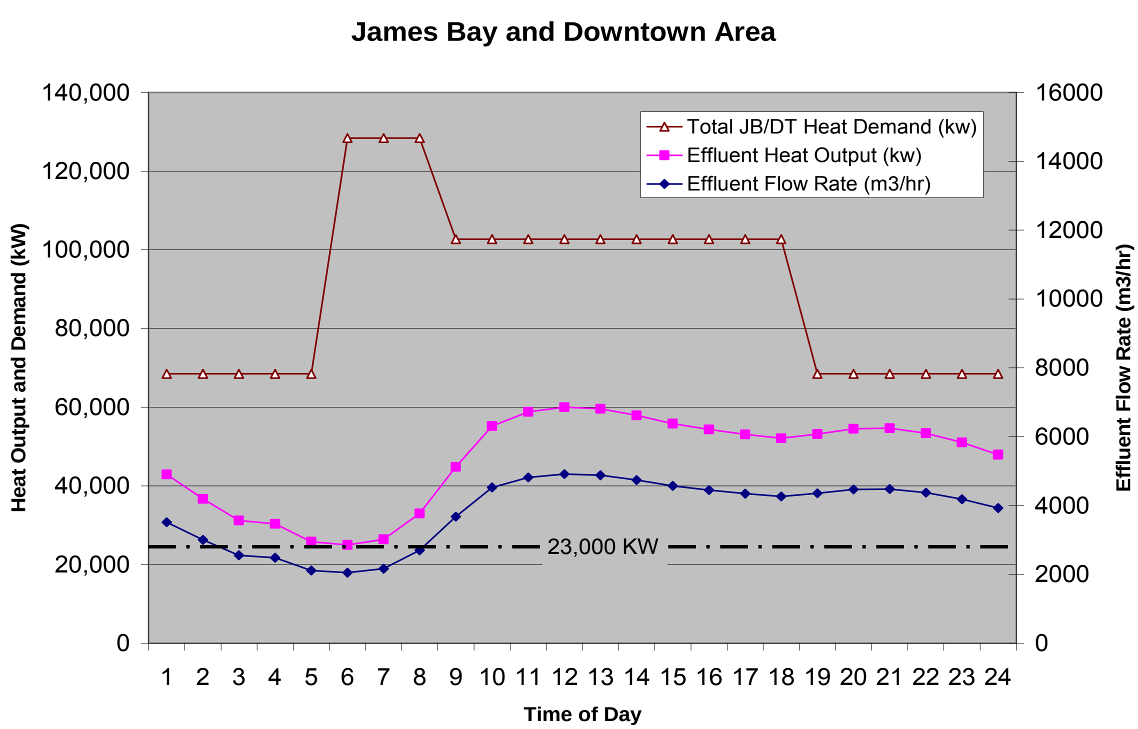


Figure 3.2 – Hourly Supply / Demand Relationship for James Bay and Downtown (2009)

Even at the 2030 average day flow of 84.2 ML/d, the consistent heat output from treated effluent would be approximately 23,000 KW. This is still insufficient to meet the winter heat demand for the DT/JB areas. Early in the morning, the supply would satisfy less than 20% of the demand. This would rise in mid-day to approximately 50% of the winter demand. As such this must be considered when the business case evaluation of the capital investment for these facilities is completed.

As discussed in subsequent sections, the proposed approach is to examine options to service a portion of the DT/JB and the demand of the biosolids treatment facility which may be located in the Upper Victoria Harbour area.

A case study review of select buildings in the downtown core was completed. Three of the buildings investigated in the DT/JB area use hot water heating systems and typically operate at temperatures of 82ºC (180ºF). The older Government and Legislature buildings are serviced by a high temperature steam plant. Steam heating systems operate on a closed loop at a much higher temperature and cannot utilize moderate temperature hot water which can be produced from recovered effluent heat.

As discussed in later sections, the highest hot water temperature that can be supplied from heat pump devices is 80 ºC (176 ºF) without major reductions in the coefficient of performance (COP). This temperature could have a significant impact on the amount of heat that may be delivered within a building from the existing heating equipment. Retrofit of existing buildings will involve significant capital costs.

Due to the curve-linear heat transfer relationship that exists for heating equipment, any reduction in system temperature impacts the amount of heat delivered significantly. The amount of space heating, however, may be sufficient for most of the shoulder season. During the coldest winter days, the boilers would need to be fired to meet demand in existing buildings designed for higher system temperatures. Further testing of specific building systems would be required to confirm both the effects of the lower temperature water on heat supply to the buildings and to see how much of the shoulder heating season the available heat from wastewater and temperature level can cover.

3.2 Sea Water Exchange for Additional Heat Source

As indicated above, a total of 23,000 KW of heating power is available from the sewage at current 2009 flows. The available heat drops through the night and is at its lowest level at 6:00 am which is also the time when the heat demand spikes. In order to provide a more consistent and reliable utility, a number of supply options would be available:

- Heat extraction from sea water
- Gas fired back-up boilers
- Solar thermal collectors
- Building heat reclaim

- Geo-thermal, and
- Effluent storage tanks

The option of supplementing the low sewage flows in early morning heat supply by extracting heat from seawater was briefly examined. In order to source the additional 25,000 KW of heat to reach a consistent 50,000 KW throughout the day in winter, approximately 1265 L/s (20,000 gpm) of seawater would need to be pumped through a titanium-stainless steel heat exchanger. The seawater would be drawn through a 900 mm diameter intake pipe laid on the seabed with the inlet being closer to the surface (shore) and the outlet running deeper to take advantage of the temperature difference. In an open loop, submersible pumps would lift the seawater to the heat exchangers and then return it directly to the ocean after the heat has been extracted. There would be no cross contamination of the seawater.

On the other side of the heat exchangers, a clean fluid pipe loop with pumps would be controlled by a Direct Digital Control (DDC) system to extract the heat in an identical way to the system that extracts heat from the effluent. A redundant pump would be installed on both the seawater and clean fluid closed loop side of the heat exchangers to compensate for periodic maintenance and unexpected failure. This is shown schematically in Figure 3.3.

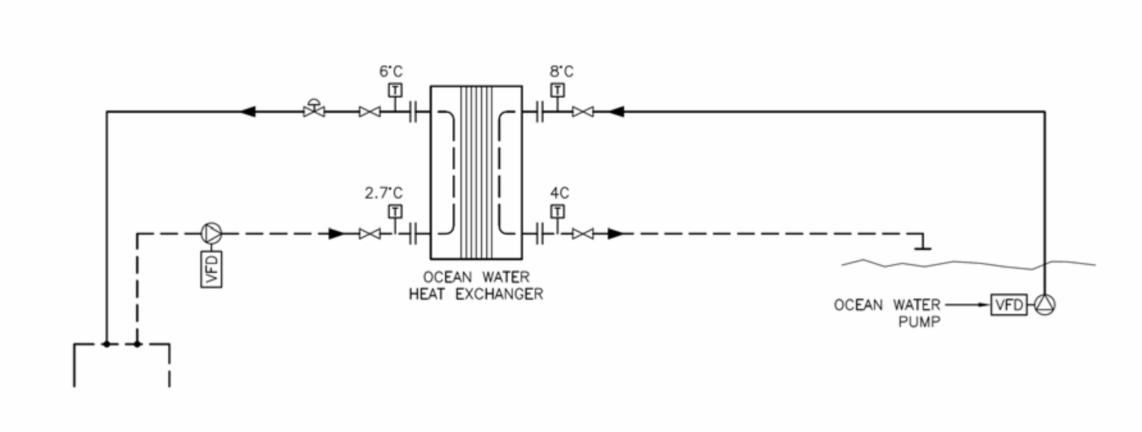


Figure 3.3 – Sea Water Heat Exchange

The costs for this system depend heavily on what type and quality of heat exchanger that is selected. The costs are estimated to be in the range of $12 to $15 million as follows:

• Ocean Intake and outlet –assumes 150 m each	$2.1 million
• Titanium-stainless steel heat exchangers and water pumping	$6.0 million
• Building	$0.7 million
• Contingency, engineering, financing, inflation to 2014	$4.4 million.
• Estimated cost	$13.2 million

This amount does not include the cost of heat pump to lift the temperature from 7^0c to 80^0F and the larger distribution pipe to carry the additional extracted heat to the various users in the James Bay and Downtown area. Because of the high cost, extraction of heat from seawater was not considered further.

3.3 Types of Heat Exchangers and Heat Pumps

Wastewater to Water Heat Pumps

The wastewater-to-water system of heat exchangers and heat pumps relies on a source of heat that has a stable temperature range and a higher level than air in winter months. The temperature of treated effluent during the winter months would be in the range of 12^0C to 14^0C with minor variations. Raising the water temperature to 55^0C (131 F) could be achieved with heat pumps having a coefficient of performance in the range of 2.5 to 3. It appears that a COP of 3 is the upper limit and could only be achieved with more expensive high quality products, under very specific conditions of steady loads that allow operation at peak efficiency. The drawback of water-to-water heat exchange is the considerable variation in diurnal sewage flows which in turn result in variations in available heat. As discussed earlier in this report, it is proposed to resolve this problem by sizing a district energy system on the basis of the minimum available heat of 23,000 KW which would occur early in the morning.

Existing buildings in James Bay and the downtown core have hot water boiler systems that operate at temperature of 80^0C or more. In order to boost the temperature to this level, two sets of heat pumps are required and the resulting COP would be in the range of 2.7 to 2.9. The dual heat pumps not only are more expensive from a capital cost perspective but they also increase operating costs significantly.

Air to Water Heat Pumps

An air-to-water system would rely on an air source that would have significant variations since outside air temperature will vary throughout the day and on a weekly and monthly basis. With an average outside air temperature of 4^0C during the month of January and a heating water temperature of 55^0C, a COP of 2.3 would be at the upper limit and only be achieved with high quality equipment. However, temperature at night often dips below freezing and under these conditions the COP would be lower.

One of the main disadvantages of air-to-water heat exchange in our coastal winter climate is that high humidity in combination with sub-freezing temperatures of the refrigerant will result in the build-up of frost on the unit. This can quickly result in an interruption of service since the heat exchanger cannot deliver heat when defrosting. For this reason, it is the practice to have two units where the constant supply of heat is critical. Additional considerations include the size of the coil, high amounts of air that need to be circulated to extract heat (air has low specific heat).

Comparison of Efficiency of Heat Pumps

It appears that the previous comparison completed by other of the efficiency of air-to-water with wastewater-to-water heat pumps indicating an overall weighted performance factor of 1.4 in favour of wastewater-to-water heat pumps is based on the following:

- Water temperature is boosted to 55^0C only.
- Treated effluent temperature of 14^0C
- Air temperature of 4^0C
- Upper limit of coefficient of performance for heat pumps using high quality products

However the wastewater-to-water heat pumps require a significant infrastructure in order to extract and convey the heat including heat exchangers to transfer the heat from the effluent to a clean liquid before the temperature of the liquid can be raised by a heat pump. Following the heat pump, this higher temperature liquid must then be conveyed to each point of use. At the point of use, another heat exchanger is required to transfer the heat from the DES to the heating system of the building.

3.4 Cooling Demand

Building cooling can be accomplished by exhausting heat to the effluent.

Cooling demand in Victoria's mild summer climate is significantly less than heating; approximately a 70/30 split or less. As well, few buildings, other than the largest high rises and larger complexes have centralized systems which would be necessary for a district cooling system (DCS) to tap in to. Most modern hotels and residential complexes employ small in suite heat pumps for cooling.

To add to the complexity, large high rise buildings in the downtown core may have their centralized cooling equipment located in rooftop mechanical rooms. To bring the DCS fluid to the rooftop may involve major re-piping within the end-users facility which would be very costly.

Another disadvantage to the cooling business case is that cooling is conducted with hydro supplied electrical power which has a low carbon footprint associated with it. The carbon cost for cooling therefore is low and has little impact on the business case for a second cooling loop or ambient system.

Section 4.0 Case Studies

A preliminary evaluation on how existing buildings could be connected to a potential District Energy System (DES) was carried out by assessing several buildings in the downtown core. This analysis was carried out in two stages:

- Review of existing boilers within the James Bay/Downtown area to identify how many boilers operating with hot water (as opposed to steam) were located in the downtown area. The location of these boilers was then shown on a plan in order to determine a preliminary alignment for the heat distribution piping.
- Building Owners and/or managers were contacted to arrange a site visit of the existing boiler installations. The purpose of the site visit was to confirm the type of boiler and heating system such as the operating temperature, the age of the boilers, how domestic hot water was produced, the physical arrangement of the boiler room including available area for heat extraction equipment and how piping connections could be done.

The intent of the site visits was to obtain a first hand appreciation of the types of challenges that may be faced with connecting to existing older mechanical systems with the DES. These issues would be representative of the conditions to be encountered in retrofitting buildings in the James Bay/ Downtown core area.

<u>Case Study No. 1 – Harbour Towers Hotel</u>

The Harbour Towers Hotel is located at 345 Quebec Street in the James Bay area. This building was converted from a residential apartment building to a hotel several decades ago. Space heating is provided by 3 boilers. The original boiler from the 1970's operates at 82ºC. This boiler is scheduled to be replaced in 2011. Domestic hot water is provided by a separate gas fired boiler connected to a hot water storage tank. A similar third and separate boiler heats the swimming pool. Both DHW and Pool boilers are newer and operate at a lower temperature of 60ºC. Space cooling is provided by individual units in each room and there is no central cooling system.

The mechanical room is located in the centre of the underground parking. It appears that the mechanical room is large enough to accommodate the heat exchangers that would be required in order to extract heat from the DES and transfer it to the building's heating system. The heat pumps, however, may require more space than is available. Also, the hotel is considering upgrading the old boiler plant in the next year with a new boiler which would be located in the same location as the new space heating boiler plant. Piping connections between the DES system and the mechanical room would require the installation of pipes attached to the ceiling of the parking area. The edge of the parking is located near the street and the piping connection from the building to the DES piping in the road would be a relatively short distance.

Based on discussions with the Chief Engineer of the hotel, the preference would be for a DES to supply heat at a temperature of 82ºC to match the existing system design. If 82ºC heating water could not be generated, the existing boiler would have to remain in place as a back-up to the DES during cold winter days.

This building would be a good candidate to connect to the DES system because the mechanical room is easily accessible and could be enlarged if necessary by encroaching into the parking areas.

Case Study No. 2 – Legislative Precinct

The Legislative precinct is serviced by a DHS that is fed by steam. The central boiler room is located in a separate building on Superior Street between Government Street and Douglas Street. This system provides heat and domestic hot water to the Legislature Buildings, the Royal BC Museum, the Douglas Building, the Douglas Building Annex, the Queen's Printer and other smaller government buildings located on the south side of Superior Street.

The Douglas Building Annex is heated by hot water that has been condensed from the steam boilers prior to being distributed into the building. The Royal BC Museum is heated by newer electric boilers. In these two buildings, the heating systems operate at a temperature of over 93ºC (200ºF). These two building could potentially be connected to a DHS during the shoulder heating season, but would need to switch back to the steam plant source for the coldest winter days. The buildings that are heated with steam cannot be converted to hot water because the piping and the radiators are sized for much higher temperatures and would be too small to provide enough heat, likely even in the shoulder season, if hot water was used instead of steam. As a result, buildings heated with steam cannot be connected to the DHS.

In order to connect the Museum and the Douglas Building Annex to the DES, the following work would be necessary. The manner in which these two buildings could be connected to a District Energy System depends on the temperature of the heating loop. This is discussed further in Section 6.

Action	Option 1 - Ambient	Option 2 - 80ºC	Option 3 - 35ºC
Trench in non-insulated pipes from the road to the heating plant and install pipes to building mechanical room	X		
Trench in insulated pipes and install pipes to bldg mechanical room		X	X
Find floor space for and install heat exchanger(s)	X	X	X
Install heating water conveyance pumps	X	X	X
Install control systems	X	X	X
Find floor space for and install heat pumps for 1st temperature lift	X		
Find floor space for and install heat pumps for 2nd temperature lift	X		X
Connect to existing building space heating system	X	X	X
Connect to existing DHW system, etc.	X	X	X

Only the Museum and the Douglas Building Annex could be connected to a district energy system. However because these building are heated with water at 93ºC (200ºF, the DES which would operate at 80^0C would only be capable of providing heat in the shoulder seasons. It is recommended not to connect these building to the DES because the benefits appear to be minimal.

Case Study No. 3 – Jack Davis Building

The Jack Davis building, located at 1810 Blanshard Street is a provincially owned 8000 m^2 office building constructed in 1992. Space heating and domestic hot water is provided by a boiler system operating at a temperature of 82 °C (180 °F). The boiler room is located in a mechanical penthouse on the roof and there is no available space for additional equipment in the existing boiler room.

In order to connect this building to the DES, the hot water supply would need to be pumped eight floors up to the roof. This would require the installation of two pipes (loop) from the street level to a newly constructed mechanical penthouse where the new heat exchangers would be housed.

The installation of hot water pipes to the mechanical penthouse and the addition of the mechanical room to allow for the installation of the heat exchangers required for the connection to a DES could result in significant expenditures. For this reason, it is recommended not to connect this building to a district energy system,

Case Study No. 4 – Richard Blanshard Building

The Richard Blanshard building is located at 1515 Blanshard Street. This is a provincially owned 2400 m^2 office building constructed in the mid 90's. Space heating and domestic hot water is provided by a boiler system operating at a temperature of 82 °C (180 °F). The boiler room is located in the below ground level. The boiler room is spacious and there is enough space to install heat exchangers but not heat pumps for Options 1 or 3.

Piping connections between the DES system and the mechanical room would require the installation of pipes attached to the ceiling of the parking area. The edge of the parking is located near the street and the piping connection from the building to the DES piping in the road would be relatively short.

This building would be a good candidate to be connected to a district energy system since the mechanical room is easily accessible and appears to have sufficient space to accommodate the heat exchangers.

Based on a review of the case study buildings noted above, it appears that in most instances significant retrofit costs would be incurred in the existing buildings to accommodate the heat generated by a DES. The age of the existing buildings and the original design criteria for these older systems does not make it cost effective to consider retrofit of these heating systems.

Section 5.0 Market Considerations

The use of heat reclaimed from wastewater must be analyzed for each end-customer's specific requirements as conditions at different sites can vary dramatically as noted in the previous section 4. What is feasible or works in one location may not necessarily work at another location. Temperature, capacity and reliability are important issues for all customers. The potential customers have stated, with respect to reliability and connect-ability of a district energy system that: "…making the ability to connect to the system as attractive as possible for the end users is of utmost importance".

Based on the case studies carried out during the course of this study, it appears that most existing boiler systems are operating at "legacy" or original design temperatures of 80^0C or more. As a result, a District Energy System (DES) would be required to supply heat at this temperature in order to meet the peak winter demand of potential customers. There are three options on how this could be achieved for a DES serving the James Bay and Downtown areas:

- Option 1 – Distribute the heat at ambient temperature and install heat pumps at each point of use to boost the water temperature to 80^0C.
- Option 2 – Install the heat pumps at the wastewater treatment plant and distribute hot water heated to 80^0C.
- Option 3 – Install heat pumps at the wastewater treatment plant for the first lift in temperature, distribute the heat at 35^0C and install a second set of heat pumps at the point of use to lift the temperature to 80^0C.

All of the options require dual heat pumps to boost the temperature to the desired 80^0C. This presents several challenges including another set of heat pumps as well as significantly increased operating costs as high power consumption is required to boost temperatures to 80^0C.

Options 1, 2 and 3 would require the installation of a 6.5 km long dual pipe distribution system from the proposed McLoughlin wastewater treatment plant to the biosolids treatment facility in the Upper Victoria Harbour. The cost associated with piping the heat over such a length will be high considering that excavation would be required in busy downtown streets which already have a significant amount of underground utilities. There is also a concern that many of the mechanical rooms in existing buildings may not have the available space to install the necessary heat exchangers and heat pumps that would be needed to connect to the DES. The practical realities of constructing such a system and retrofitting existing building that were designed for use of high temperature water are significant and costs are prohibitive.

For these reasons, a fourth option was identified where the service area would be reduced in scope to include only the biosolids handling facility located in the Upper Harbour and the north portion of the downtown area north of Pandora Street. This area is not as developed as the portion of the downtown core located further south and it is anticipated that most of the customers of a DES would consist of new buildings. New buildings are typically designed using lower temperature heating systems.

Modern heating systems, primarily in the last decade or so, are designed using condensing boilers that operate at significantly lower temperatures of approximately 60ºC (140^{0}F). As well, the proposed digesters will be designed to operate at 55^{0}C. These temperature levels align much better with the temperature-coefficient of performance (COP) constraints of modern heat pumps and there is no need to have a dual boost heat pump system. The COP at these temperatures could make the business case more favorable as factors such as transmission heat loss, equipment size and needed electrical energy would be reduced.

Section 6.0 Alternatives for Heat Extraction

6.1 In-Pipe Heat Exchanger

The extraction of heat from raw sewage using heat exchangers built into the conveyance piping was investigated. This included gravity mains, forcemains or treated effluent outfall pipes using the Rabtherm® product. This product consists of a pipeline with the heat exchanger tubing built into the pipe wall. Currently this patented product must be imported from Europe, however, the North American representative has indicated that it could be manufactured in Canada using imported parts.

Due to the high cost of removal and the product, the use of this in pipe heat exchanger would be limited to newly conveyed mains. In the case of the Mc Loughlin Point WWTP, without considering the significant cost, the in-pipe heat exchanger could be used.

There is one significant limiting factor to the cost vs. heat extraction business metric for this product. The heat potential in raw sewage is constrained by the temperature to which it can be dropped. For the sewage treatment process, the temperature of the raw sewage can only be reduced to 10 ºC before the treatment process is impacted. Since effluent is at the end of the sewage treatment process, its temperature can be reduced to near seawater temperature levels of 5 ºC before it is ejected. This additional 5 ºC temperature difference has a significant effect on both the size of the Rabtherm heat exchange system and on the amount of heat that can be extracted from the wastewater. The in-pipe heat exchanger for a forcemain is shown on Figure 6.1. The heat exchanger tubing is built into the pipe wall with separate inlet and outlet connections for each 5 m long section of pipe.

Figure 6.1 – Rabtherm, Forcemain Heat Exchanger (Left) and Gravity Pipe Exchanger (Right)

If a 900 mm diameter heat exchange pipe was installed in the proposed 2.8 km long forcemain between Clover Point and Ogden Point, the amount of extractable heat would be 10,000 KW. With an 1800 mm diameter heat exchange pipe installed in the land portion of the outfall between McLoughlin Point and Macaulay Point, the amount of extractable heat would be 13,420 KW. The material cost of a 3 m long section is $18,400 for a 900 mm pipe and $34,000 for an 1800 mm diameter pipe. The cost of material alone is estimated at $16.8 million for the 900 mm pipe and $11.3 million for the 1800 mm pipe.

As shown in Figure 6..1, each section of the forcemain heat exchanger must be connected to two heat loop pipes parallel to the pipe and installed in the same trench. A service building to house the water pumps, heat pumps and controls is required.

The cost of material does not include the installation cost or the dual parallel heat conveyance pipes that have to be installed in the same trench as the heat extraction pipe. Because of the high cost of this product, it is recommended to carry out heat exchange using other proven and locally available types of heat exchanger products as discussed in Section 6.2.

6.2 Direct Heat Exchangers

There are various options available for direct heat exchange to closed loop piping systems from treated effluent, seawater and groundwater. Potential options include: brazed plate, plate & frame, tube in tube coiled helical, and shell and tube heat exchanger technology. Each heat exchanger technology has various characteristics that make them either more or less suitable for duty in various functions of the proposed heat distribution system. Each technology is discussed in the sections below.

6.2.1 Brazed Plate Heat Exchangers

Plate and frame heat exchangers are a sandwich of very thin plates of stainless steel that have a thin layer of brazing alloy fitted between each plate during manufacturing. The raw assembly of loose plates are stacked together, and “sintered” or fused together at high temperature in a combination oven/hydraulic press. The resulting assembly is very light in weight for a given output and arguably the most compact of all heat exchangers.

High internal velocities result from the closely spaced thin plates, with a high heat transfer rate. These heat exchangers can be utilized with fluids that contain suspended solids, as their high internal scouring velocities promote continuous cleaning. Brazed plate heat exchangers cannot tolerate coarse suspended solids such as sand or marine organisms, as the plate tolerances are so small that the exchanger will clog quickly.

This product is limited by the quality of the treated effluent including suspended solids. For the MPWWTP plant, it is proposed to construct an ultra-filtration membrane plant that will produce a high quality effluent with turbidity that approaches drinking water quality. The main drawback of brazed plate heat exchangers using treated effluent systems, however, is that the high pH and high amount of entrained oxygen in the effluent will accelerate the corrosion of the brazing alloy that forms the bond between plates. Life expectancy is about 5-6 years for treated effluent applications. They have excellent usage as a customer’s heat exchanger, due to their suitability in closed loop systems that are treated with corrosion inhibitors, pH monitored, and with no oxygen present.

The image above has been reprinted from Mueller, www.muel.com.

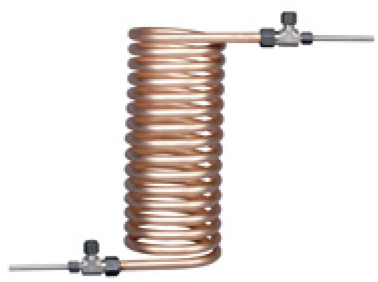
6.2.2 Plate and Frame Heat Exchangers

Plate and frame heat exchangers are characterized by their multiple plate configuration, gaskets between plates, frame/header assembly, compact size (relative to conventional shell/tube configurations), availability in a wide variety of plate and header metallurgy for different applications, availability in double wall atmospheric vented construction for leak detection, and ability to be disassembled in the field for cleaning and gasket replacement. This use of this product is limited by suspended solids. The ultra-filtration membrane plant, however, would eliminate this problem.

Biofouling from organisms found in effluent can be an issue with plate and frame exchangers, including the supply and return pipelines. Products are available that prevent biofouling. One such product is from Blame Worldwide Services. Their product provides both anti-fouling and anti-corrosion protection through the generation of trace amounts of copper ions and the dissipation of trace aluminum hydroxide into the pipeline system. The Blume system will be discussed in further detail below, in the "Heat Exchanger Cleaning Options" section of this report. The image above has been reprinted from Mueller, showing their Accu-Therm models, www.muel.com.

6.2.3 Tube in Tube Heat Exchangers

Another product available for heat exchange are the helical or coiled "tube-in-tube" models shown in the photos below. Their high scouring velocity could make them usable for heat exchange between the treated effluent and closed loop systems. Provided that large enough models are available, the high scouring velocity is of particular benefit for the treated effluent side of the heat exchangers. The treated effluent will contain micro-organisms that can foul heat exchange surfaces. Also of interest is their availability in a variety of metallurgy options, and thus the ability for construction in corrosion resistant options for treated effluent duty.



The images above have been reprinted from Sentry Equipment Corp. www.sentry-equip.com

6.2.4 Shell and Tube Heat Exchangers:

Shell and tube heat exchangers are characterized by their outer shell and inner tube bundle construction, complete with headers. They typically require substantially more floor space than other heat exchanger technologies, both because they are long and narrow and also because the tube bundles are removable from one end of the exchanger. Usually, the space that a shell and tube exchanger requires for tube bundle removal must be incorporated into the building or space in which the exchanger is installed, and the length required for the total installation is twice the operating length of the exchanger. Their main advantage is that they are the easiest of all the heat exchangers to clean and maintain, when the heat exchanger is handling a fluid with suspended solids. Shell and tube heat exchangers are available in a wide variety of metallurgy options, and thus can easily be adapted to treated effluent heat recovery usage.

The preliminary cost estimates are based on shell and tube heat exchanger. The final selection of the heat exchanger should be carried out at the time of detailed design.

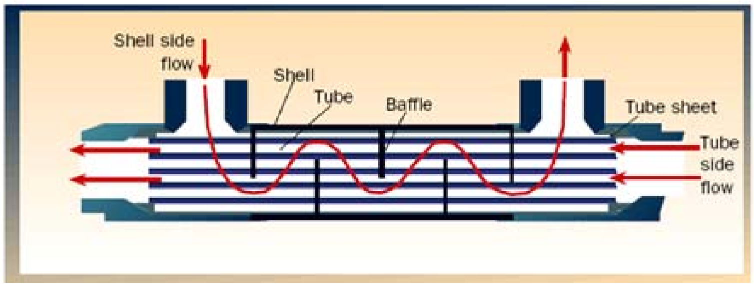
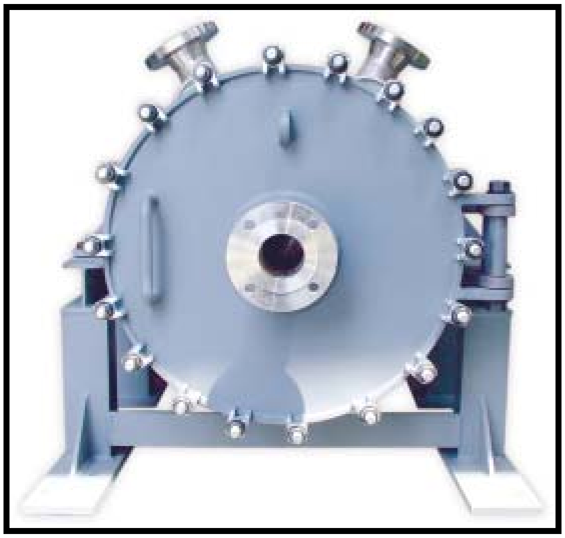
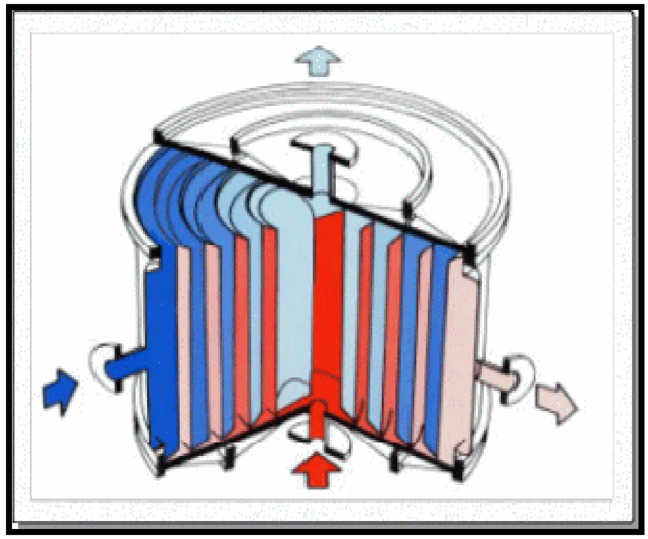


Diagram of shell and tube heat exchanger operation, and photos of shell and tube heat exchangers is courtesy of Logichem Process Engineering, www.heatexchangers.co.za.

6.2.5 Spiral Heat Exchangers:

Spiral heat exchangers (SHE) are configured using helical (coiled) tubes. In general, the device consists of a pair of flat surfaces that are coiled into two channels in a counter-flow arrangement. Each of the channels has a long curved path that is connected at the outer arms of the spiral to the loop.





Main advantages of the SHE is its highly efficient use of space and anti fouling characteristics. As well, a notable tradeoff is capital cost vs operating cost. A compact SHE has a smaller footprint, and thus lower capital cost to house it. SHE's can therefore be oversized to lower pressure drop, lower required pumping energy and have higher thermal efficiency.

SHEs are often used in heating fluids that contain solids. Other heat exchangers have a tendency to foul in such environments. The SHE uses a "self cleaning" mechanism, whereby fouled surfaces cause a localized increase in fluid velocity, thus increasing the drag friction on the fouled surface. This helps dislodge small blockages and keeps the heat exchanger clean. "The internal walls that make up the heat transfer surface are often rather thick, which makes the SHE very robust and durable in demanding environments." The units are also easily cleaned and opened easily so any foulant can be removed with pressure washing.

The SHE is suited for applications such as digester heating, heat recovery and effluent cooling. For most applications SHEs are smaller than other types of heat exchangers.

6.2.6 Heat Exchanger Cleaning Options

The heat exchangers will be prone to fouling from suspended solids and bacteria in the treated effluent. Treated effluent heat exchangers will require either manual cleaning, some form of automatic cleaning system or an anti-fouling system to maintain heat transfer efficiency for reduction of manual cleaning by maintenance staff. It is recommended that the treated effluent be piped through the tubes and not the shell side of the exchanger. There are options available for "online timed" interval cleaning of the heat exchanger internal tube surfaces:

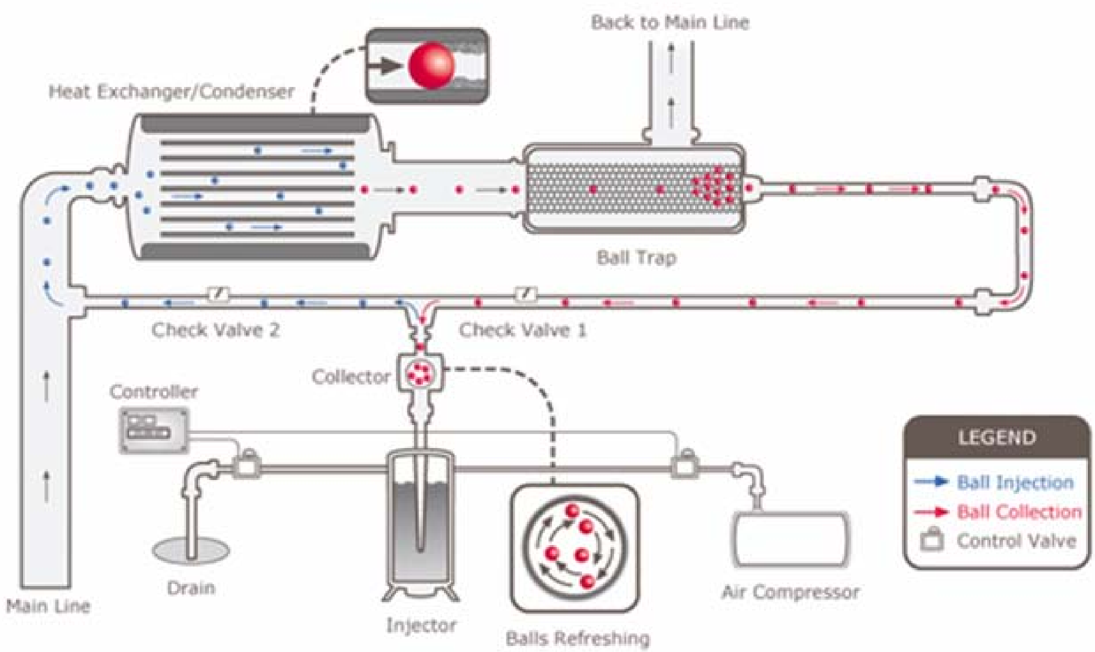
- One such cleaning system manufactured by CQM Tech is called "ATCS Ecodenser". The ATCS system works by injecting foam balls into the fluid stream periodically, and automatically collecting and cleaning the balls for repeated automatic usage. A more detailed description of this system follows.

- Blume Worldwide manufactures an anti-corrosion/anti-fouling system specifically for seawater systems and undersea structures such as offshore oil platforms. It is recommended that an anti-corrosion and anti-fouling system be fitted to the seawater heat exchangers for this project.

It should be noted that both the Blume and ATCS systems will not eliminate maintenance from the treated effluent heat exchangers entirely, however, these automatic systems do have the potential to reduce maintenance substantially and keep internal heat exchanger surfaces clean enough to promote maximum heat transfer efficiency.

How ATCS Works

The CQM ATCS is installed on the chiller's condenser and keeps tubes clean without human intervention. The system periodically injects into the tubes sponge balls that are slightly larger in diameter then the tubes themselves. The natural pressure head pushes the balls through the tube, which is thus rubbed clean. The balls are then trapped in the outlet of the heat exchanger, where they are prepared for the next cleaning cycle.



Section 7.0 Alternatives For Heat Supply System

7.1 General

In this study, four options for a district heat distribution system are evaluated:

Option 1: Ambient temperature distribution system to service the James Bay and Downtown area (up to 20 ºC);

Option 2: Moderate temperature distribution system to service the James Bay and Downtown area (80 ºC);

Option 3: Low temperature distribution system to service the James Bay and Downtown area (35 ºC), and

Option 4: Hybrid system with ambient temperature pipeline from the wastewater treatment plant to the biosolids facility and 60^{0}C temperature for the distribution system to service the North Downtown area.

These district heating systems would generally consist of the following components:

1. Heat exchangers – to transfer heat from the treated effluent to a clean liquid in a district heating loop;

2. Water pumping – a first set of pumps to flow effluent through the heat exchangers and then a second set of pumps to flow the clean fluid though the district heating loop;

3. Heat pumps – the temperature of the clean liquid has to be “lifted” to the requirements of the building heating system in order to be useful for the end customer;

4. Distribution piping – to distribute the clean heating liquid from the wastewater treatment plant to the end users;

5. Various treatment, expansion and buffer tanks, and

6. Direct Digital Control (DDC) System.

The following system component options have been identified and are further discussed in Section 7.2 to 7..5.

Components	**Option 1 - Ambient Temp. (up to 20^{0}C)**	**Option 2 - Moderate Temp. (80^{0}C)**	**Option 3 - Low Temp. (35^{0}C)**	**Option 4 - Hybrid Option for North Downtown**
Heat exchangers	At sewage treatment plant and end user's facility	At sewage treatment plant and end user's facility	At sewage treatment plant and end user's facility	At sewage treatment plant and end user's facility
Water pumps	At sewage treatment plant	At sewage treatment plant	At sewage treatment plant	At sewage treatment plant
Heat pumps	At end user's facility	At sewage treatment plant	First lift heat pump at STP and second heat pump at point of use	At end user's facility
Distribution piping	Non insulated pipe - PVC or HDPE	Insulated welded steel pipe	Insulated PVC or HDPE	Non insulated pipe - PVC or HDPE

7.2 Option 1 – Ambient Temperature System for James Bay and Downtown

Option 1 is shown schematically in **Figure 7.1** and consists of an ambient temperature system that will provide the Owner of the district energy system (DES) with the ability to meter utility customer's usage in both heating and cooling modes or heating only, if a customer chooses this option.

With this option, a closed loop distribution piping consisting of 750 mm diameter non-insulated pipe system would be required. Utility customers could draw water from the DES utility and water would be fed to a heat exchanger(s) in each building. Customers could in turn use heat pumps for both heating and cooling within their facilities, and the customers heat pumps would be connected on the load side of the heat exchanger. The heat exchangers in each customer's building would serve two purposes:

- As a means to separate the DES closed loop treated water from the customer's hydronic (fluid based) heating and cooling systems in order to ensure that any customer issues with maintaining their water chemistry does not impact CRD's systems.
- As a means to separate the DES systems from systems with a higher operating pressure. For example, customers with high buildings might exert a higher than anticipated static pressure on the DES distribution systems if there were no heat exchangers fitted to the piping network. The benefit of separating higher pressure

systems from the DES results from being able to utilize pipeline components with lower pressure ratings where possible.

System Basics:

This option is termed a “net-metering” solution. Thus, it is expected that customers with differing heating and cooling load profiles would connect to the same network of closed loop piping, and the DES closed loop utility would allow energy sharing between buildings that simultaneously require heating and cooling.

For example, a transit repair shop connected to the utility might have a large makeup air heating requirement, with a heating load from the makeup air that might occur at any ambient temperature below 15 degrees Celsius. Nearby, a large office building may have many interior areas with no interaction to the envelope of the building, and resulting heating/cooling load variations with weather, time of year, and solar effects. The interior spaces of the large office building would normally be filled with people, lighting and computers that would require cooling year round, independent of outside temperature, and would thus be rejecting heat either from heat pump or central chiller operation.

Conventional stand alone HVAC systems for each building would dictate that the transit repair shop systems be designed to utilize natural gas fired equipment for makeup air heating, while the nearby office building would be operating a cooling tower or closed circuit fluid cooler almost year round in order to reject heat from the interior spaces. With an energy sharing utility, energy can be transferred between customers. Each utility customer would require their buildings to be fitted with a heat pump, either water to air or water to water type. It is anticipated that the best candidates for a water source heat pump system are those with existing hydronic heating and cooling systems within their facilities.

Facilities with rooftop packaged, or unitary equipment are not anticipated to be potential customers due to the high costs of system retrofit. However, it should be noted that as CO2 emissions penalties legislated by the BC Provincial Government grow over time, a treated effluent utility coupled with heat pumps fed from renewable hydroelectric power may become more attractive to potential customers, both for reasons of economics and for environmental stewardship. During periods of low cooling load operation, customer bypass valves can be used on the load side of customer heat exchangers to potentially provide chilled water directly from the customer heat exchanger, by operating the seawater exchanger to provide chilled water.

System Operation:

As mentioned above, the proposed system type is a closed circuit utilizing tap water treated with corrosion inhibitors as a heat transfer fluid. Water would be circulated amongst all buildings connected to the utility, and temperature of the closed loop would be monitored and adjusted by automatic temperature control systems. Common water source heat pumps have the ability to operate within a wide temperature range at their water inlet, of approximately 2^0C to 20^0C in heating mode, and between 15.5^{0}C and 32^{0}C in cooling mode. Therefore, it is expected that the closed loop utility would operate in a temperature range between 5^{0}C and 20^{0}C during all conditions. Automatic valves, recirculation valves and temperature controls on the utility heat exchanger and customer connection would ensure that the fluid temperature at the inlet to each customer heat pump would be maintained within an optimum range.

If return water temperature at any point in the system moved near to the limits of either 5^{0}C or 25^{0}C operating range, automatic controls would use a combination of additional flow and the addition or rejection of energy to the loop via the treated effluent to maintain proper closed loop operating temperatures.

The DES would meter water usage with both flow meters and accurate temperature measuring devices in order to bill the customers for usage. The added advantage of a "closed loop net-metering solution" is that separate customers demanding both heating and cooling simultaneously can be charged for their usage, while the DES only energy cost is for circulating the fluid to the customers. Two or more customers "share" energy. The potential impact of eliminating natural gas usage from combustion for heating, while sharing energy with a customer that is simultaneously requiring cooling is significant. The only penalty of this approach is that pumping energy is needed for fluid transfer between customers, and heat pump energy is required for heating.

<u>System Advantages:</u>

- Can be expanded to an energy management system;
- Heating and cooling capability with a single pipe loop;
- Conveyance loop does not require welded steel insulated pipe; pipe is cheaper; and
- Essentially no transmission heat loss.

<u>System Disadvantages:</u>

- More costly for end customer to connect since a heat pump is required at each point of use and may require costly building modification to expand the mechanical room to accommodate the heat pumps;
- Conveyance is more difficult with larger pipe and therefore cost implications;
- Will need backup boiler for coldest winter months; and
- May need very expensive "single lift" heat pump to achieve required DHS temperatures.

- There will be higher electrical usage at the end user's plant. This may trigger the need for improved electrical infrastructure such as transformers and improved distribution network.

7.3 Option 2 – Moderate Temperature System (80ºC) for James Bay and Downtown

This is the classic type of DES that runs at higher temperatures incorporating an insulated distribution loop and a simple heat exchanger at the end customer's facility. This system is shown schematically in **Figure 7.2**.

<u>System Basics</u>:

The system consists of heat exchangers and heat pumps at the wastewater treatment plant, which extract heat from the treated effluent. The heated water is then pumped through an insulated closed loop piping system to the end customer where it can be extracted to the existing building heating system. This extraction by the end customer is accomplished with a simple low maintenance heat exchange system, incorporating pumps and heat exchangers.

<u>System Operation</u>:

The closed loop transmission fluid temperature would be increased in 2 stages. The first stage would be through heat pumps or chillers to accomplish the first lift to 35 ºC. The second lift would be through modular heat pumps to raise the fluid temperature to 80 ºC. This 80 ºC water would then be transmitted through an insulated 500 mm diameter closed loop pipe to the end customers in the James Bay and Downtown areas.

The two temperature lifts would be controlled by a direct digital control system with temperature meters on supply and return lines in order to optimize the coefficient of performance (COP) between heat output and required electrical power. As well, calibrated temperature and flow meters would be employed to measure consumption so that the customer could have accurate consumption and billing information.

<u>System Advantages</u>:

- Simpler end customer hook up: At the end customer's facility, only heat exchangers, pumps and controls would be installed. Heat pumps would not be required at the end users facility as the district loop water has already been lifted to the required temperature. Less equipment means less initial capital cost for the end customer and therefore greater incentive to connect;

- End customer does not need to find copious amounts of space in existing mechanical rooms to house heat pumps and related equipment.

- Less maintenance and lower initial capital cost for end customer to get connected;

- Maintenance of heat pump equipment is centralized at the sewage treatment plant – this is an ongoing incentive for the end customer;

- Due to the presence of the insulated pipe loop, a fully modulating back-up boiler could be located at the wastewater treatment plant and maintained centrally. The moderate or higher temperature water from the back-up boiler could boost system capacity and be transmitted to the end user to accommodate more of the shoulder/winter season demand;

- End customers do not have to pay direct capital costs for heat pumps at their facility or pay hydro costs for extracting heat at their facility with heat pumps, and

- The pipe diameter for the transmission loop is smaller than for the ambient system. This reduces conveyance costs.

<u>System Disadvantages:</u>

- There will be higher heat losses in the conveyance pipe at this elevated temperature Conductive heat loss is proportional to the square of the temperature (i.e. $Q_{loss} \alpha T^2$);

- There will be a lower coefficient of performance (COP) from the heat pumps at higher temperatures, and

- There is no ability to both heat and cool at the same time with this system unless a second insulated loop is installed to solely carry cooling water. Installation of a second loop would have a significant effect on conveyance costs. With the mild summer temperatures in Victoria, mechanical cooling does not appear financially viable or worthwhile for this option.

7.4 Option 3 - Low Temperature System (35ºC) for James Bay and Downtown

The 35ºC low temperature system is similar to the 80ºC system above, but with minor differences that affect the conveyance cost, transmission losses and end customer operations. See attached system schematic on **Figure 7.3.**

<u>System Basics:</u>

This is a lower temperature system than the 80ºC system above, but it carries more heat capacity per fluid volume in the distribution pipe than the ambient system. Since temperatures are lower, a less expensive plastic pipe can be used for the distribution loop instead of welded steel. The distribution pipe still requires insulation; however transmission losses due to the lower fluid temperature are significantly reduced.

The heat extraction and first temperature lift of the distribution loop is conducted at the sewage treatment facility and 35ºC water is then pumped through the loop. The end customer must then conduct the final temperature lift with a heat pump located within their facility. Operating parameters can then be controlled by the end user to satisfy their specific heating system(s) needs of operating temperatures and demand.

System Operation:

The system operation is similar to the 80 ºC loop, however the second temperature lift occurs in a different location; at the end users facility.

The fluid carried in the closed 600 mm diameter transmission loop is increased to 35ºC in a single stage. Then a second lift is conducted at the end customer's facility to 80ºC. Chillers accomplish the first lift, pumps convey the 35ºC fluid to the end users facility where the second lift is provided by modular heat pumps to raise the fluid temperature to 80ºC.

The temperature lifts, which occur in separate locations, would be controlled by separate direct digital control systems. The system at the end users facility, located before the customer's heat pumps, would employ calibrated temperature and flow meters to measure consumption so that the customer could have accurate consumption and billing information.

System Advantages:

- The system would incur less transmission losses than with the 80ºC system;
- There is lower conveyance and pumping costs due to more heat capacity in fluid and smaller diameter pipe;
- The end customer has more control over temperature and COP with control over both the heat exchanger and the heat pump, and
- The insulated plastic transmission pipe should be more economical than the welded steel pipe of the 80ºC system.

System Disadvantages:

- The cost of the insulated transmission pipe is likely more expensive than the ambient pipe. The conveyance of the larger ambient pipe my have significance however;
- There is more heat loss in the low temperature system transmission pipe than for the ambient system;
- A better COP could be achieved in early shoulder seasons than in the higher temperature system

- The ability to heat and cool at the same time is reduced as the system would require a second (expensive) insulated distribution loop. Having the end user's DHW system connected to the boiler makes cooling in summer infeasible.

- There will be higher electrical usage at the end user's plant. This may trigger the need for improved electrical infrastructure such as transformers and improved distribution network.

- For this option, significant direct digital control systems with feedback loops would need to be installed in the wastewater plant and in the end users plant. This will nearly double the controls cost and impact operations and maintenance.

7.5 Option 4 – Hybrid District Energy System for North Portion of Downtown

With this option, a closed loop distribution piping consisting of 600 mm diameter non-insulated pipe system would be installed through Victoria West between the wastewater treatment plant at McLoughlin Point and the solids handling facility in the Upper Victoria Harbour for a distance of 3.5 km. From this point, the dual loop could be extended by approximately 1.6 km to service the north portion of the downtown area. This would reduce the overall length of the dual piping system from 6.5 km to 5.1 km and avoid the high cost associated with crossing Victoria Harbour in a tunnel. The heat pipes could be attached to the Bay Street Bridge but this would have to be confirmed with the City of Victoria.

The projected energy demand for the north downtown area, which covers approximately 65 ha averages 10,000 GJ/ha/y for the year 2030 and 25,000 GJ/ha/yr. It is also assumed that 70% of the annual demand would be for space heating and domestic hot water. Based on these assumptions, the future total energy demand would be 450,000 GJ/yr in 2030 and 1,135,000 GJ/yr in 2065. The energy demand for the biosolids facility is estimated at 84,000 GJ/yr. The amount of sealable heat that can be extracted from the effluent is 1,100,000 GJ/yr.

Considering the difficulties in accurately forecasting the 50-year total energy demand for the north downtown area, it is proposed to size the ambient temperature pipe on the basis of providing capacity for two-thirds of the heat available from treated effluent and to use a dual 600 mm diameter non insulated pipe loop.

<u>Systems Basics</u>

The 600 mm diameter ambient temperature pipe loop could initially end at the biosolids facility in the Upper Harbour. Heat pumps could be installed to supply heat to the biosolids facility. The heat demand of this facility includes sludge and digester heating, space heating for buildings and sludge drying. The peak demand for process heat at the biosolids facility corresponds to 21% of the available heat capacity of a 600 mm diameter pipe.

To service the north Downtown area, a separate District Energy System originating at the biosolids facility could be constructed at a later stage. The north Downtown DES would include heats pumps located at biosolids facility followed by a closed loop insulated heat distribution system operating at the temperature required for the heating system of the new buildings. It is anticipated that the heating systems of most new buildings would be designed to operate at 60^0C. Thus the DES for the north Downtown area could be designed to distributed heat at this temperature of higher if required. The heat piping could be located on roads located north of Pandora Street such as Government Street and Douglas Street. The actual routing the DES would depend on where new developments would be located.

The ambient temperature pipeline from the wastewater plant to the biosolids site would likely follow existing roads through Esquimalt and Victoria West. This would allow tapping into the ambient temperature pipe to extract the heat and distribute it through separate local DES system(s) in Esquimalt or in Victoria West.

<u>System Operation – Ambient Temperature Loop from McLoughlin Point to Biosolids Facility</u>

This portion of the system is conceptually similar to Option 1 and is shown schematically in **Figure 7.1**.

The proposed system type is a closed circuit utilizing tap water treated with corrosion inhibitors as a heat transfer fluid. Water would be circulated from the wastewater treatment plant to the biosolids site and the temperature of this closed loop would be monitored and adjusted by automatic temperature control systems. Common water source heat pumps have the ability to operate within a wide temperature range at their water inlet, of approximately 2 C to 20 C in heating mode, and between 15.5 C and 32 C in cooling mode. Therefore, it is expected that the closed ambient temperature loop would operate in a temperature range between 5 C and 25 C during all conditions. Automatic valves, recirculation valves and temperature controls on the utility heat exchanger and customer connection would ensure that the fluid temperature at the inlet to each customer heat pump would be maintained within an optimum range.

<u>System Advantages:</u>

- Can provide a source of heat for localized district energy systems, each operating a temperature that best meet the specific needs of the specific future developments;
- Potential areas to be services with localized DES include the north Downtown area, Victoria West and Esquimalt;
- A separate set of heat pumps could be installed to meet the energy demand of the biosolids treatment facility. These could operate at a different temperature than those required by the local DES;
- Heating and cooling capability;

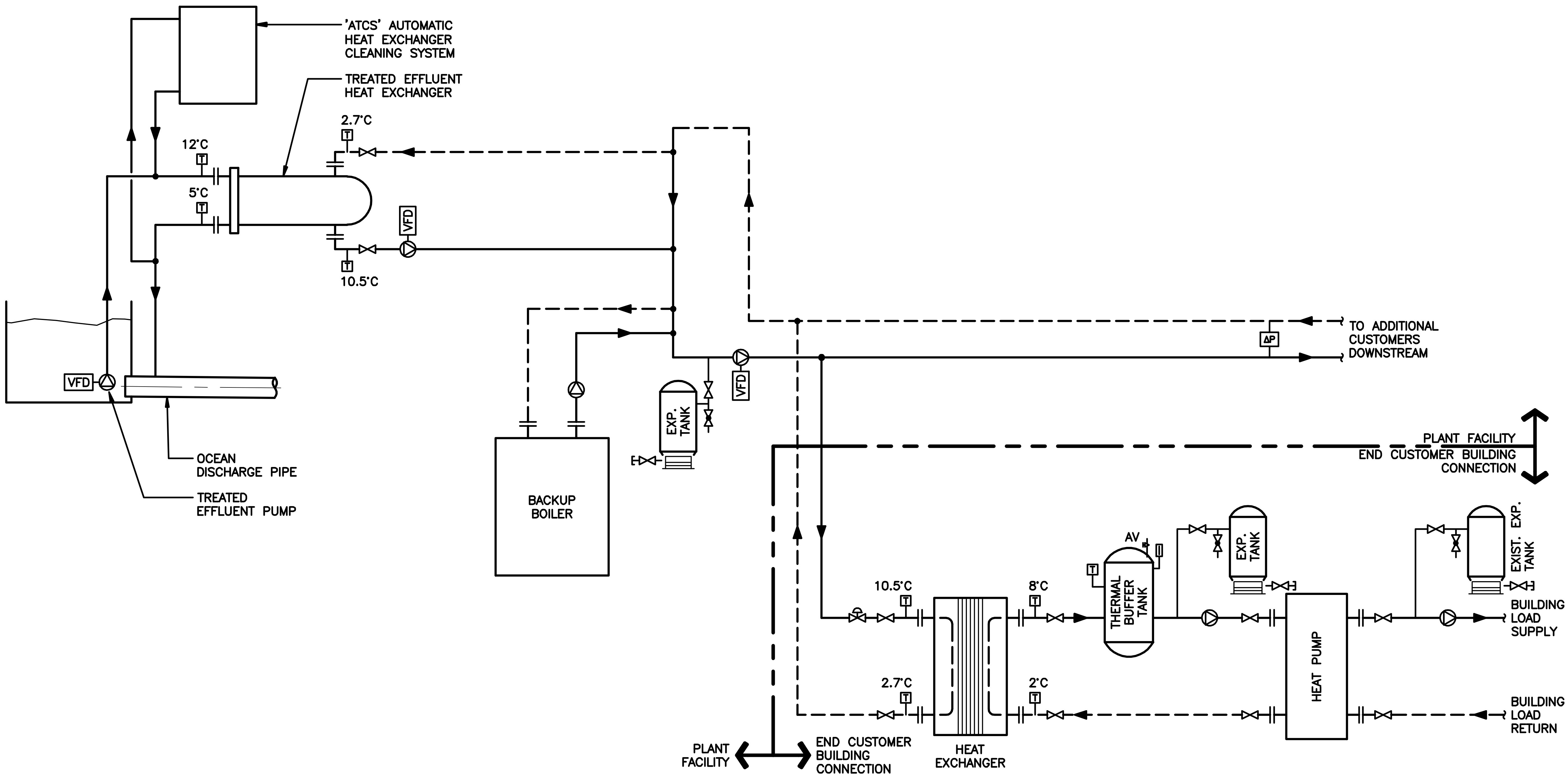
- Conveyance loop does not require welded steel insulated pipe; pipe is cheaper;
- Avoiding the added cost of tunneling in order to cross Victoria Harbour, and
- Essentially no transmission heat loss between the plant and the biosolids facilities.

System Disadvantages:

- This system would not service James Bay and the south downtown areas;
- There will be higher electrical usage at each of the local DES. This may trigger the need for improved electrical infrastructure such as transformers and improved distribution network.

System Operation – District Energy System for North Downtown Area

This portion of the system is conceptually similar to Option 2 and is shown schematically in **Figure 7.2**. The only difference could be that this system may operate at a lower temperature than 80^0C if it services only new development with heating systems designed to operate at a temperature of 60^0C. The advantages and disadvantages are similar to Option 2.



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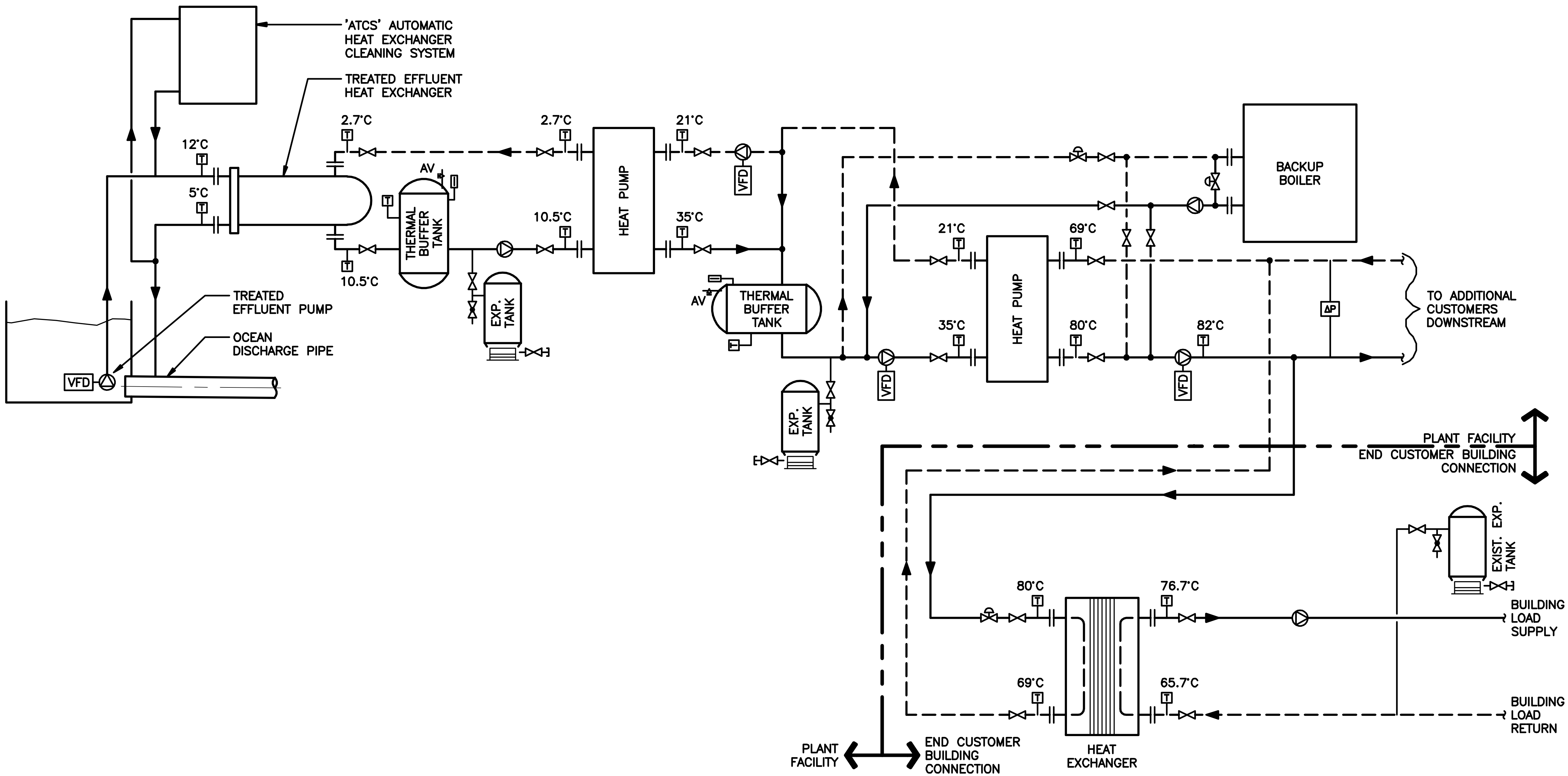
CORE AREA WASTEWATER TREATMENT PROJECT

HEAT RECOVERY – AMBIENT TEMPERATURE WATER LOOP – DOWNTOWN OPTION 1

CONTRACT NUMBER	DRAWING NUMBER	ISSUE	SHT. No.
149009002	Fig 7.1	X	1 OF 3



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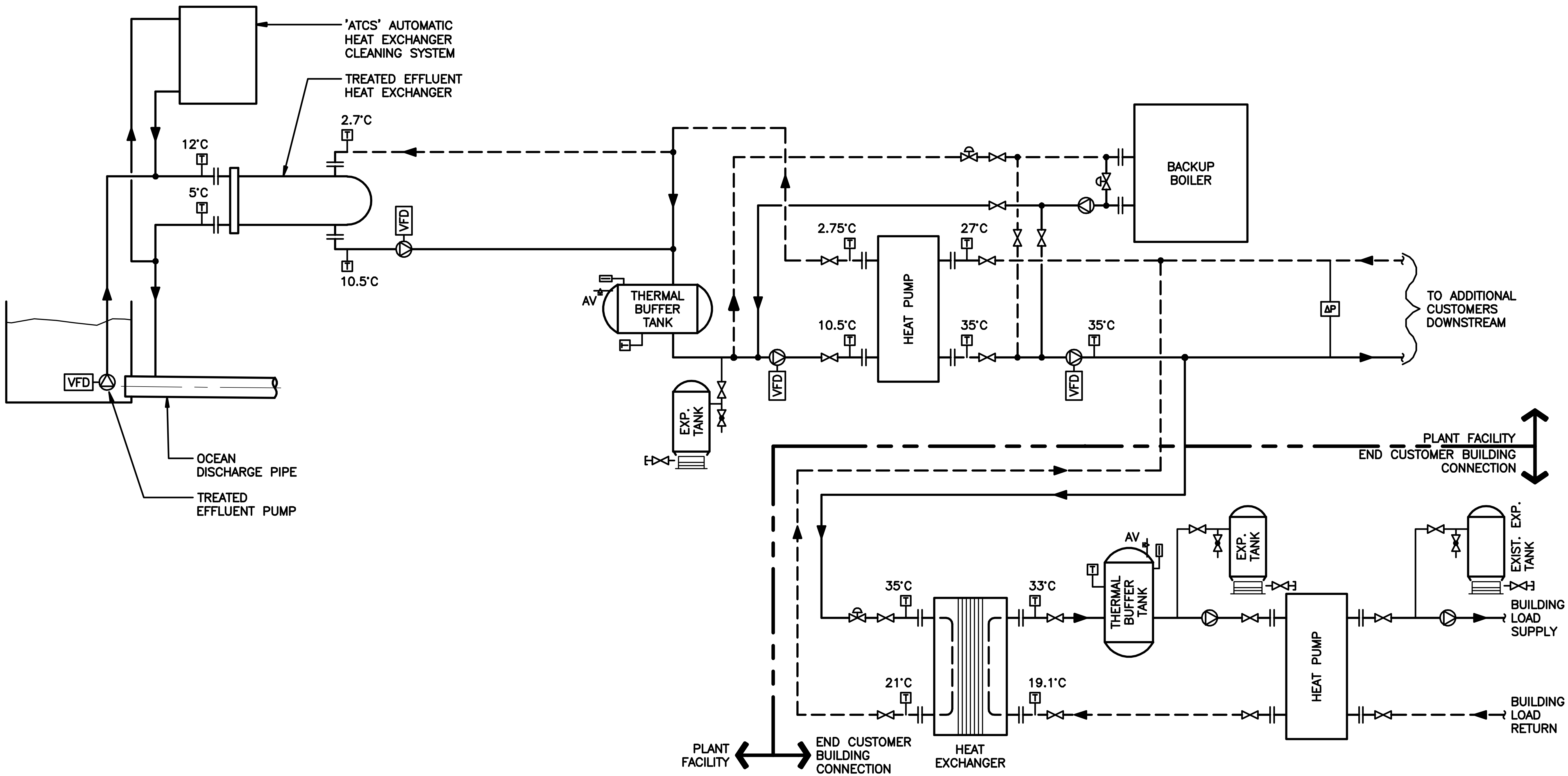
CORE AREA WASTEWATER TREATMENT PROJECT

HEAT RECOVERY – LOW TEMPERATURE(80°C) WATER LOOP – DOWNTOWN OPTION 2

CONTRACT NUMBER 149009002 DRAWING NUMBER Fig 7.2 ISSUE X 2 SHT. No. OF 3



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CORE AREA WASTEWATER TREATMENT PROJECT

HEAT RECOVERY – LOW TEMPERATURE(35°C) WATER LOOP – DOWNTOWN OPTION 3

CONTRACT NUMBER	DRAWING NUMBER	ISSUE	SHT. No.
149009002	Fig 7.3	X 3	3 OF 3

Section 8.0 Opinion Of Probable Cost

8.1 Capital Cost

To enable completion of the triple bottom line assessment and to obtain an initial indication of capital cost for each of Options 1, 2, 3 and 4, cost estimates were prepared for each option. The basis of the estimates includes the following:

Direct Cost

- Capital construction cost
- Design and construction contingency costs at 25% of construction cost

Indirect Cost

- Engineering at 15% of direct cost
- Administration and miscellaneous at 6% of direct cost

Financing Cost

- Interim financing at 4% of direct and indirect cost
- Inflation to midpoint of the construction of the McLoughlin Point treatment facility at 2% per annum to 2015 (14%)

Furthermore, the following assumptions have been made regarding the cost of equipment that must be installed on private property at each point of use:

- The cost of equipment required at each point of use has been included. Depending on the option, this includes (1) heat exchangers, (2) pumping, piping, valves and controls and (3) heat pumps, and
- For Option 1, an allowance of $40,000 per customer has been added for building modifications/addition to the mechanical room in order to allow the installation of equipment needed to connect to the DES. For Options 2 and 4, this allowance has been reduced to $20,000.

The capital cost estimate for the four options of a District Energy System (DES) is shown in **Table 8.1**. In order to allow a comparison of a DES serving the James Bay and Downtown area with a smaller DES serving only the north portion of the Downtown area, assumptions were made regarding the number of customers connected to each system. For Options 1, 2 and 3, the cost of work at each point of use is based on 50 customers. For a smaller system serving the north portion of the downtown area, it was assumed there would be 30 customers.

Table 8.1 –Capital Cost of DES Including Equipment Required at the Point of Use

	Component	Option 1 - Ambient Temp. (<20^{0}C)	Option 2 - Moderate Temp. (80^{0}C)	Option 3 - Low Temp. (35^{0}C)	Option 4 - Hybrid Option
		James Bay and Downtown Area			North Downtown
1	Heat pumps at STP	-	$5,950,000	$1,225,000	
2	Heat exchangers and water pumping system at STP	$2,340,000	$3,540,000	$3,100,000	$1,750,000
3	Buildings at STP to house equipment	$720,000	$2,790,000	$1,530,000	$500,000
4	<u>Closed Loop Distribution piping:</u>				
	Option 1 - 750 mm dia PVC pipe non-insulated; L= 13000 m	$14,376,000	-	-	
	Option 2- 500 mm welded steel insulated pipe; L= 13000 m	-	$11,905,000	-	
	Option 3 - 600 mm HDPE insulated; L= 13000 m	-	-	$13,054,000	
	Option 4 – 7 km of 600 mm dia PVC non-insulated and 3.2 km m of 300 mm dia insulated steel				$7,048,000
5	Heat pumps at point of use	$7,500,000		$5,670,000	$4,000,000
6	Allowance for building addition at point of use for heat pumps	$2,000,000	-	$1,000,000	$600,000
7	Pumping system and heat exchangers at point of use	$4,620,000	$2,280,000	$3,847,000	$3,080,000
	Sub total - Items 1 to 7	$31,556,000	$26,465,000	$29,426,000	$16,978,000
8	Design and construction contingencies (25%)	$7,889,000	$6,616,000	$7,356,000	$4,244,000
	Sub total - Items 1 to 8	$39,445,000	$33,081,000	$36,782,000	$21,222,000
9	Engineering and project management (21%)	$8,283,000	$6,947,000	$7,724,000	$4,457,000
10	Interim financing and inflation to 2014 (14%)	$6,682,000	$5,604,000	$6,231,000	$3,595,000
	TOTAL ESTIMATED COST	**$54,410,000**	**$45,632,000**	**$50,737,000**	**$29,274,000**

The cost of a heat extraction and distribution system to provide process heat to the biosolids facility only is shown in Table 8.2. This cost estimate includes the over-sizing the ambient temperature piping between the wastewater treatment plant and the biosolids facility from 450 mm to 600 mm dia to allow for future servicing of the north downtown area. Servicing the biosolids facility only could be the first phase of a smaller district energy system to service the north portion of the downtown area.

Table 8.2 – Cost of Heat Extraction System for Biosolids Process Heat Only

	Component	Estimated Cost
1	Heat exchangers and water pumping system at STP	$600,000
2	Buildings at STP to house equipment (water pumps and heat exchanger)	$300,000
3	Closed Loop ambient temperature distribution piping from WWTP to biosolids facility (oversized to supply north downtown area); 600 mm dia PVC pipe non-insulated; L= 7,000 m including bridge crossing	$2,740,000
4	Heat pumps at point of use	$1,150,000
5	Pumping system and heat exchangers at point of use	$720,000
6	Allowance for building addition at point of use to house heat pumps	$900,000
	Sub total - Items 1 to 7	$7,110,000
8	Design and construction contingencies (25%)	$1,777,000
	Sub total - Items 1 to 8	$8,887,000
9	Engineering and project management (21%)	$1,866,000
10	Interim financing and inflation to 2014 (14%)	$1,505,000
	TOTAL ESTIMATED COST	**$12,258,000**

The smaller DES to service the north portion of the downtown area only as described in Option 4 could be constructed in two stages as follows.

<u>Stage 1 – Heating Needs of Biosolids Facility Only</u>

- Heat exchangers at the wastewater treatment plant to meet heat demand of the biosolids facility only;

- Ambient temperature dual loop piping from the wastewater treatment plant to the biosolids facility through Victoria West and Esquimalt – pipe sized for the future heating needs of the north downtown area;
- Heat pumps to meet the requirement of the biosolids facility only and including building and controls, and
- Estimated cost of $12,258,000 as per table 8.2 above

Stage 2 - Expansion of District Energy System into North Downtown Area

- Additional heat exchangers at the WWTP to provide heat for north downtown area;
- Additional heat pumps at the biosolids facility to provide heat for the north downtown area including building;
- Moderate temperature (65^{0}C) insulated piping loop through north portion of downtown, and
- Estimated cost of $17,016,000

For the large DES to service the James Bay and downtown area as described in Options 1, 2 and 3, it is anticipated that it could take several years before there are enough customers to use all the available heat. Considering the high capital cost of such a system, the construction of a district energy system could be staged as shown in Table 8.3

Table 8.3 –Staging of Large DES for the Downtown & James Bay Area

	Stage 1	**Stage 2**	**Stage 3**
Heat pumps, heat exchangers and pumping systems	Sized for 30% of available heat + plant use	Sized for 60% of available heat + plant use	Sized for 100% of available heat
Building at STP to house equipment	Sized for 30% of available heat	Sized for 60% of available heat	Sized for 100% of available heat
Distribution piping	Sized for 100% of available heat	Sized for 100% of available heat	Sized for 100% of available heat

8.2 Operations and Maintenance Cost

The operations and maintenance costs, and the estimated revenues at 30%, 60% and 90% of heat sold, are detailed in **Tables 8.4 to Table 8.6**.

As indicated in these tables, the power cost is a major expenditure and can represent over 80% of the O&M cost. This is because a significant amount of power is required to run the heat pumps.

With Options 2 and 3, heat pumps are located on private property at each point of use. In order to allow a direct cost comparison between the various options, the cost of power cost to run the heat pumps located on private properties is included in the O&M cost.

The capital costs include interim financing estimated at 4% of all direct and indirect costs. The O&M costs do not include the annual debt servicing. However, it should be noted that based on interest rate at 6% and an amortization period of 25 years, the annual debt servicing would be at $54,000 for each $1 million of capital cost not covered by senior government grants.

Table 8.4 – O&M Cost at 30% of Available Heat Sold

	Component	Option 1 - Ambient Temp. (<20^{0}C)	Option 2 - Moderate Temp. (80^{0}C)	Option 3 - Low Temp. (35^{0}C)	Option 4 - Hybrid Option
		James Bay and Downtown Area			North Downtown
1	Annual power cost based on $0.08/kwh	$1,224,000	$1,188,000	$1,207,000	$743,000
2	Labour cost	$96,000	$96,000	$96,000	$80,000
3	Equipment and buildings maintenance and repairs	$46,000	$39,000	$46,000	$38,000
4	Distribution system maintenance and repairs	$71,000	$59,000	$65,000	$48,000
5	Vehicle allowance and miscellaneous	$12,000	$12,000	$12,000	$10,000
	TOTAL ESTIMATED COST	**$1,449,000**	**$1,394,000**	**$1,426,000**	**$919,000**
	Revenues Based on 30% of Heat Sold	*$1,532,000*	*$1,410,000*	*$1,410,000*	*$1,006,000*
	Net Revenues	*$83,000*	*$16,000*	*- $16,000*	*$87,000*

Table 8.5 – O&M Cost at 60% of Available Heat Sold

	Component	Option 1 - Ambient Temp. (<20⁰C)	Option 2 - Moderate Temp. (80⁰C)	Option 3 - Low Temp. (35⁰C)	Option 4 - Hybrid Option
		James Bay and Downtown Area			**North Downtown**
1	Annual power cost based on $0.08/kwh	$2,448,000	$2,376,000	$2,413,000	$1,485,000
2	Labour cost	$128,000	$128,000	$128,000	$100,000
3	Equipment and buildings maintenance and repairs	$93,000	$78,000	$91,000	$68,000
4	Distribution system maintenance and repairs	$71,000	$59,000	$65,000	$48,000
5	Vehicle allowance and miscellaneous	$18,000	$18,000	$18,000	$13,000
	TOTAL ESTIMATED COST	**$2,758,000**	**$2,659,000**	**$2,715,000**	**$1,714,000**
	Revenues Based on 60% of Heat Sold	*$3,064,000*	*$2,819,000*	*$2,941,000*	*$2,012,000*
	Net Revenues	*$306,000*	*$160,000*	*$226,000*	*$298,000*

Table 8.6 – O&M Cost at 90% of Available Heat Sold

	Component	Option 1 - Ambient Temp. (<20⁰C)	Option 2 - Moderate Temp. (80⁰C)	Option 3 - Low Temp. (35⁰C)	Option 4 - Hybrid Option
		James Bay and Downtown Area			**North Downtown**
1	Annual power cost based on $0.08/kwh	$3,672,000	$3,564,000	$3,620,000	$2,228,000
2	Labour cost	$160,000	$160,000	$160,000	$130,000
3	Equipment and buildings maintenance and repairs	$154,000	$129,000	$152,000	$97,000
4	Distribution system maintenance and repairs	$72,000	$59,000	$65,000	$48,000
5	Vehicle allowance and miscellaneous	$20,000	$20,000	$20,000	$18,000
	TOTAL ESTIMATED COST	**$4,078,000**	**$3,933,000**	**$4,017,000**	**$2,521,000**

	Revenues based on 90% of Heat Sold	*$4,596,000*	*$4,228,000*	*$4,412,000*	*$3,018,000*
	Net Revenues	*$518,000*	*$295,000*	*$395,000*	*$497,000*

The following assumptions were made when estimating projected revenues from the sale of heat:

- An incentive price of $10/GJ for the sale of heat generated by effluent;
- The transmission losses are 8% for Option 2 and 4% for Options 3 and 4;
- The process heat for the digesters and the space heating at the plant are excluded from the revenues, and
- The heat supplied to the digester is included in the revenues.

8.3 Business Model

A potential business model for a District Energy System would consist of the following:

- Ownership of District Energy System by the CRD;
- Governance oversight by the Board of Director of the CRD;
- Operations managed by the Environmental Services Department, integrated with other operations of the Department;
- Capital funding provided by grants from senior levels of government and annual revenues including carbon credit.
- Operating and maintenance cost funded by annual revenues including carbon credit

Because of high capital cost, it appears that the business model will have to be based on 25-year period. The above business model is similar to the model adopted by the City of Vancouver for the South East False Creek DES. Another option may be to consider construction and operation of a DES by a private sector partner who would be responsible for construction and operation of the system.

Section 9.0 Triple Bottom Line Analysis

9.1 Carbon Footprint Analysis

A carbon footprint analysis was performed as a part of the evaluation of the environmental impacts of the four alternatives. A carbon footprint measures the amount of greenhouse gas (GHG) released or stored as a result of a process or activity. A detailed description of the carbon footprint analysis methodology can be found in the September 16, 2009 report by Stantec Consulting and Brown and Caldwell titled "*Core Area Wastewater Treatment Assessment of Wastewater Treatment Options 1A,1B and 1C.*"

The emission factors used to calculate the GHG emissions/savings associated with the heat recovery project are as follows:

- Heat pumps and water pumps for district heating 0.000072 tonne/kwhr (electricity)
- Saleable heat for district heating offset 0.0503 tonne CO_2/GJ (based on natural gas)

In addition, there are one-time emissions associated with construction activities as follows:

- Concrete 0.272154 tonne CO_2/m^3
- Steel (re-bar, piping, equipment 0.0032 tonne CO_2/tonne product
- Excavation 0.000981 tonne CO_2/m^3

The estimated annual carbon footprint in tones of CO_2 associated with each heat recovery system option, based on current available heat is summarized in Table 9.1. The value of carbon credit based on $25/tonne and $50/tonne is shown in Table 9.2.

Table 9.1 – Summary of GHG Emissions for Heat Recovery System Options (Tonnes of CO_2)

	Option 1 - Ambient Temp. (<25^{0}C)	**Option 2 - Moderate Temp. (80^{0}C)**	**Option 3 - Low Temp. (35^{0}C)**	**Option 4 - Hybrid Option**
Power for heat pumps and conveyance (pumping)	3,672	3,564	3,619	2,904
Saleable Heat for District Heating	- 25,686	- 23,632	- 24,659	-16,866
Total Annual Emissions (Excluding Construction)	- 22,014	- 20,068	- 21,040	-13,962

Table 9.2 – Value of Carbon Credit

	Option 1 - Ambient Temp. (<25^{0}C)	**Option 2 - Moderate Temp. (80^{0}C)**	**Option 3 - Low Temp. (35^{0}C)**	**Option 4 - Hybrid Option**
Based on \$25/tonne of CO_2	\$550,350	\$501,700	\$526,000	\$349,050
Based on \$50/tonne of CO_2	\$1,100,700	\$1,003,400	\$1,052,000	\$698,100

9.2 Triple Bottom Line Methodology

This chapter outlines the triple bottom line analysis that was used to evaluate the four options for a heat extraction and distribution system for the James Bay and Downtown area. A complete listing of impacts included in the model and sorted by the three categories is provided in Table 9.3.

TABLE 9.3 - Impacts Evaluated for Triple Bottom Line Analysis

Criteria Group	No.	Criteria Categories	Measure Description
Economic	EC-01	Capital Costs	Construction cost and markup for soft costs adjusted to midpoint of construction
	EC-02	Capital Costs Eligible for Grants	Not available at this time
	EC-03	Present Worth of Net O&M costs	O&M costs
	EC-04	Flexibility for Future Expansion	Cost and number of additional buildings to accommodate future equipment
Environmental	EN-01	Carbon Footprint	Tons of eCO2 created/saved
	EN-02	Power (energy) usage	Heat energy replacing natural gas
	EN-03	Heat loss in distribution piping	Loss of revenues
	EN-04	System Reliability	Number of water pumps and heat pumps
	EN-05	Non-renewable Resource Use	Gallons of diesel consumed per year
	EN-06	Non-renewable Resource Generated	Net sale of heat
Social	SO-01	Operations Traffic in Sensitive Areas	Cost of traffic inconvenience during operations
	SO-02	Disruption on Private Property and Customer Acceptability	Construction cost of work on private property
	SO-03	Loss of Usable Building Space on Private Property	Cost of building space required on private property for heat pumps and building
	SO-04	Cultural Resource Impacts	Risk cost of a cultural site find

9.2.1 Economic Factor

EC-01 Capital Costs

Capital costs measure the construction cost and soft costs for each option escalated to the midpoint of construction. Data input included the estimated construction cost and a 2014 midpoint of construction. Assumptions included an inflation rate of 3%. The scoring for capital costs was scaled based on the NPV of costs for all three options with an NPV of $12 million worth three points, higher NPVs worth fewer points and lower NPVs worth more.

EC-02 Capital Costs Eligible for Grants

This impact was intended to measure the value of grants to offset construction costs but at this time, insufficient information is available to adequately account for this impact.

EC-03 Present Worth O&M Costs

Present worth included annual expenditures for operations and maintenance (O&M), and for replacement and refurbishment (R&R) projects. Data input included annual O&M and R&R costs. Assumptions included a 3% rate of inflation for each annual cost. The scoring was scaled based on the annual costs with an annual cost of $88 million worth 3 points, a higher annual cost worth fewer points and lower annual costs worth more.

EC-04 Flexibility for Future Expansion

This impact was intended to measure the flexibility for each option to allow for expansion of the heat recovery system. To measure this, the cost of providing equipment on private property such as heat exchangers and heat pump was estimated for each option. Scoring was based on the following scale:

EC-04 Scoring	
1	More than $12 million
2	$9 to 12 million
3	$6 to 9 million
4	$3 to 6 million
5	Less than $3 million

9.2.2 Environmental Factors

EN-01 Carbon Footprint

The details of the carbon footprint calculation are presented in Section 7.1. Scoring was based on the annual value of offsets for equivalent tonnes of carbon dioxide emitted (assuming $25 per tonne) using the following scale.

EN-01 Scoring:	
1	Less than -$5 million
2	-$5 million to -$10 million
3	-$10 million to -$15 million
4	-$15 million to -$20 million
5	More than -$20 million

EN-02 Power (energy) Use

This impact compares the electrical energy usage for each option. Data input included annual power consumption and a $0.08/kW-hr cost of power. Assumptions included a 3% rate of inflation for power costs. The NPV for electrical costs was calculated for each option and then scaled as follows:

EN-02 Scoring:	
1	More than $60 million
2	$45 to $60 million
3	$30 to $45 million
4	$15 to $30 million
5	Less than $15 million

EN-03 Heat Losses in Distribution Piping

Some of the heat extracted from the effluent will be lost in the transmission lines between the heat exchange at the sewage treatment and the point of use. The NPV of the loss in revenues resulting from heat losses was estimated. The following 1 to 5 score was used.

EN-03 Scoring:	
1	More than $1.5 million
2	$1 to $1.5 million
3	$0.5 to $1 million
4	Less than $0.5 million
5	No loss

EN-04 System Reliability

This impact measures the relative risk carried for each option in terms of system complexity. The number of water pumps and heat pumps required varies for each option. The complexity of each option was compared by multiplying the number water pumps by the number of heat pumps. A $15,000 risk cost per unit was assumed. The following 1 to 5 score scaled was used.

EN-04 Scoring:	
1	More than $100,000
2	$75,000 to $100,000
3	$50,000 to $75,000
4	$25,000 to $50,000
5	Less than $25,000

EN-05 Non-Renewable Resource Use

This impact measured diesel fuel consumption during construction and operations. Diesel consumption during construction was assumed to be 2% of construction costs and diesel consumption during operations was assumed to be 2% of O&M costs. Therefore, data inputted was construction costs and O&M costs. A 3% inflation rate was assumed and a NPV was calculated for each option. The options were scored using the scale below.

EN-05 Scoring:	
1	More than $5 million
2	$4 to $5 million
3	$4 to $4 million
4	$2 to $3 million
5	Less than $2 million

EN-6 Non-Renewable Resource Generated

Non-renewable resource generated measured the available heat to sell for each option after taking into account the heat lost in the transmission. The sale price for heat was assumed at $10 per GJ. The NPV based on annual revenue for each option was calculated and scores were given based on the following scale.

EN-6 Scoring:	
1	Less than $50 million
2	$50 to $75 million
3	$75 to $100 million
4	$100 to $125 million
5	More than $125 million

9.2.3 Social Impacts

SO-01 Construction Disruption

Traffic during construction can be particularly noisome to neighboring residents and businesses. To measure this disruption, the volume of traffic potentially impacted by the district energy system construction was estimated by using traffic counts at nearby intersections for each site. These traffic counts came from CRD's 2005 evaluations. The number of construction trips was calculated by estimating one construction trip per day for every $2,500 of construction budget. The traffic count was multiplied by the daily construction traffic at each site and a plant construction disruption cost was calculated assuming a $1 cost per trip delayed, a 1% probability of delay due to construction and a 12 month construction period.

SO-01 Scoring:	
1	More than $5 million
2	$4 to $5 million
3	$3 to $4 million
4	$2 to $3 million
5	Less than $2 million

SO-02 - Disruption on Private Property and Customer Acceptability

In order to connect to the heat recovery system, equipment and piping may be required at the site of each potential customer. Depending on the option for the distribution system, the equipment at each point of use could include heat exchangers and heat pumps. In many cases, the existing mechanical rooms have to be expanded to allow construction of this work adding to the cost of the system. The cost of this one-time expense of work on private property at each point of use was estimated and a qualitative 1 to 5 score was given as shown below.

SO-02 Scoring:	
1	More than $16 million
2	$12 to $16 million
3	$8 to $12 million
4	$4 to $8 million
5	Less than $4 million

SO-03 Loss of Usable Building Space on Private Properties

The installation of heat pumps and other equipment in the mechanical room on private properties may preclude the use of the building space for other types of use. To measure this impact, the loss of usable building space was estimated and an assumption of a $1,500 per square meter for using the space for heat recovery equipment. The scale used to compare options is presented below.

SO-03 Scoring:	
1	More than $4 million
2	$2 to $3 million
3	$1 to $2 million
4	$0.5 to $1 million
5	Less than $0.5 million

SO-04 Cultural Resource Impacts

A cultural resource find would cause additional cost and delay to site construction. The probability of a cultural find for each site and the resulting delay was estimated along with the estimated construction cost. An assumed 3% inflation rate was used to quantify the delay cost of a cultural find. By multiplying the delay cost by the probability of a find, the risk cost of a cultural find was calculated for each option and compared using the following scale.

SO-04 Scoring:	
1	More than $400,000
2	$300,000 to $400,000
3	$200,000 to $300,000
4	$100,000 to $200,000
5	Less than $100,000

9.3 Results

The results of the triple bottom line analysis is summarized in Table 9.2. The discussion of the results can be found in Section 10.

Table 9.2 – Summary of Triple Bottom Line

	Option 1 - Ambient Temp. (<25^{0}C)	**Option 2 - Moderate Temp. (80^{0}C)**	**Option 3 - Low Temp. (35^{0}C)**	**Option 4 - Hybrid Option**
Economic	49	62	51	88
Environmental	63	53	57	67
Social	36	70	45	70
Total	147	185	153	225

Table 9.3 **Triple Bottom Line Analysis for Heat Recovery**

Criteria Group	No.	Criteria Categories	Measure Description	Weight	Option Results 1	2	3	4
Economic	**EC-01**	Capital Costs	Construction cost and markup for soft costs adjusted to midpoint of construction	9	2.2	2.6	2.4	4.1
	EC-02	Capital Costs Eligible for Grants	Not available at this time	-				
	EC-03	Present Worth of O&M costs	O&M costs	9	2.9	3.2	3.0	5.0
	EC-04	Flexibility for Future Expansion	Cost and number of additional buildings to accommodate future equipment	2	2	5	1	3
			Economic Subtotal (100 pts max)[1]:		**49**	**62**	**51**	**88**
Environmental	**EN-01**	Carbon Footprint	Tons of eCO2 created/saved	3.34	4	4	4	3
	EN-02	Power (energy) usage	Heat energy replacing natural gas	3.34	1	1	1	3
	EN-03	Heat loss in distribution piping	Loss of revenues	3.33	5	3	4	5
	EN-04	System Reliability	Number of water pumps and heat pumps	3.33	4	3	3	3
	EN-05	Non-renewable Resource Use	Gallons of diesel consumed per year	3.33	2	2	2	4
	EN-06	Non-renewable Resource Generated	Net sale of heat	3.33	3	3	3	2
			Environmental Subtotal (100 pts max):		**63**	**53**	**57**	**67**
Social	**SO-01**	Operations Traffic in Sensitive Areas	Cost of traffic inconvenience during operations	5	1	1	1	2
	SO-02	Disruption on Private Property and Customer Acceptability	Construction cost of work on private property	5	1	5	2	4
	SO-03	Loss of Usable Building Space on Private Property	Cost of building space required on private property for heat pumps and building	5	2	5	3	4
	SO-04	Cultural Resource Impacts	Risk cost of a cultural site find	5	3	3	3	4
			Social Subtotal (100 pts max):		**35**	**70**	**45**	**70**
			TOTAL SCORE (300 pts max):		**147**	**185**	**153**	**225**

1 - Economic weighting is proportional to NPV results

Section 10.0 Analysis of Results and Conclusions

10.1 Triple Bottom Line Assessment

The difference in capital and in O&M costs between the three options for a large District Energy System for James Bay and Downtown is not significant. The capital cost of Option 2 is the lowest of the three options for a large DES mainly because of the economies of scale resulting from having all equipment and the heat pumps at one location. Another factor is the lower cost of the transmission line from the sewage treatment plant through downtown to the biosolids facility since hotter water requires a smaller pipe and the added cost of insulation does not offset the cost of larger pipe size for Options 1 and 3.

Option 2 has a lower environmental score of the three options for a large DES because of the heat losses in the transmission main. These heat loss estimated at 8% will result in a corresponding reduction in the amount of saleable heat and a higher energy consumption. The main drawback of Options 1 and 3 is the need to install heat pumps in existing buildings at each point of use. It is likely that the mechanical rooms in many existing buildings will be too small to accommodate the equipment. The need to install equipment on private property could result in significant disruption and could affect the marketability of the heat recovery system. On the basis of the triple bottom line analysis, if a large DES was constructed, Option 2 would be the preferred configuration. With this option, heat pumps are located at the wastewater treatment facility and the hot water at a temperature of 80^0C is distributed throughout the area.

However, the capital costs for Option 4 are much lower since the district energy system would be serving a smaller area, namely the north portion of the downtown area and the biosolids facility. This system would be designed to operate at a lower temperature with lower capital and operating costs. Since that portion of the downtown core will likely see major re-developments, the heating systems of these new developments could be designed on the basis of the requirements of a district energy system. This includes the installation of equipment at the point of use and a heating system designed to operate at lower temperatures. This option has the highest score as a result of the lower capital and O&M cost, less disruption on private properties and higher customer acceptability.

10.2 District Energy System for James Bay and Downtown

As indicated in previous sections of this report, the use of heat reclaimed from wastewater must be analyzed for each end-customer's specific requirements as conditions at different sites can vary dramatically. What is feasible or works in one location may not necessarily work at another location. Temperature, capacity and reliability are important issues from all customers. The potential customers have stated, with respect to reliability and connect-ability of a district energy system that: "…making the ability to connect to the system as attractive as possible for the end users is of utmost importance".

Based on the case studies carried out during the course of this study, it appears that most existing boiler systems are operating at "legacy" temperatures of 80^0C or more. As a result, a DES would be required to supply heat at this temperature in order to meet the peak winter demand of potential customers. If the DES were to supply heat at a lower temperature, either ambient temperature or up to 60ºC, a combination of heat exchangers and heat pumps or a back-up-boiler would be needed on the customer's private property to increase temperatures. It appears, however that in most cases, the mechanical rooms in existing buildings would not be large enough to accommodate this equipment. As well, it is doubtful that a building owner would want to operate, maintain and pay for a second system such as a back-up-boiler for the 30 coldest winter days. This additional expense of a parallel system would seriously affect the marketability of such a DES. It is our opinion therefore that for existing infrastructure areas such as James Bay and Downtown Victoria, a DES must supply heat at a temperature of 80^0C and that Option 2 would be the preferred option for a large system.

The average and maximum process heat demand for the biosolids facility corresponds to 11% and 14% respectively of the available heat of 25,000 KW. In an 80^0C heat distribution system with the long transmission lines proposed, heat losses amount to approximately 8%. Therefore, on average, only 81% of the heat that can be extracted from treated effluent is available for sale. For the purpose of this analysis, however, it has been assumed that the heat required by the digesters would be considered revenue for the DES

The heat supply and distribution system for the Downtown and James Bay area has been sized as follows:

- A 13 km long pipe loop (6.5 km double pipe) sized to convey all the available heat that can extracted from treated effluent in early morning hours (25,000 KW);
- The equipment, such as heat exchangers, heat pumps and water pumps, could be installed in three stages to supply 30%, 60% and 100% of the available heat, and
- The building to house the equipment could be staged as well.

Based on the above staging, the capital cost of a large DES based on Option 2 is estimated as follows:

- Stage 1 $29,314,000
- Stage 2 $8,787,000
- Stage 3 <u>$7,531,000</u>
- **Total** **$45,632,000**

The operating and maintenance cost and the estimated revenues at 30%, 60% and 90% of viable heat sold are summarized in **Table 10.1**. The value of the carbon credits based on $25 and $50 per tonne of CO_2 are also shown in **Table 10.1.**

Table 10.1 – Summary of O&M Cost and Revenues for DES for James Bay & Downtown

	O& M Cost	Revenues	Net Revenues	Carbon Credit	
				$25/tonne	$50/tonne
30% of heat sold	$1,394,000	$1,410,000	$1600	$150,000	$300,000
60% of heat sold	$2,659,000	$2,819,000	$160,000	$301,000	$602,000
90% of heat sold	$3,933,000	$4,228,000	$295,000	$451,000	$902,000

When the value of the carbon credit is added to the net revenues, the revenues could increase significantly. However the payback period is in excess of 50 years assuming net revenues of $295,000 and a carbon credit of $25/tonne.

In order to reduce the payback from 50 years to 12 years, the following conditions would be required:

- The revenues would have to increase from $10/GJ to $15/GJ
- The value of the carbon credit would have to increase from $25/tonne to $50/tonne
- The cost of electricity to run the heat pumps would remain at $0.08/kWh

There are several reasons why the capital, O&M costs and payback period are high:

- The length and resulting cost of the insulated transmission main of 13 km distributing heat (pipe loop, 6.5 km each direction) from the WWTP to the most distant point of use, which would be the digesters located in the Upper Harbour;
- The heat extracted from the effluent must be lifted twice from a temperature difference (potential) of 7ºC in winter (12ºC – 5ºC) to the required end user temperature of 80ºC. The size and cost of the equipment to accomplish these two lifts is significant. In addition, the electrical power consumption for the pumps and heat pumps is significant and increases operating costs substantially;
- The low flows early in the morning limit the amount of consistent available heat that can be extracted from the effluent. Since the peak demand occurs when flows are lowest and therefore the amount of heat that can be extracted, the net sales are limited. These low net sales adversely affect the payback on the huge capital costs for equipment, and

- Energy prices for heating with current energy sources, mainly natural gas, are too low to be able to charge more for a DES unit of energy. If energy prices were more in line with European prices, revenues would be higher and the payback period would be reduced.

10.3 District Energy System for the North Downtown Area

Modern heating systems, primarily in the last decade or so, are designed using condensing boilers which operate at significantly lower temperatures of approximately (140^{0}F). As well, the proposed digesters will be designed to operate at 55^{0}C. These temperature levels align much better with the temperature-coefficient of performance (COP) constraints of modern heat pumps. The COP at these temperatures would make the business case more favorable as factors like transmission heat loss, equipment size and needed electrical energy would be reduced. This would allow the DES to operate a lower temperature of 60-65^{0}C instead of 80^{0}C. A recent example is the South East False Creek DES which is designed to supply water at a temperature of 65^{0}C.

Further to this, there is an opportunity to start with a smaller DES designed for a smaller heat load that would include the digesters and future building developments. The heat extracted from the effluent could be conveyed to the digesters by a shorter route through Esquimalt and Victoria West. In a second phase, the DES loop could be extended into the north portion of the downtown area where it is anticipated that significant residential and commercial developments will occur. These developments would likely include lower temperature heating systems which correspond to higher COP's from heat pumps.

The heat supply and distribution system for the north portion of the Downtown area has been sized as follows:

- A 7 km long ambient temperature pipe loop to convey heat extracted from the wastewater treatment plant at McLoughlin Point to biosolids handling facility in the Upper Harbour area. This would convey two-third of the available heat that can extracted from treated effluent in early morning hours (16,750 KW);

- In a first stage, heat pumps could be installed to provide process heat to the biosolids facility.

- In a second stage, a separate 3.2 km long pipe loop could distribute heat at a temperature of 60 to 65^{0}C. Additional heat pumps would be installed as the demand for heat increases.

Option 4 improves the business case in several aspects as follows:

- The supply temperature to future infrastructure in Downtown North would be at lower temperatures allowing higher coefficients of performance, less heat loss and smaller equipment sizes and therefore, less equipment cost and lower power consumption.

- This is reflected in the lower capital and O&M cost and increased revenues for Option 4 as follows:
  - Capital cost $29,274,000 (based on conveying 16,750 KW)
  - O&M Cost $2,521,000
  - Revenues $3,018,000 (based on selling 90% of heat)
  - Net Revenue $497,000
  - Carbon credit $314,000 (based on $25/tonne)

10.4 Conclusions

It would be very challenging to implement a district energy system to service the James Bay and Downtown area. The huge capital cost needed to lift wastewater heat to 80ºC and convey it in a 13 km pipe loop does not make a good business case based current energy prices and carbon credit. The payback period for system serving the James Bay and downtown area exceeds 50 years based on current electricity and natural gas prices and the value of the carbon credit of $25/tonne.

Consideration should be given to constructing a smaller energy system to service new developments in the north portion of the Downtown area. This smaller energy system could be integrated with the energy requirements of the biosolids facility that could potentially be located in the Upper Victoria Harbour. Heat extracted from the effluent would be conveyed from the wastewater treatment plant to the biosolids facility at ambient temperature thus eliminating heat losses along this 3.5 km long line. This system could be constructed once further market assessment for heat demand in the North downtown core is completed.

A district heating facility housing the heat pumps could be located at the biosolids facility and hot water at a temperature of 60-65^{0}C would be distributed to the biosolids process equipment and the nearby north portion of the downtown area. This system would be designed to take into account the lower operating temperature of newer heating systems.

The capital cost of this smaller DES system is estimated at $29,274,000. This system can be phased with the cost of the first phase estimated at $12,258,000. This amount includes the construction a non-insulated ambient temperature transmission line from the WWTP to the biosolids facility and sized for the needs of the north downtown area. This amount includes the heat exchangers and the heat pumps sized for the biosolids facility only. In a second phase, estimated at $17,016,000, a loop to serve the north downtown area with an insulated line to a temperature of 65^{0}C together with additional heat exchangers and heat pumps would be constructed.

Since it is proposed to use only two thirds of the extractable heat to provide process heat to the biosolids facility and the north Downtown area, a significant amount of energy would be available for other developments in Victoria West and Esquimalt. This could be incorporated into the energy loop between the plant and the biosolids facility by upsizing this 3.5 km long line from 600 mm to 750 mm at an additional cost of $2.5 million.

Capital Regional District

Core Area Wastewater Treatment Program
Effluent Reuse and Heat Recovery for the University of Victoria and Surrounding Area

Stantec

Executive Summary

The proposed wastewater treatment facilities for the Core Area present potential opportunities for recovery of resources from wastewater. There are a number of factors which must be considered when assessing these opportunities. In order to further examine this matter, a more detailed feasibility study on the recovery of heat and effluent reuse for the University of Victoria and surrounding areas was carried out.

Part A – Reuse of Reclaimed Water

In order to maximize the water reuse potential of the Saanich East- North Oak Bay (SENOB) plant, it is proposed to construct a tertiary membrane filtration plant for the majority of the plant flow to treat up to 1.75 times the projected 2065 average daily flow of 17.2 ML/day. The infrastructure generally needed to reuse reclaimed water includes: (1) filtration of effluent to produce high quality water, (2) disinfection using chlorine, (3) equalization storage, (4) high lift pumping, (5) “purple pipe” distribution system, (6) connection to the customers, and (7) modification of existing building plumbing and irrigation systems to accept reclaimed water.

Regulatory Framework

The use of reclaimed water in British Columbia is governed by the Municipal Sewage Regulation issued under the Waste Management Act. This document regulates the treatment standards and the allowable uses for reclaimed water. In addition, the Province has developed a *Code of Practice for the Use of Reclaimed Water*. The BC Ministry of the Environment intends to revise the Municipal Sewage Regulation. In November 2009, the Province released a *Policy Intentions Paper for Consultation* to this effect.

The Health and Safety criteria in the current Regulation indicate that no contact with reclaimed water must occur when using reclaimed water on parks, playground and school grounds, that irrigation with reclaimed water must not occur within 60 m of areas where food is handled or consumed and that direct public contact with reclaimed water must be minimized. The Policy Paper proposes to remove the 60 m setback from areas where food is handled or consumed. The no contact requirements will be retained and are generally considered good practice when dealing with reclaimed water.

The Municipal Sewage Regulation indicates that a minimum of 20 days of emergency storage must be provided at the wastewater treatment facility to allow the effluent flow to be diverted to storage in case the water does not meet the standards required. However, if the treatment plant is built with multiple units capable of meeting the reclaimed water standard with one unit out of operation, emergency storage may be reduced to a minimum of 2 days. The Policy Paper proposes to replace the storage requirements with a requirement that treatment processes must be built with multiple units capable of meeting reclaimed water standard with one unit not in operation.

The Municipal Sewage Regulation indicates that treatment requirements for areas with unrestricted public access are as follows:

- Secondary treatment followed by chemical addition and filtration:
  - BOD $\leq$10 mg/L
  - Turbidity $\leq$ 2 NTU
  - pH = 6 - 9
  - Fecal coliform $\leq$ 2.2/100 mL
  - Minimum total residual chlorine of 0.5 mg/L at point of use

The Policy Intentions Paper proposed the following treatment requirements for areas with the highest exposure potential such as parks, golf courses, playground and landscaping around buildings :

- Treatment requirement is virus removal via chemical addition and filtration:
  - BOD: 10 mg/L maximum
  - Turbidity: 2 NTU average and 5 NTU maximum
  - pH = 6 - 9
  - Fecal coliform: 2.2/100 mL median and 14/100 mL maximum
  - Chlorine residual to be maintained

Proposed SENOB Treatment Plant

The proposed SENOB treatment plant can meet the treatment requirements of the current MSR and of the Policy Intentions Paper through the use of membrane bioreactor ultrafiltration which can produce an effluent with low BOD and turbidity and by the provision of chemical addition and coagulation in the primary clarifiers upstream of the biological and filtration processes.

During the dry weather months, the proposed SENOB treatment plant can meet the alternative storage requirements of having multiple units capable of meeting reclaimed water standard with one unit out of operation and an alternative method of disposing or reclaimed water. From May to October, the plant can meet the reclaimed water standards with one unit out of operation. However, during the winter months, the secondary biological treatment process may not be capable of meeting effluent requirements with one unit out of operation when wet weather flows are exceeding 1.15 x ADWF. This would preclude the use of reclaimed water during the winter months unless the number or aeration basins are increased from two to three. However it is noted that reclaimed water for irrigation purposes would not be required during the winter months. Similarly the number of primary clarifiers would have to be increased from two to three. However as discussed later, the demand for reclaimed water in the months is minimal.

Demand for Reclaimed Water

a) Golf Courses Irrigation

The maximum daily demand reported by each of the three golf courses in the area ranges from 1.3 ML/d and 2.0 ML/d. However, the Cedar Hill golf course reported obtaining approximately two thirds of their irrigation water from wells located on site and the balance from the municipal water system.

b) University of Victoria Irrigation

At the University of Victoria, about two thirds of the irrigated landscaped areas are located near buildings and pathways. Because of the pedestrian nature of the campus and the variety of usage, the risk that people would get into direct contact with reclaimed water is very high in many parts of the campus. However, the northwest and west portions of the campus include large lawn areas and several sport fields which have controlled public access at night. In order to reduce risks of direct contact between the public and reclaimed water, it is proposed to use reclaimed water irrigation in the sport fields and the landscaped areas on the perimeter of the campus. With these restrictions, the irrigation water demand using reclaimed water is estimated at 1.21 ML/d.

c) Other Potential Irrigation Water Users

There are a number of small municipal parks in the area around the University of Victoria and these are usually associated with adjacent schools. The irrigable area in these areas is approximately 13 ha and the peak demand is estimated at 0.43 ML/d .

d) Toilet Flushing

The University has indicated that the building floor area on campus could increase by 10% to 15% over the next 15 to 20 years. Based on a 12.5% increase in floor area and one third of water being used for toilet flushing, the future demand for reclaimed water is estimated at 57m3/day (0.057 ML/d). This demand is negligible compared with irrigation demand. It would be impractical to retrofit existing buildings with a separate reclaimed water piping system to be used for toilet flushing only.

Options for Reclaimed Water Systems

The following four options were examined for a potential reclaimed water system:

- Option 1 – University of Victoria and surrounding schools and institutions. Daily irrigation demand of 1.62 ML/d.
- Option 2 – University of Victoria and one major golf course. Daily irrigation demand of 3.0 ML/d.

- Option 3 – University of Victoria and two major golf courses with Cedar Hill golf course obtaining two third of irrigation water from wells. Daily irrigation demand of 3.4 ML/d.

- Option 4 – University of Victoria and two major golf courses with no well supply at Cedar Hill golf course. Daily irrigation demand of 4.3 ML/d.

The irrigation demand occurs mainly in at night in between 10:00 PM and 6:00 AM when the golf courses, playground and the sports fields are not in use and to minimize direct contact with reclaimed water. However the irrigation demand occurs at night when sewage flows are low. In order to provide enough reclaimed water at night to meet the irrigation demand, equalization storage is required if one or more golf courses are irrigated in addition to irrigation at the University of Victoria. To ensure the microbial water quality is met for fecal coliform, adequate contact time is required and a chlorine contact chamber is needed. The daily demand for the various options and the sizing of the main components of a reclaimed water system are summarized in Tables E.1 and E.2.

Table E.1 – Daily Demand for Reclaimed Water (ML/d)

	Option 1 – UVic Only	Option 2 – UVic & One Major Golf Course	Option 3 – UVic & Two Major Golf Courses – Partial well supply	Option 4 – UVic & Two Major Golf Courses – No well water
UVic Irrigation Demand	1.21	1.21	1.21	1.21
UVic Reclaimed Water Demand	0.06	0.06	0.06	0.06
Major Golf Course Water Demand		1.30	1.74	2.60
Schools, parks and other institutions	0.35	0.43	0.43	0.43
Total Daily Demand	1.62	3.0	3.44	4.3

Table E.2 – Summary of Reclaimed Water System Components

	Option 1 –	Option 2	Option 3	Option 4
Chlorine Contact Chamber (m^3)	310	570	650	865
Equalization Storage (m^3)	0	340	575	1160
Pump motor size (HP)	120	200	250	250
Distribution system	2.0 km long 300 mm pipe	4.3 km long 250 - 350 mm pipe	6.5 km long 150 - 400 mm pipe	6.5 km long 250 -400 mm pipe

Capital and operating and maintenance (O&M) costs were developed for all four options. The projected gross annual revenues are based on an incentive pricing of $0.72/ m^3. The CRD sells treated water to the local area municipalities at a rate of $0.5433/m^3. In turn, the District of Saanich sells potable water at a rate of $1.05/m^3. The District of Oak Bay sells water to golf courses at a bulk rate of $0.55/m^3. The sale of reclaimed water will result in a corresponding reduction in the sale of treated water.

Table E.3 summarizes the capital and O&M costs for the four options. When taking into account the annual O&M cost and the loss in revenues from the sale of treated water, the CRD will incur an operating loss from the sale of reclaimed water at a rate of $0.72/m^3.

Table E.3 – Summary of Estimated Cost & Operating Loss

	Option 1 – UVic and Surrounding Schools	Option 2 – UVic & One Major Golf Course	Option 3 – UVic & Two Major Golf Courses – One course with wells	Option 4 – UVic & Two Major Golf Courses – No well water
Total Capital Costs	$3,877,000	$7,820,000	$10,288,000	$11,840,000
Annual O & M Costs	$70,500	$102,400	$128,400	$141,500
Projected Gross Annual Revenues (based on $0.72/m^3)	$103,000	$167,000	$194,400	$226,800
Lost Revenues from Sale of Treated Water	$77,700	$126,000	$146,600	$147,800
Loss	- $45,200	- $61,400	- $80,600	- $85,700

In order to increase the revenues and avoid an operating loss, the price of reclaimed water would have to be increased to $1.05 m^3 which is similar to the price of potable water. Policy changes would be necessary to provide an incentive for users to use reclaimed water.

The above capital cost estimates are based on locating the SENOB plant at or near a site owned by the CRD on Arbutus Road. The capital cost of the reclaimed water system would be reduced by $1.5 million if the SENOB plant was built at the UVic Field Site located on the north side of McKenzie Avenue near Gordon Head Road. However the cost of the SENOB plant would be approximately $25 to $30 million higher as a result of the need to build a large pumping station and 1.5 km long forcemain to pump all the sewage from the trunk line on Haro Woods to the UVic Field Site and also to extend the outfall pipe by the same distance.

Triple Bottom Line Assessment

A value-based triple bottom line evaluation has been completed for the four options. Equal total weighting has provided a value for social, environmental and economic categories.. The results of the TBL indicate the following relative scores.

Table E.4 – Summary of Triple Bottom Line

	Option 1	Option 2	Option 3	Option 4
Economic	83	55	45	40
Environmental	74	66	51	51
Social	92	72	32	28
Total	249	193	128	119

Conclusions – Reuse of Reclaimed Water

All four options provide for varying volumes of reuse of reclaimed water mainly by the use of spray irrigation in urban areas. The use of reclaimed water for toilet flushing has also been investigated. Toilet flushing could be implemented on new construction but conversion of existing plumbing systems would be very costly in existing building and is not feasible.

Public acceptability of irrigation using reclaimed water needs to be established and starting with Option 1, which provides for irrigation on the University of Victoria campus, could be seen as a phased demonstration project to provide the opportunity for public education. As the reuse of reclaimed water becomes more acceptable, the system could be extended to service adjacent large users such as golf courses.

As the reclaimed water system is expanded, the chlorine contact chamber will have to be enlarged and pumping equalization storage will be required. However there are opportunities to share the equalization storage needed for irrigation with the equalization storage required to deal with heat extraction. This is further discussed in Part B of the report.

A reclaimed water system would provide social and environmental benefits such as promoting public awareness of water conservation and reducing the effluent discharge into the ocean during the summer months. There are no financial benefits since the annual revenues will only cover the annual O&M and the corresponding loss of revenues from the sale of treated water. This assumes that reclaimed water is sold at the same price as potable water. If reclaimed water is sold at a lower price, there would be an annual operating loss. None of the capital cost of the water reclamation system would be recovered by the revenues.

Part B – Heat Recovery

The existing 2009 average daily sewage flow at the proposed Saanich East/North Oak Bay SENOB sewage treatment plant is 9.6 ML/d. The sewage flows are projected to increase substantially to 16.6 ML/day for 2030 and 17.2 ML/day for 2065. The estimated saleable heat and the heat demand at the University of Victoria is shown in Table E.5

Table E.5 – Estimated Saleable Heat from SENOB STP (GJ/yr)

Year	Estimated Saleable Heat	Heat Demand
2009	94,250	211,762
2030	162,970	243,500*
2065	168,800	280,000*

When this demand is compared with the estimated saleable heat as shown in Table E.4, it can be seen that based on current sewage flows, the saleable heat is less than 50% of the annual demand. At the estimated 2030 sewage flow, the available heat is approximately 67% of the demand. Because of the limited supply of heat, long conveyance distances, high capital cost and proportionally small demand, it is proposed not to consider the heat demand of adjacent schools and institutions.

The UVic Campus is currently served by a high temperature (230F) natural gas fired District Heating System (DHS). Unfortunately this system has been designed to operate at much higher temperatures than are available from effluent heat pumps. In addition, hourly variations in available heat from treated effluent must be considered.

Figure E.1 shows the hourly variations in heat demand of the DHS for the entire campus of the University of Victoria assuming a 12^0C winter wastewater temperature. The heating systems go into set-back mode between the hours of 8pm - 5am. This is when demand is at its lowest. At approximately 5 – 6 am, there is a sharp spike in demand as the boilers ramp-up to heat the buildings for the students and staff arriving between 7 am and 9 am. The system reaches a daytime equilibrium and then drops in the evening. Unfortunately, the morning peak heating demand occurs while the sewage flows are still low thus limiting the supply of heat at peak demand time.

It order to provide additional heat early in the morning, it is proposed to install a 1540 m^3 storage tank to make up for low sewage flows. Otherwise the amount of available heat as compared to the heat demand is extremely low. Also, since most boilers are not designed for frequent start and stop, the existing boilers cannot be used to supplement available heat for a few hours only.

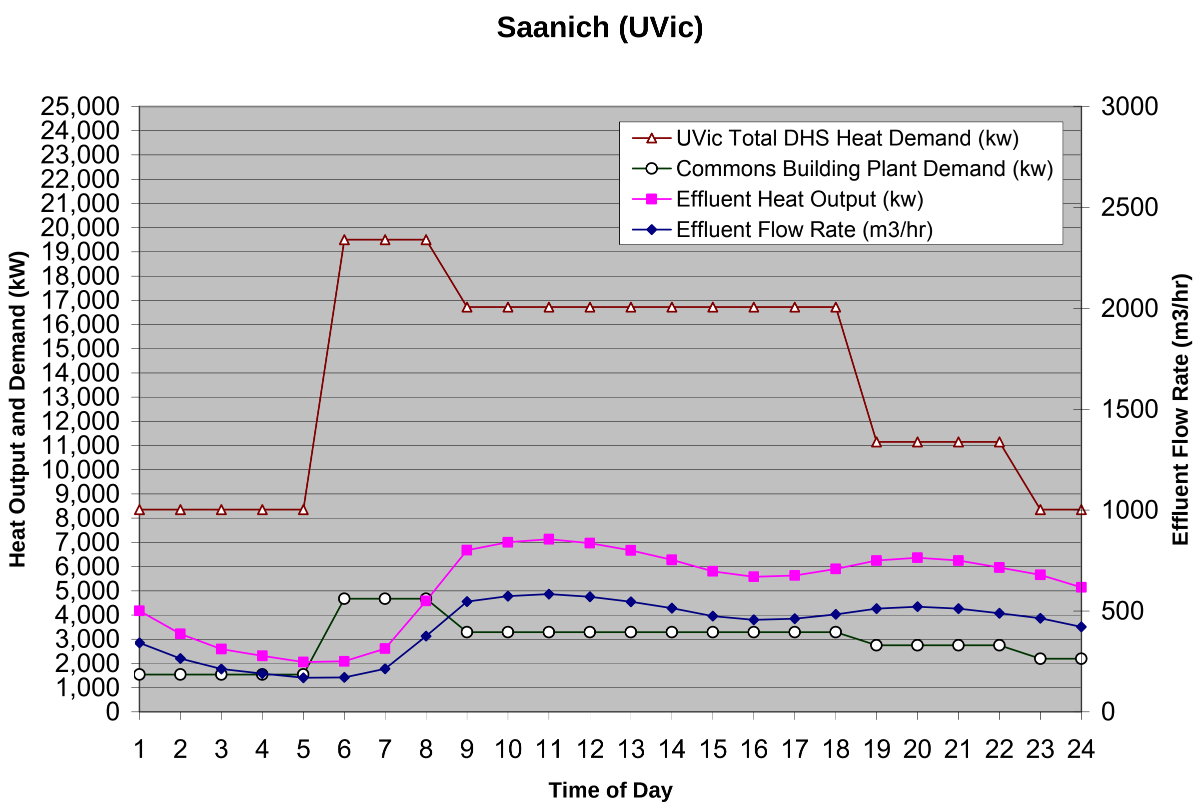


Figure E.1 – Hourly Variations in Heat Demand and Heat Available from Effluent

In order to deal with the limited heat supply, it is proposed to service only a portion of the campus with the effluent heat extraction system. The heat demand for space heating and domestic hot water for the entire campus is normally provided by 4 boilers in a central heating plant located in the Engineering Laboratory building (No. 4 boiler room). All the buildings on campus except smaller residential buildings are connected to a district heating system. There are three older boiler rooms on campus. One of these boiler plants, the Commons Building, is fired during the coldest period of the year to supplement the newer No. 4 boiler room.

It is proposed to supply heat extracted from effluent to the portion of the central heating system that can be valved off and supplied from the No. 2 boiler room located in the Commons Building. This would include the following buildings: The Commons, Student Union Building, Craigdarroch residences (David Thompson, Emily Carr, Margaret Newton, Arthur Currie) and the Lansdowne residences. The Commons plant is connected to the remainder of the University's district heating system by an 8 inch diameter pipe loop. In the summer, when space heating demand is low, the available heat from effluent could instead be used to provide domestic hot water heating. It appears there is enough heat available from wastewater to serve both DHW and heat for the swimming pool in the McKinnon building. This would permit the

University to shut down the 4000 KW natural gas fired boiler in the main boiler plant that they currently run all summer to serve the domestic hot water and McKinnon pool demand.

The highest hot water temperature that can be supplied from heat pump devices is 80 C (176 F) without major reductions in the coefficient of performance (COP). This could have a major impact on the amount of heat that may be delivered from the existing heating equipment in these older buildings. The Campus boilers currently run at 230 F.

The amount of heat at a lower temperature of 80 C would be sufficient for most of the shoulder season and domestic hot water heating. During the coldest winter days, the boilers may need to be fired to meet the demand from the 7 residence buildings. Further testing of the system will be required to confirm both the effects of the lower temperature water on heat supply to the buildings and to see how much of the shoulder heating season the wastewater heat extraction can cover.

Three alternatives of systems to provide heat extracted from the effluent to the University were evaluated:

Option 1: Ambient temperature distribution system (up to 20 ºC)

Option 2: Moderate temperature distribution system (80 ºC)

Option 3: Low temperature distribution system (35 ºC)

The district heating system would generally consist of the following components:

1. Heat exchangers – to transfer heat from the treated effluent to a clean liquid in a district heating loop;
2. Water pumping – a first set of pumps to flow effluent through the heat exchangers and then a second set of pumps to flow the clean fluid though the district heating loop;
3. Heat pumps – the temperature of the clean liquid has to be “lifted” to the requirements of the building heating system in order to be useful for the end customer;
4. Distribution piping – to distribute the clean heating liquid from the wastewater treatment plant to the end users;
5. Various treatment, expansion and buffer tanks, and
6. Direct Digital Control (DDC) System.

The system components are summarized in Table E.6

Table E.6 – Summary of Options for District Energy System

Components	Option 1 – Ambient Temp. Distribution System (up to 20C)	Option 2 – Moderate Temp. Distribution System (80 C)	Option 3 – Low Temp. Distribution System (35 C)
Heat exchangers	At sewage treatment plant and end user's facility	At sewage treatment plant and end user's facility	At sewage treatment plant and end user's facility
Water pumps	At sewage treatment plant	At sewage treatment plant	At sewage treatment plant
Heat pumps	At end user's facility	At sewage treatment plant	First lift heat pump at STP and second heat pump at point of use
Distribution piping	Non insulated pipe - PVC or HDPE	Insulated welded steel pipe	Insulated PVC or HDPE

The capital cost the O&M cost and the estimated revenues for the three options are summarized in Table E.7. This table also shows the value of the carbon credit resulting from the reduction in use of natural gas at the University of Victoria

Table E.7 - Summary of Costs and Revenues

	Option 1 – Ambient Temp. Distribution System (up to 20 C)	Option 2 – Moderate Temp. Distribution System (80 C)	Option 3 – Low Temp. Distribution System (35 C)
Capital Cost	$13,125,000	$12,083,000	$12,797,000
O&M Cost	$1,056,000	$1,006,000	$1,035,000
Annual Revenues Based on Available Heat (Current Sewage Flows)	$1,110,000	$1,021,200	$1,065,600
Estimated Value of Carbon Credit ($25/tonne CO_2)	$119,525	$108,625	$114,200
Estimated Value of Carbon Credit ($50/tonne CO_2)	$239,050	$217,250	$228,400

The difference in capital and in O&M costs between the three options under consideration is not significant. The capital cost of Option 2 is lower mainly because of the economies of scale resulting from having all equipment and the heat pumps at one location. Another factor is the lower cost of the transmission line from the sewage treatment plant to the campus since hotter water requires a smaller pipe and the added cost of insulation does not offset the larger pipe size. However, Option 2 has a lower environmental score because of the heat losses in the transmission main. These heat loss estimated at 4% will result is a corresponding reduction in the amount of saleable heat and a higher energy consumption. The main drawback of Options 1 and 3 is the need to construct a new building on campus in order to house the heat pumps and other equipment at the point of use. The need to construct facilities on private property could result in significant disruption as well as the loss of land. This could also affect the marketability of the heat recovery system.

Conclusions – Heat Recovery and Reclaimed Water

The use of reclaimed water and recovered heat must be analyzed for every specific situation as conditions at different sites can vary dramatically and what is feasible or works in one location may not necessarily work at another location. This report has investigated the feasibility of effluent reuse and heat recovery for the specific conditions at the campus of the University of Victoria and surrounding area. The capital costs for the recovery of heat and reclaimed water at the proposed SENOB wastewater treatment plant for reuse on the campus of the University of Victoria are significant and are summarized as follows:

- Capital cost of reclaimed water system (Option 1) $3,877,000
- Capital cost of heat recovery system (Option 2) $12,083,000
- Total capital cost $15,960,000

The operating and maintenance costs and the revenues generated by the recovery of heat and reclaimed water are summarized in the following table:

	Reuse of Reclaimed Water	Heat Recovery
O&M cost	$70,500	$1,006,000
Revenues	$103,000	$1,021,000
Lost revenues from the sale of potable water	- $77,700	0
Net revenues/loss	- $45,200	$15,000
Carbon credit	0	$108,000

Based on current available heat, a sales price for heat of $10/GJ and a carbon credit of $25/tonne, the payback period is 98 years for a heat recovery system.

There are several reasons why the capital costs are high for both the reclaimed water and the heat recovery systems:

- The length of the transmissions mains, 2 km for reclaimed water and 3.2 km for heat (dual pipe system 1.6 km each) from the WWTP to the point of use on the campus is a factor in the cost. However there would be a major increase in the cost of the wastewater treatment plant, estimated at $25 million, if the SENOB plant was moved from its proposed location on Arbutus Road to a location on the Campus;

- The MSR and public health restrictions on the use of reclaimed water for spray irrigation have reduced the irrigable campus area by two-thirds so only one third of the campus can be considered for irrigation and this significantly reduces the water demand and potential revenues. The proposed changes to the MSR will eliminate some but not all the restrictions on using reclaimed water in areas with public access. Most notable, is the requirement to avoid direct public contacts for parks, playgrounds and schools and in other areas to minimize direct public contact with reclaimed water. There is a real potential for students to come in contact with non-potable reclaimed water so irrigation areas at UVic must be selected carefully ;

- The cost of irrigation using municipal water is much lower than reclaimed water and there are no public health limitations placed on use of this water;

- The heat extracted from the effluent is low grade heat which has a temperature of 12 C during the winter heating season. Following heat exchange between the effluent and clean water, the water temperature has to be boosted twice with heat pumps in order to achiever the minimum useful temperature of 80 C. The power consumption of the heat pumps is significant and this increases operating costs substantially;

- Even at 80 C, this is lower than the operating temperature the campus district heating system which is in the range of 105-115C. As a result, the use of extracted heat is limited to supplying domestic hot water in summer and space heating in the shoulder seasons. During the colder winter months, boilers will have to be fired up in order to meet the demand for space heating;

- The peak demand for heat occurs early in the morning and this corresponds to the lowest flow rate of the day. In order to supplement the low available heat, equalization storage is proposed since the life expectancy of boilers will be severely reduced by frequent stop and start cycles. (Boilers are designed to stay on for extended periods of times and not daily off-on cycles);

- Even with equalization storage, the amount of available heat from treated effluent represents only 25% of the morning peak demand for the campus based on existing sewage flows of 10 ML/d;

- The reclaimed water and the heated water must be pumped in separate pipelines over a 30 m difference in elevation.

- The existing sewage flow at the proposed SENOB plant averages 10 ML/d. This is significantly lower than the 2030 design flow of 16.6 ML/d. The amount of available heat is proportionally reduced.

The Climate Action Plan by the Province of British Columbia may result in an increased carbon tax and a carbon trading system. These initiatives could place a higher value on carbon and increase the benefit of heat extraction.

The proposed SENOB plant should be designed in such a manner that the footprint and piping connections required for the infrastructure needed for resource recovery are provided. This would allow the implementation of resource recovery either now or in the future. Heat recovery for the new buildings at the SENOB WWTP could be considered as it is likely this system could be implemented economically.

Table of Contents

Section 1 Introduction

1.1 Introduction

The Capital Regional District is planning the construction of a wastewater treatment facility in the Saanich East-North Oak Bay (SENOB) area. One potential location for this plant is on a parcel owned by the CRD on Arbutus Road. This site is known as the Finnerty Arbutus site. Two other potential sites for this facility are owned by the University of Victoria. The proximity of the proposed SENOB plant to the University of Victoria campus provides an opportunity for the recovery of heat and effluent reuse on the University grounds, and the surrounding area.

In order to maximize the water reuse potential of the SENOB plant, it is proposed to construct a tertiary membrane filtration plant for the majority of the plant flow to treat up to 1.75 times the project 2065 average daily flow of 17.2 ML/day. The *Core Area Wastewater Treatment* Program *Assessment Options 1A, 1B and 1C* report prepared by Stantec Consulting Ltd. and dated September 16, 2009 indicated that this would provide high quality reclaimed water for uses not only on campus but also for other users in the surrounding area such as golf courses. One of the objectives of this study is to carry out a more detailed assessment of the local water reuse market and to develop a draft water reuse plan. A separate “purple pipe” effluent distribution system would be required to implement such a system.

The recovery of heat from raw sewage or from treated effluent to supply heat to large users is also a major focus of resources that can be recovered from wastewater. A preliminary assessment has indicated that all of the heat generated from the wastewater could be utilized by the University of Victoria to meet some of their needs for space heating and domestic hot water.

Heat recovery requires infrastructure to: (1) transfer the heat from the effluent to a clean liquid through heat exchangers, (2) lift the temperature of the clean liquid to a level that is usable by boiler systems through the use of heat pumps, (3) pumping of heated liquid, (4) distribution of the heated liquid through a network of pipe, and (5) connection to the customers.

The infrastructure needed to use reclaimed water include: (1) filtration of effluent to produce high quality water, (2) disinfection using chlorine, (3) equalization storage, (4) high lift pumping, (5) “purple pipe” distribution system, and (6) connection to the customers.

This report examines various options and requirements for the various components of the infrastructure needed to deliver heat and reclaimed water to potential users, including the vicinity of the SENOB wastewater treatment facility.

1.2 Challenges and Opportunities

Perceptions of treated effluent as a waste material can affect the willingness of clients, public, potential customers and regulators to embrace the idea that treated effluent is a resource that can be utilized for irrigation and as a source of heat or cooling. Open loop geo-exchange systems often rely on water from aquifers in the earth that is usually pumped from wells at approximately 12^0C, the very same expected lowest temperature of treated effluent water! Treated effluent represents an excellent source of water for operating heat pumps and when the effluent is between 12^0C and $20\ ^0$ C, heat pumps operate even more efficiently than with 12^0 C source water.

Before options for a treated effluent utility are described in detail, the technical, regulatory and perception challenges of heat exchange from wastewater must be addressed. Previous effluent heat recovery projects and studies have identified the following challenges.

The lowest treated effluent flows occur at night and in the early hours of the morning when heating demands are generally the highest. Buildings typically experience a demand spike in the morning to heat up the building for user comfort. Effluent flow, and therefore heat supply typically lag demand by a few hours in the early morning. Treated effluent flows can also vary from season to seasons and even during certain weather conditions if groundwater infiltration into the sanitary sewer system is an issue. Therefore, the careful selection of design constraints that consider peak and lowest treated effluent flows is essential to a successful system.

Total required heating power demand (KW) far exceeds the heat supply. This shortfall would have to be compensated by either reducing demand (e.g. reducing number of buildings connected) or increasing supply by employing an “energy source mix” from, for example, sea water, backup boiler possibly fired with bio-methane or natural gas, solar thermal and/or geothermal.

Treated effluent can be corrosive and any metal components can corrode if proper materials are not specified. Entrained air is present in large quantities in treated effluent, thus making the design of high capacity air venting systems essential for any closed loop or circulating pipelines. The presence of available entrained air, corrosive sewage and thus oxygen accelerates the corrosion of any metal components in the pipeline system.

Secondary treated wastewater contains small amounts of suspended solids, thus the fouling of any heat transfer or heat exchange surface can be an ongoing concern. Treatments for this condition include online heat exchanger cleaning systems, spiral “tube in tube” heat exchangers similar to those used in the pulp and paper industry, and heat exchangers with a high internal scouring velocity in order to prevent fouling. At the SENOB plant high quality MBR effluent should assist in minimizing fouling potential.

Pipelines for conveyance of the treated effluent are costly and must have proper clearance from watermains in order to avoid cross contamination with domestic water utilities and satisfy regulatory requirements.

Ministry of Environment standards dictate the quality and temperature of discharged effluent, as well as the requirement to not contaminate the discharged effluent in any way. Usually, any treated effluent heat exchangers must be of the double wall type, adding cost and complexity to whatever heat recovery system is installed.

1.3 Report Organization

This report is divided as follows:

- Part A – Reclaimed Water Reuse for the University of Victoria and the surrounding area. This portion of the report includes Sections 2 to 7.
- Part B – Heat Recovery System for the University of Victoria. This portion of the report includes Sections 8 to 14.

Separate analyses and recommendations were carried out for the water reuse and the heat recovery portions of this report.

PART A – Reclaimed Water

Section 2 Regulatory Framework for Water Reuse

2.1 Examples of Reuse of Reclaimed Water

Several communities in British Columbia use reclaimed water from treated effluent. These include the BC Interior communities of Vernon, Osoyoos, Oliver, Armstrong and Penticton, as well as Cranbrook and Kamloops. Vernon reclaims a large proportion of its treated municipal wastewater for irrigation of 2,500 acres of agriculture, forestry and recreational lands. In Kamloops, 300 acres of agricultural land producing hay and silage is irrigated with effluent.

Spray irrigation of golf course also takes place in several locations including Parksville at the Morningstar Golf Course, Vernon at the Predator Ridge Golf course and Osoyoos

2.2 BC Municipal Sewage Regulation

The use of reclaimed water in British Columbia is governed by the Municipal Sewage Regulation issued under the Waste Management Act. This document regulates the treatment standards and the allowable uses for reclaimed water. In addition, the Province has developed a *Code of Practice for the Use of Reclaimed Water*. These two documents are titled:

> *Municipal Sewage Regulation* under the Waste Management Act; BC Regulation 129/99.
>
> *Code of Practice for the Use of Reclaimed Water* – A Companion Document to the Municipal Sewage Regulation; Issued May 2001; BC Ministry of the Environment.

Schedule 2 of the Municipal Sewage Regulation prescribes treatment standards and requirements for two types of uses for reclaimed water:

> Category 1 - Unrestricted public access. In this category, water is of high enough standard that it can be used in areas with public access.
>
> Category 2 - Restricted public access. Category 2 reclaimed water is at a level more stringent than discharge to water and marine environment; though the resulting water quality still requires that the public be restricted from contact with it.

In an urban environment, the higher Category 1 treatment standard that is applicable for unrestricted public access should be provided. The permitted uses for areas with unrestricted public access include:

Parks	Playgrounds
Cemeteries	Golf courses
Road rights-of-way	School grounds
Residential lawns	Greenbelts
Vehicle and driveway washing	Landscaping around buildings
Toilet flushing	Outside landscape fountains
Outside fire protection	Street cleaning

The treatment and effluent quality requirements for Category 1 effluent for unrestricted public access, as indicated in the Municipal Sewage Regulation, are as follows:

- Secondary treatment followed by chemical addition and filtration:
  - BOD $\leq$10 mg/L
  - Turbidity $\leq$ 2 NTU
  - pH = 6 - 9
- Disinfection
  - Fecal coliform $\leq$ 2.2/100 mL
  - Minimum total residual chlorine of 0.5 mg/L at point of use
- Storage requirements
  - 20 days minimum storage
  - Can be reduced to 2 days if treatment plant has multiple units

The monitoring requirements are as follows:

• BOD and pH	Weekly
• Coliform	Daily
• Turbidity	Continuous

Other requirements of the Municipal Sewage Regulation include:

- An environmental impact study (EIS) must be carried out by a qualified professional. At a minimum, the EIS must consider the other uses of the groundwater, determine maximum application rates to ensure there is no surface runoff generated by irrigation and establish a monitoring program with locations, sampling frequencies and parameters, and

- Approval is required from the Ministry of the Environment and the Vancouver Island Health Authority. Some of the health and safety criteria included in the Regulation and that are applicable to this project are as follows:

  - For use of reclaimed water on parks, playground and school grounds, the reclaimed water provider must ensure that no direct contact between the reclaimed water and any person occurs while the irrigation is occurring.

  - Irrigation with reclaimed water must not occur within 60 m of areas where food is handled or consumed.

2.3 MSR Policy Intentions Paper

The BC Ministry of the Environment intends to review and revise the Municipal Sewage Regulation in three stages. The first stage will focus on reclaimed water, the second stage will harmonize the Regulation with the Municipal Wastewater Effluent Strategy of the Canadian Council of Ministers of the Environment and the third stage will deal with design and operation issues. In November 2009, the Province released a *Policy Intentions Paper for Consultation* for the first stage of the amendments. The proposed changes that could affect the proposed use of reclaimed water in the study area are summarized as follows:

- The designation of permitted uses in the "*Unrestricted Public Access"* is to be replaced with permitted use in areas with "*Highest Exposure Potential".* The allowed uses in urban areas under these two designations are similar.
- The permitted uses and standard for reclaimed water as indicated in Schedule 2 of the MSR would be revised. For the use of reclaimed water where there is the highest exposure potential of public contact with reclaimed water, the treatment requirement is as follows:
    - Virus removal via coagulation and filtration
    - Turbidity of 2 NTU average and a maximum of 5 NTU
- The storage requirements are replaced with a requirement that the treatment plant is built with multiple units capable of meeting the reclaimed water standard with one unit not in operation and an alternate method of disposing of reclaimed water be provided.
- The health and safety criteria for a 60 m setback from areas where food is prepared is to be deleted.

2.4 California Regulations Related to Recycle Water

California has been practicing water reuse for a number of years and have developed water reuse regulations which are often quoted and used by many jurisdictions in the US. The California Department of Public Health issued regulations related to recycled water in January 2009. These regulations define the following types of reclaimed water:

- *Disinfected secondary-2.2 recycled water* – recycled water that has been oxidized and disinfected such that the concentration of total coliform does not exceed 2.2/100 ml;
- *Disinfected secondary-23 recycled water*– recycled water that has been oxidized and disinfected such that the concentration of total coliform does not exceed 23/100 ml;

- *Disinfected tertiary recycled water* – a chlorine disinfection process that provides a CT value of not less than 450 milligram-minutes with a minimum contact time of 90 minutes based on peak dry weather flow. As an alternative to coagulation and filtration, filtered wastewater can be water that has passed through microfiltration, ultrafiltration, nanofiltration or reverse osmosis membrane such that the turbidity does not exceed 0.2 NTU more than 5% of the time and never exceeds 0.5 NTU. The median concentration of total coliform bacteria measured in the disinfected effluent shall not exceed 2.2/100 ml.

Disinfected tertiary recycled water can be used for irrigation of the following areas:

- Food crops;
- Parks and playgrounds;
- School yards;
- Residential landscaping; and
- Unrestricted public access golf courses.

Any use of recycled water shall comply with the following:

- No irrigation within 50 metres of a domestic water supply;
- Irrigation runoff shall be confined to the recycled water use areas;
- Spray, mist, or runoff shall not enter dwellings, designated outdoor eating areas, or food handling facilities;
- Drinking water fountains shall be protected against contact with recycled water spray, and
- All use areas where recycled water is used shall be posted with signs.

2.5 Proposed Wastewater Treatment Plant

It is proposed to construct a membrane bioreactor (MBR) plant to service the Saanich East-North Oak Bay area. This type of treatment plant uses membrane bioreactor ultrafiltration, which is a vacuum-driven membrane with pore sizes of 0.05 to 0.1 micron depending on the supplier. This provides a barrier to suspended solids, bacteria and many viruses to produce effluent water with very high quality and low turbidity. These types of plants typically will achieve the following effluent water quality before disinfection:

Table 2.1 – Typical Effluent Quality of MBR Plant

BOD	$\leq$ 2 mg/L
TSS	$\leq$ 2 mg/L
Turbidity	$\leq$ 1 NTU
Fecal Coliform	$\leq$ 10 CFU/ 100 mL

The proposed SENOB MBR plant meets the stringent requirements to produce disinfected tertiary recycled water as per the California regulations, which require a concentration of total suspended solids less than 2 mg/L and turbidity less than 0.2 NTU. It also meets the BC MSR requirements for reclaimed water unrestricted public access, which requires a BOD of less than 10 mg/L a turbidity of less than 2 NTU. In order to consistently meet the fecal coliform requirements of 2.2/100 mL for both regulations and maintain a chlorine residual, disinfection using chlorine is required.

<u>Sizing of Tertiary Plant</u>

As indicated in the September 16, 2008 report titled *Core Area Wastewater Treatment Assessment of Wastewater Treatment Options 1A, 1B and 1C*, it is proposed to size the SENOB plant as follows:

- Sizing of primary clarifiers based on 2065 flow (4 x ADWF) 68.8 ML/d
- Number of primary clarifiers 2
- Capacity of each primary clarifier 34.4 ML/d
- Secondary and tertiary/filtration treatment for 2065 flow (1.75 x ADWF) 30.1 ML/d (1)
- Membrane plant sizing for 2030 flow (1.75 x ADWF) 29.0 ML/d (2)
- Number of process trains for membranes 4
- Capacity of each membrane process train 7.25 ML/d

Notes:

(1) Portion of flow in excess of 30.1 ML/d to bypass secondary and tertiary treatment and to receive primary treatment only followed by ocean discharge.

(2) Additional membrane units to be installed in the future to meet the 2065 projected flow of 30.1 ML/d

2.6 Reclaimed Water Storage

<u>BC Municipal Sewage Regulation</u>

The Municipal Sewage Regulation indicates that a minimum of 20 days of emergency storage must be provided at the sewage treatment facility to allow the effluent flow to be diverted to storage in case the water does not meet the standards required - see Clause 10 (1) (c). However, if the treatment plant is built with multiple units capable of meeting the reclaimed water standard with one unit out of operation, emergency storage may be reduced to a minimum of 2 days. The Code of Practice indicates that storage of reclaimed water is required for the following uses:

- Irrigation purpose – for times when the method of application is not continuous; storage is required for the non-growing season;
- Normal balancing (seasonal) storage;
- Emergency storage – for times when reclaimed water usage is unexpectedly interrupted, or the reclaimed water does not meet the quality standards; and
- Storage for treatment (in lieu of providing filtration).

The Code of Practice further indicates that if emergency disposal is not available, emergency storage must be available to retain 75% of the normal reclaimed water production for a period of at least 20 days. In the SENOB case emergency disposal via the Finnerty Cove outfall is available.

At the Saanich East / North Oak Bay sewage treatment plant, an ocean outfall at Finnerty will be provided for the discharge of the water that is not reclaimed for other uses. The ocean outfall will be sized for the entire peak flow into the plant. Based on the analysis of potential use of reclaimed water in the area, as discussed later in this report, the maximum potential irrigation demand is approximately 50% of the current plant flow and 30% of the plant design flow for the year 2030. There will always be a significant portion of the treated effluent that will be discharged to the ocean. During the winter months when there is no irrigation demand, it is anticipated that most, if not all, of the plant effluent will be discharged to the outfall. Since the plant will have a properly sized ocean outfall, it is proposed not to provide storage at the plant except for process requirements and equalization.

As discussed in Section 4, the estimated irrigation demand of varies between 1,600 m^3/day and 4,300 m^3/day depending on the extent of the irrigated areas. Bases on these flows, the storage requirements indicated in the MSR would be as follows:

	2-day Storage (m^3)	20-day Storage (m^3)
Volume	3,200 to 8,600 m^3	64,000 to 172,000 m^3
Storage Dimensions based on 6 m depth	• 24 m x 24 m • 39 m x 39 m	• 105 m x 105 m • 171 m x 171 m

The cost of providing 20 days of storage is major expenditure and would likely result in effluent irrigation not being feasible. The cost of providing two days of storage would range from $1.2 million to $3.0 million.

<u>MSR Policy Intentions Paper</u>

In the Policy Intentions Paper for Discussions, it is proposed to replace the storage requirements with: (1) a requirement the wastewater treatment plant must by built with multiple units capable of meeting the reclaimed water standard with one unit out of operation, and (2) an alternate method of disposing the effluent is provided. How this proposed requirement can be met is discussed in Section 2.8.

<u>California Public Heath Regulation</u>

The California regulation for disinfected tertiary recycled water requires storage to provide sufficient contact time after the addition of chlorine. The minimum size of the tank is to provide 90 minutes of contact time. These regulations also require that multiple treatment units be provided such that the effluent water quality can be achieved with one unit out of service.

2.7 Health and Safety Criteria for the Use of Reclaimed Water

The Municipal Sewage Regulation (Appendix 3 to Schedule 7) and the Code of Practice specifies the following construction and operating requirements:

<u>Construction Requirements:</u>

- All piping, valves, meters and irrigation equipment must be marked to differentiate reclaimed water from domestic water (purple pipe);
- Hose and hose bibs on reclaimed water irrigation system are not permitted;
- There must be 3 metre horizontal and 0.3 metre vertical separation between reclaimed water pipes and other water pipes;
- No irrigation with reclaimed water within 30 m of any water well;

- Any water impoundment with reclaimed water must have warning signs, and
- At all areas irrigated with reclaimed water, warning signs must be posted in sufficient numbers to advise the public that reclaimed water is being used and is not safe for drinking.

Operating Criteria:

- In parks, playgrounds and school grounds, there shall be no contact between the reclaimed water and any person while irrigation is occurring;
- Golf score cards and signage must be posted to indicate that reclaimed water is used;
- Irrigation with reclaimed water must not occur within 60 m of areas where food is handled or consumed;
- Precaution must be taken that reclaimed water will not drift outside of property or on passing vehicles, buildings, water facilities and food handling facilities;
- Irrigation must be controlled to prevent ponding and run-off from reclaimed water;
- Direct public contact with reclaimed water must be minimized;
- Irrigation systems using reclaimed water in a residential area can operate only between 10:00 PM and 6:00 AM, and
- Use only pop-up heads or drip irrigation systems.

As indicated in the MSR Policy Intentions Paper it is proposed to remove the 60 m setback distance related to food. However the requirements of not contact between reclaimed water and any person for parks, playgrounds and school grounds and minimizing direct public contact with reclaimed water will be maintained. Golf courses are closed to the public during the evening and at night, and they usually irrigate between 10 pm and 6 am. As a result, the health and safety criteria can be met for irrigation using reclaimed water. A more detailed discussion on how these criteria will affect the use of reclaimed water on the campus of the University of Victoria is included in Section 4.

2.8 Analysis

This section describes how the requirements outlined in the Policy Intentions Paper for amending the MSR can be met with the proposed SENOB plant and if modifications to the proposed design of the plant are required in order to meet these proposed amendments. The two main issues are (1) provision for coagulation and filtration and (2) provision for multiple units to meet reclaimed water standards.

Coagulation and Filtration

The main difference between MBR plants and conventional processes is that very low level of turbidity is obtained without the use of chemical coagulation.

With conventional sewage treatment processes such as activated sludge, biological treatment must be followed by coagulation and filtration in order to achieve turbidity lower than 2 NTU as required for high quality reclaimed water suitable for unrestricted public access in the BC MSR. This is typically done with sand filtration preceded by chemical addition for coagulation. Because of the small pore size, the ultrafiltration membrane process (MBR) on its own will achieve equivalent or better water quality and will produce water with turbidity of less than 1 NTU. Furthermore, the membrane filtration process does not require chemical addition to achieve this low turbidity. An ultrafiltration MBR plant, in conjunction with chlorine disinfection followed by adequate contact time of 90 minutes or more, would meet the requirement of the fecal coliform requirements of the proposed MSR regulation.

However both the Municipal Sewage Regulation and the Intentions Paper require chemical addition and coagulation prior to filtration. It appears that the current MSR requirements were developed prior to MBR development and were aimed at conventional filtration processes which often require a coagulant chemical to provide good filter performance. In order to deal with this regulatory requirement, there are two options:

Option 1 – Provide evidence of acceptable microbial water quality

Section 10 (9) of the MSR states: “Methods of treatment for reclaimed water other than those included in this regulation and their reliability features, may be accepted by the Director if the discharger demonstrates to the satisfaction of the Director that the method of treatment and their reliability features will assure an equal degree of treatment, public health protection and treatment reliability.”

In order to eliminate the chemical addition component of the treatment train, a submission to the Minister must present evidence that the membrane bioreactor without chemical addition will meet this test. Evidence to this effect could be obtained from numerous operating MBR plants in North America. The CRD also has a membrane bioreactor plant at the Ganges sewage treatment facility and effluent water quality data could be obtained from this plant as well.

Option 2 – Chemical addition

A coagulant such as alum could be added to the wastewater following preliminary treatment. The primary sedimentation tank would act as both a coagulation tank and a settling tank. The coagulation and sedimentation phase in the primary clarifiers would be followed by biological treatment and membrane filtration. The addition of coagulant would be required on a year-long basis if reclaimed water is to be used for toilet flushing.

If reclaimed water is used only for irrigation, then coagulation would be required from mid-April to mid-October during the irrigation season.

It is proposed to meet with treatment requirements of the MSR Policy Intentions Paper by chemical addition and coagulation. The cost of the equipment for the addition of chemicals following preliminary treatment is already included in the preliminary cost estimate for the project and no modification to the proposed design would be necessary.

Multiple Units

The proposed plant is designed to deal with high flows resulting from inflow and infiltration. These high flows occur during the winter months when the groundwater table rises as a result of increased precipitation. During the summer months, when irrigation using reclaimed water is practiced, the peak flow is significantly less than the wet weather peak flow which occurs during the winter months. Based on current flow record the peak dry weather flow is 1.15 times the average dry weather flow (1.15 x ADWF)

Primary treatment at the SENOB plant is sized for four times the average dry weather flow, a condition that occurs only in the winter. Each of the two primary clarifiers can handle two times the average dry weather flow which is higher than the peak dry weather flow (1.15 x ADWF). The primary clarifiers are followed by two aeration tanks for biological treatment and four tanks with membrane cassettes. The maximum allowable organic loading on the aeration tank is 1.3 times the design flow of 1.75 x ADWF for a total organic loading of 2.3 x ADWF. Each aeration tank could handle the peak dry weather flow of 1.15 x ADWF. The membrane portion of the SENOB plant will have 4 process trains, each designed for a flow of 7.25 ML/d which corresponds to 0.44 x ADWF. With one of the four membrane tanks out of service, the filtration membranes will have the capacity to treat 1.32 x ADWF. This exceeds the peak dry weather flow of 1.15 x ADWF.

In summary, the proposed SENOB plant will be capable of meeting the treatment requirements for reclaimed water to be used in unrestricted public access areas during the dry weather months. The dry weather months correspond to the irrigation season. However during the winter months, the treatment plant is not designed to meet the stringent effluent requirements for water reclamation with one unit of our service if the unit is out of service during flows exceeding 1.15 x ADWF.

Section 3 Reclaimed Water Demand

3.1 Irrigation Water Demand

In this section, potential uses for reclaimed water are examined. These include irrigation and toilet flushing. The two largest potential users of reclaimed water are golf courses and the University of Victoria. Information gathering meetings were held with potential users in order to determine how much of the current and future water demand could be met with reclaimed water.

Golf Courses

The potential irrigation water demand in the vicinity of the SENOB plant was estimated based on actual irrigation volumes obtained from local golf courses. Irrigation at the local golf courses takes place every day between 10:00 PM and 6:00 AM. The maximum daily demand reported by each of the three golf courses in the area varies ranges from 1.3 ML/d and 2.0 ML/d. However, the Cedar Hill golf course reported obtaining approximately two third of their irrigation water from wells located on site and the balance from the municipal water system. At this golf course, both the well water and the municipal water are discharged into a holding pond. Water is then pumped from the pond into the irrigation system. The other two local golf courses do not use well water for irrigation because of an inadequate aquifer.

Assuming that the two major and the small golf courses located within 4 km of the proposed SENOB plant were to be irrigated with reclaimed water and that the use of wells at the Cedar Hill golf course would be discontinued, the total demand for reclaimed water would be approximately 2.7 ML/d. If a third major golf course located 6 km from the SENOB plant was added, the total demand for reclaimed water would increase to 4.7 ML/d. However, considering that an additional 4 km long pipeline would be needed, this option was not retained for further analysis.

A detailed review of the existing golf course irrigation system would be required to ensure that adjacent residential areas are not affected by wind drift during irrigation. It was assumed that the current irrigation system met these requirements.

University of Victoria

The total annual water demand at the University of Victoria is 740 ML/y. Approximately 185 ML/y or 25% of the annual demand is for irrigation. The irrigation demand can be further divided as follows:

- Playing fields 58 ML/y
- Landscaped areas 127 ML/y

Almost all of the irrigation is done with pop-ups spray heads but a very small amount totaling approximately 5,000 litres per day, is done using drip irrigation. There are 10 drip irrigation systems on the campus.

About two thirds of the irrigated landscaped areas are located near buildings and pathways. The northeast quadrant of the campus consists mainly of residences. The central potion of the campus has several facilities that are open late in the evening including libraries, sports facilities, a cinema, a pub, a book store and a major transit exchange. The University of Victoria is a pedestrian oriented campus. It is likely there would be pedestrian traffic late in the evening and early in the morning in the central and eastern portions of the campus when irrigation would take place. Because of the pedestrian nature of the campus and the variety of usage, the risk that people would get into direct contact with reclaimed water is very high in many parts of the campus

However, the northwest and west portions of the campus include large lawn areas and several sport fields which have controlled public access at night. This portion of the campus located along McKenzie Avenue east of Finnerty Road, is isolated from the rest of the campus and has significant pedestrian traffic. Other potential areas that could be irrigated with reclaimed water include the ornamental public gardens that are closed during the evenings and isolated lawn areas in the south portion of the campus near Cedar Hill Cross Road. In order to reduce risks of direct contact between the public and reclaimed water, it is proposed to use reclaimed water irrigation in the sport fields and the landscaped areas on the perimeter of the campus.

Approximately one third of the landscaped and lawn area could be irrigated with reclaimed water as well as most of the playing fields. With these restrictions, the irrigation water demand using reclaimed water is estimated as follows:

- Playing fields 0.65 ML/d
- Landscaped areas away from buildings and drip irrigation 0.45 ML/d
- Allowance for future expansion <u>0.10 ML/d</u>
- Total irrigation demand at UVic 1.20 ML/d

<u>Municipal Parks, Playgrounds and Other Institutions</u>

There are a number of small municipal parks in the area around the University of Victoria and these are usually associated with adjacent schools. The larger Mount Tolmie Park and Uplands Park are not irrigated as they contain significant areas with Gary Oak natural habitat which should not be irrigated in the summer. The small municipal parks, schools and other institutions which could potentially be irrigated with reclaimed water include:

- Queen Alexandra Children's Hospital
- Mount Douglas High School
- Campus View School
- Henderson Park and Uplands School
- Arbutus Middle School

The irrigable area in these institutions totals approximately 13 ha and the peak demand is estimated at 0.4 ML/d

Summary of Irrigation Demand

The potential total demand for reclaimed water for irrigation for the University of Victoria and for the golf courses within 4 km of the SENOB plant is as follows.

- University of Victoria 1.2 ML/d
- Golf courses within 4 km of SENOB plant 2.7 ML/d
- Parks, schools and other institutions 0.4 ML/d
- Estimated Total Irrigation Demand 4.3 ML/d

3.2 Other Potential Uses of Reclaimed Water

The following potential uses for reclaimed water were also investigated: (1) toilet flushing in future buildings at the University of Victoria and, (2) outside water features at the University of Victoria. Existing buildings were not considered for toilet flushing because plumbing modifications would be very costly and disruptive.

The total water consumption at the University of Victoria for the one year period ending in September 2009 is 737,400 m^3. Approximately 25% of the water consumption is made up of irrigation demand with the balance for other uses throughout the campus. This includes domestic water usage in residences, hot water and toilet flushing in faculty buildings, and other uses. Dual plumbing systems with purple pipes for reclaimed water to be used for toilet flushing could be included in future buildings. The University has indicated that the building floor area on campus could increase by 10% to 15% over the next 15 to 20 years. Based on a 12.5% increase in floor area and one third of water being used for toilet flushing, the future demand for reclaimed water is estimated as follows:

- Current non-irrigation water demand 555 ML/y
- Estimated non-irrigation water demand of future developments 63 ML/y
- Portion of non-irrigation water demand for toilet flushing 30%
- Estimated water additional demand for toilet flushing 20.7 ML/y (57 m^3/d)

All existing water features on the campus function as a component of storm water management. The addition of external reclaimed water would deter the water features from their main functions.

3.3 Reclaimed Water Demand

Four options are examined for the reclaimed water distribution system:

- Option 1 – University of Victoria and surrounding parks and institutions
- Option 2 – University of Victoria, surrounding parks and one major golf course
- Option 3 – University of Victoria, surrounding parks and two major golf courses with Cedar Hill golf course obtaining two third of irrigation water from wells
- Option 4 – University of Victoria and two major golf courses with no well supply

Peak demands were estimated for each of these four options and are detailed in Table 3.1. The peak demand is used to size the reclaimed water system including the chlorination system, the chlorine contact chamber, the high lift pumps and the distribution piping. The irrigation on golf courses takes place between 10:00 am and 6:00 pm. On the campus, it is also proposed to irrigate with reclaimed water at night in order to minimize risks to the public and because the sports fields are used during the day and the evening. The peak demand rates for options 2, 3 and 4 exceed the available effluent flow at night and equalization storage will be required. Equalization storage would be in addition to the 90 minute chorine contact tank.

Table 3.2 shows the daily demand for reclaimed water. The maximum daily demand is for Option 4 at 4.300 ML/d. Table 3.3 lists the estimated total annual demand for reclaimed water. The annual demand is used in estimating the potential revenues for the sale of reclaimed water as discussed further in Section 5. The total annual demand from the golf courses is based on their current water consumption records.

Table 3.1 – Peak Demand for Reclaimed Water (L/s)

	Option 1 – UVic Only	Option 2 – UVic & One Major Golf Course	Option 3 – UVic & Two Major Golf Courses – One course with wells	Option 4 – UVic & Two Major Golf Courses – No well water
UVic Irrigation Demand	42	42	42	42
UVic Toilet Flushing Water Demand	3	3	3	3
Golf Course Water Demand	0	45	60	90
Schools, parks and other institutions	12	15	15	15
Total Peak Demand	57	105	120	150

Table 3.2 – Daily Demand for Reclaimed Water (ML/d)

	Option 1 – UVic Only	Option 2 – UVic & One Major Golf Course	Option 3 – UVic & Two Major Golf Courses – One course with wells	Option 4 – UVic & Two Major Golf Courses – No well water
UVic Irrigation Demand	1.21	1.21	1.21	1.21
UVic Reclaimed Water Demand	0.06	0.06	0.06	0.06
Major Golf Course Water Demand		1.30	1.74	2.60
Schools, parks and other institutions	0.35	0.43	0.43	0.43
Total Daily Demand	1.62	3.0	3.44	4.3

Table 3.3 –Annual Demand for Reclaimed Water (ML/y)

	Option 1 – UVic Only	Option 2 – UVic & One Major Golf Course	Option 3 – UVic & Two Major Golf Courses – One course with wells	Option 4 – UVic & Two Major Golf Courses – No well water
UVic Irrigation Demand	100.3	100.3	100.3	100.3
UVic Reclaimed Water Demand	20.7	20.7	20.7	20.7
Golf Courses Water Demand		83.3	121.1	166.6
Schools, parks and other institutions	22.2	27.7	27.7	27.7
Total Annual Demand	143.2	232	269.8	315.3

3.4 Availability of Reclaimed Water

The proposed SENOB tertiary sewage treatment plant will provide treatment for up to 1.75 times the average daily flow of 16.6 ML/d for the year 2030 and 17.2 ML/d for the year 2065. However the current average annual flows in the SENOB drainage area average 9.5 ML/d. Average monthly plant flows during the irrigation months of June to September are as follows:

June 2008	9,135 m^3/day
July 2008	8,934 m^3/day
August 2008	8,950 m^3/day
September 2008	9,677 m^3/day

As indicated in Table 3.2, the maximum daily irrigation demand varies from 1,600 to 4,300 m^3/day. There is enough water to meet the demand.

However, all golf courses are irrigating at night between 10:00 pm and 6:00 am. The sports fields and lawn areas at the University of Victoria will also be irrigated at night because the sports fields are used in the evening and to minimize direct contact between the public and reclaimed water. The peak irrigation demand will therefore occur at night which is the time when the sewage flow is low. As indicated in Table 3.4, there is not enough sewage flow a night to meet the irrigation peak demand which occurs at the same time. Therefore, storage will be required. The storage volume required for the projected flows in 2012 and 2030 is shown in Table 3.5.

Table 3.4 – Hourly Sewage Flow Variations at Proposed SENOB plant (2009)

Time	Existing Hourly Flow (l/s)	Projected 2030 Hourly Flow (l/s)
0:00	117	194
1:00	95	158
2:00	73	121
3:00	59	98
4:00	53	88
5:00	47	78
6:00	48	80
7:00	59	98
8:00	104	172
Daily Average	116	192
Option 1 Peak Demand	**57**	
Option 2 Peak Demand	**105**	
Option 3 Peak Demand	**120**	
Option 4 Peak Demand	**150**	

Table 3.5 – Storage Volume to Meet Night Time Peak Irrigation Demand (m3)

	2012 Flows	2030 Flows
Option 1 – UVic and Adjacent Schools	0	0
Option 2 – UVic, Adjacent Schools and one Golf Course	980	340
Option 3 – UVic, Adjacent Schools and Two Golf Courses supplemented by well water	1330	575
Option 4 – UVic, Adjacent Schools and Two Golf Courses with no well water	2400	1160

It may take several years before the reclaimed water system is fully developed and expanded to include golf courses. Equalization storage will not be required until the first golf course starts using reclaimed water. It is proposed to size the equalization on the basis of the projected 2030 sewage flows.

Section 4 Effluent Reuse System Configuration

4.1 General

Following treatment in the MBR treatment plant, the treated filtered effluent would be directed to a flow splitting chamber. The portion of the flow to be used as reclaimed water would be disinfected with ultraviolet light followed by chlorination prior to discharge into the chlorine contact tank with a detention time of 90 minutes. The disinfected effluent would then flow into the equalization storage. High lift pumps would then pump the reclaimed water into a separate "purple pipe" distribution system. The flow splitting at the outlet of the treatment plant would be controlled by automated valves. The valve controlling the flow of reclaimed water would open as the water level in the equalization tank or pumping chamber drops. The disinfection system, the chlorine contact chamber, the equalization storage and the high lift pump station would all be located at the treatment plant.

The irrigation demand for golf courses is between 10:00 am and 6:00 pm. On the campus, it is also proposed to irrigate with reclaimed water at night in order to minimize risks to the public and because the sports fields are used during the day. Equalization storage is required when the irrigation water demand exceeds the sewage flow. Equalization storage is required for Option 2, 3 and 4.

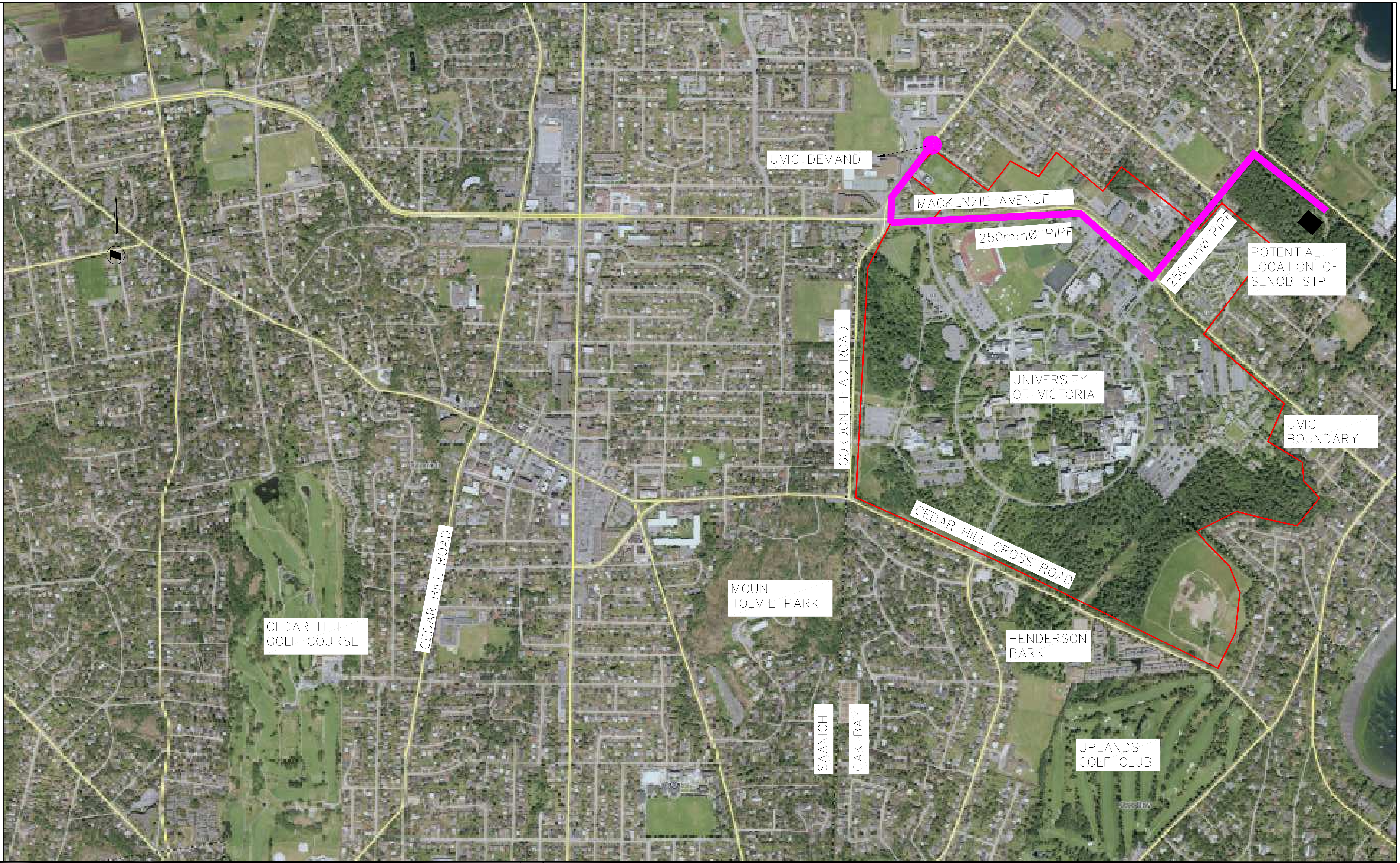
4.2 Major Components of Reclaimed Water System

The sizing of the major components of a reclaimed water supply system is shown in Table 4.1. All the components except equalization storage are sized on the basis of the peak demands shown in Table 4.1. It should be noted that the difference in elevation between the plant and the campus of the University of Victoria and nearby golf courses is approximately 27 m. This high static head coupled with a pressure of 275 kPa at the customer's lot line has resulted in the selection of large high lift pumps. The pumps are also sized for maximum velocity in the distribution system of 1.12 m/s. Equalization storage is not required for Option 1.

The preliminary layout for the reclaimed water distribution system is shown on the attached Figures 4.1 to 4.3. These layouts are based on the assumption that the SENOB plant will be located at the CRD owned site on Arbutus Road. The routing of distribution systems is designed to allow for future expansion. Since the irrigation demand for the University of Victoria is concentrated in the northwest portion of the campus, the reclaimed water pipe for Option 1 stops at the intersection of McKenzie Avenue and Gordon Head Road. The distribution system could be extended southerly on Gordon Head Road and easterly on Cedar Hill Cross Road. This would allow other areas of the campus to be connected as well as Henderson Park and a golf course. To allow for the future expansion of the reclaimed water distribution system, the 2 km long pipe from the plant to the intersection of McKenzie Ave and Gordon Head Road would have to be upsized from 250 mm to 400 mm diameter.

Table 4.1 – Summary of Reclaimed Water System Components

	Option 1 – UVic & Adjacent Schools	**Option 2 – UVic & One Major Golf Course**	**Option 3 – UVic & Two Major Golf Courses – One course with wells**	**Option 4 – UVic & Two Major Golf Courses – No well water**
System Capacity (l/s)	57	105	120	160
Chlorine Contact Chamber (m^3)	310	570	650	865
Equalization Storage (m^3)	0	340	575	1160
High Lift Pump Motor Size (HP)	120	200	250	250
Distribution System	300 mm; 2.0 km	350 mm; 2.0 km 250 mm; 2.3 km	400 mm; 2.0 km 300 mm; 0.9 km 250 mm; 1.4 km 150 mm; 2.2 km	400 mm; 2.0 km 350 mm; 0.9 km 350 mm; 1.4 km 250 mm; 2.2 km



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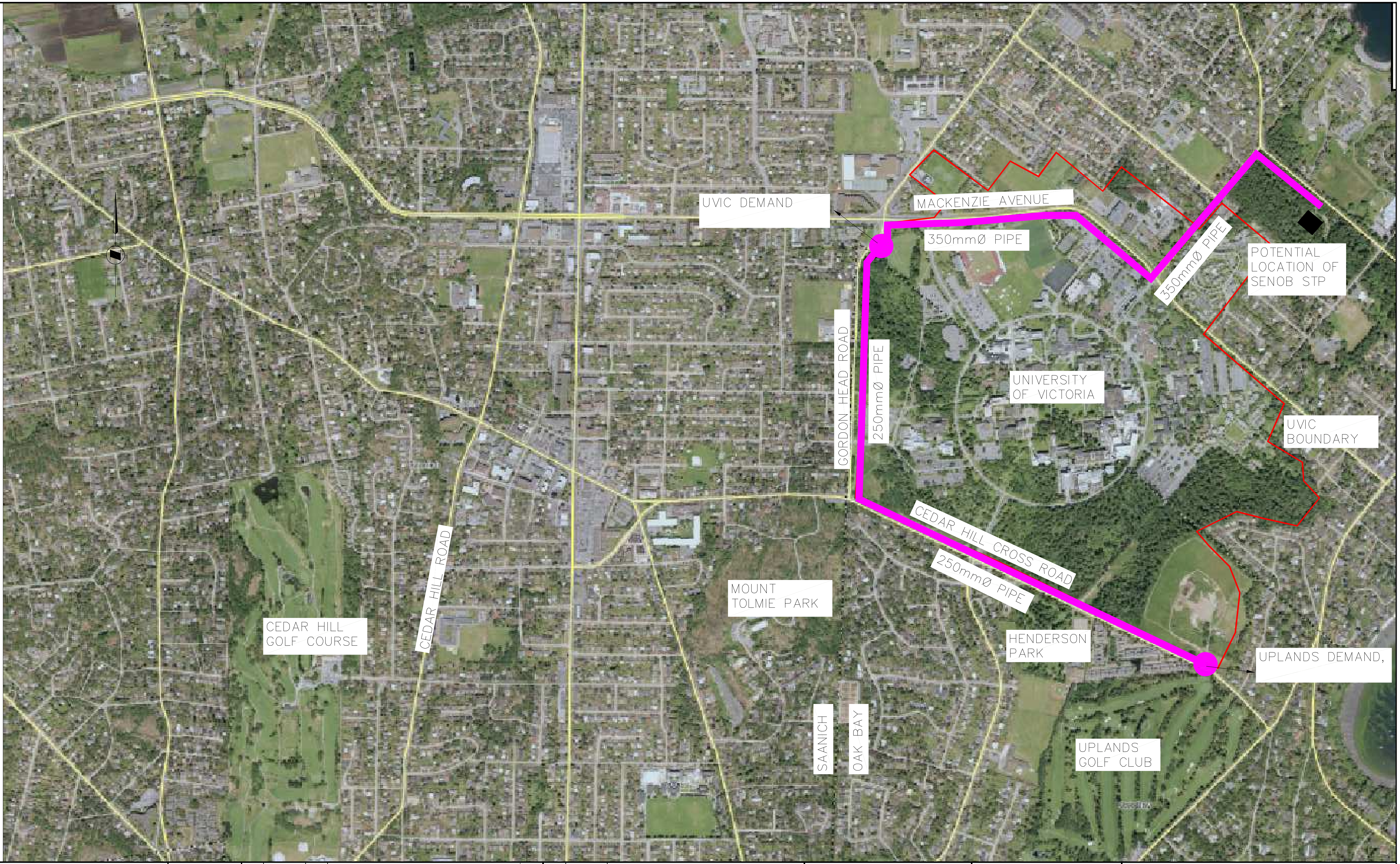
CORE AREA WASTEWATER TREATMENT PROJECT

EFFLUENT REUSE CONCEPT PLAN FOR UNIVERSITY OF VICTORIA AREA – OPTION 1

CONTRACT NUMBER	DRAWING NUMBER	ISSUE	SHT. No.
149009002	4.1	1	1 OF 3



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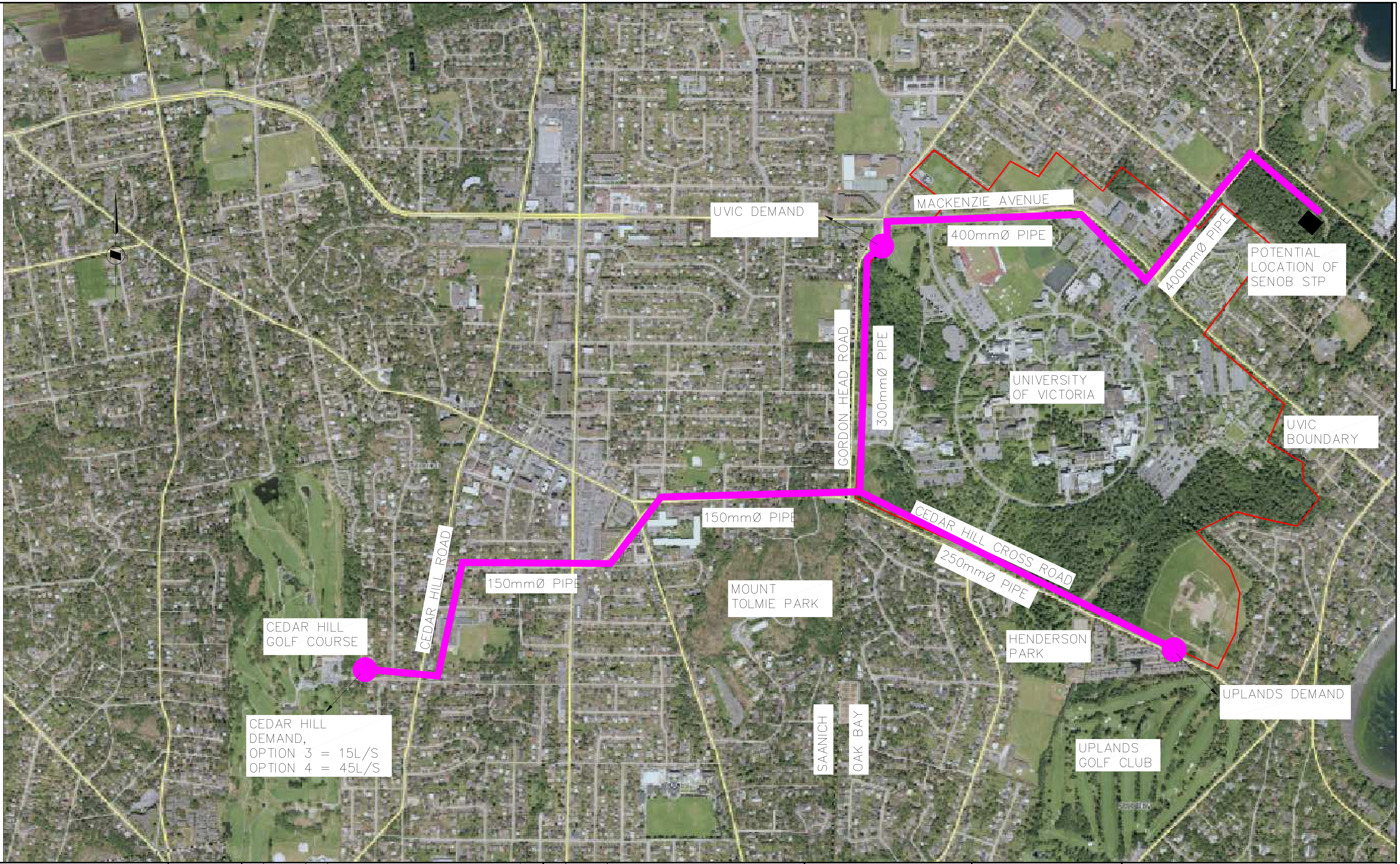
CORE AREA WASTEWATER TREATMENT PROJECT

EFFLUENT REUSE CONCEPT PLAN FOR UNIVERSITY OF VICTORIA AREA – OPTION 2

CONTRACT NUMBER	DRAWING NUMBER	ISSUE	SHT. No.
149009002	Fig 4.2	1	2 OF 4



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CORE AREA WASTEWATER TREATMENT PROJECT

EFFLUENT REUSE CONCEPT PLAN FOR UNIVERSITY OF VICTORIA AREA –OPTION 3 AND 4

CONTRACT NUMBER	149009002	DRAWING NUMBER	Fig 4.3	ISSUE 1	SHT. No. 3 OF 4

Section 5 Opinion of Probable Costs for Effluent Reuse

5.1 Capital Cost

To enable completion of the triple bottom line assessment and to obtain an initial indication of capital cost for each of Options 1, 2, 3 and 4, cost estimates were prepared for each option. The basis of the estimates includes the following:

Direct Cost

- Capital construction cost
- Design and construction contingency costs at 25% of construction cost

Indirect Cost

- Engineering at 15% of direct cost
- Administration, project management and miscellaneous at 6% of direct cost

Financing Cost

- Interim financing at 4% of direct and indirect cost
- Inflation to midpoint of SENOB construction 2% per annum to 2011 (4%)

The capital cost is based on constructing distribution pipelines for reclaimed water in public road up to the property lines of the University and other institutions. The cost of extending the reclaimed water lines into the campus and to disconnect the numerous individual irrigation systems from the internal potable water system and to reconnect these to the reclaimed water system is not included in Table 5.1.

The capital cost estimates are based on locating the SENOB plant at or near a site owned by the CRD on Arbutus Road. The capital cost of the reclaimed water system would be reduced by $1.5 million if the SENOB plant was built at the University of Victoria Field Site located on the north side of McKenzie Avenue near Gordon Head Road. However the cost of the SENOB plant would be approximately $15 million higher as a result of the need to build a large pumping station and 1.5 km long forcemain to pump all the sewage from the trunk line on Haro Woods to the UVic Field Site and also to extend the outfall pipe by the same distance.

Table 5.1 – Estimated Capital Cost

Description	Option 1 University of Victoria Only	Option 2 UVic & One Major Golf Course	Option 3 UVic & Two Major Golf Courses	Option 4 UVic & Two Major Golf Courses - No Well Water
Design Peak Flow	57 L/s	105 L/s	120 L/s	160 L/s
General Requirement	$207,200	$405,600	$533,600	$614,100
Chlorine Contact Chamber	$210,000	$360,000	$400,000	$475,000
High Lift Pumping Station:				
- Equalization Storage Tank	$0	$263,000	$359,000	$598,000
- Wet Well	$120,000	Utilize Equalization Storage Tank	Utilize Equalization Storage Tank	Utilize Equalization Storage Tank
- Submersible Pumps	$162,000	$216,000	$252,000	$255,600
- Piping and Valves	$200,000	$250,000	$300,000	$320,000
Distribution System	$980,000	$2,467,000	$3,424,900	$3,882,600
Electrical Control & Instrumentation	$250,000	$300,000	$350,000	$360,000
Standby Power	$150,000	$200,000	$250,000	$250,000
Total Construction Costs	**$2,279,200**	**$4,461,600**	**$5,869,500**	**$6,755,300**
Design & Construction Contingencies (26% of Construction Costs)	$569,800	$1,115,400	$1,467,400	$1,688,800
Subtotal - Direct Costs	**$2,849,000**	**$5,577,000**	**$7,336,900**	**$8,444,100**
Indirect Costs (Engineering, Administration, Program Management, & Misc.) (20% of Direct Costs)	$740,700	$1,282,700	$1,687,500	$1,942,100
Subtotal - Direct & Indirect Costs	**$3,589,700**	**$6,859,700**	**$9,024,400**	**$10,386,200**
Interim Financing & Inflation Allowance (8% of Above)	$287,200	$960,400	$1,263,400	$1,454,100
Total Capital Costs	**$3,876,900**	**$7,820,100**	**$10,287,800**	**$11,840,300**

5.2 Operating and Maintenance Cost

Table 5.2 provides the operations and maintenance costs for each option.

Table 5.2 – O&M Costs

	Option 1 – UVic Only	**Option 2 – UVic & One Major Golf Course**	**Option 3 – UVic & Two Major Golf Courses – One course with wells**	**Option 4 – UVic & Two Major Golf Courses – No well water**
Annual O & M Costs	$70,500	$102,400	$128,400	$141,500

5.3 Projected Revenues

The District of Saanich current water rates are $1.05/m^3. This amount does not include the sewer surcharge. The golf courses located in the District of Oak Bay are being charged a bulk rate for water of $0.55/m^3. It was suggested in earlier studies that an incentive pricing of $0.72/m^3 be used for reclaimed water. However, this is higher than the bulk rate in Oak Bay. It appears that the bulk rate in Oak Bay is equivalent to the cost of purchasing water from the Capital Regional District. Table 5.3 shows the projected revenues based on the rates of $1.05/m^3, $0.72/m^3 and $0.55/m^3.

Table 5.3 – Projected Revenues from Reclaimed Water

	Option 1	**Option 2**	**Option 3**	**Option 4**
Estimated Annual Reclaimed Water Consumption (ML/Y)	143	232	270	315
Estimated Revenues at $1.05/m^3	$150,100	$243,600	$283,500	$330,800
Estimated Revenues at $0.72/ m^3	$103,000	$167,000	$194,400	$226,800
Estimated Revenues at $0.55/ m^3	$76,700	$127,600	$158,500	$173,300

It should be noted that the Cedar Hill golf course presently obtains two-thirds of their irrigation water from wells. The estimated revenues of Option 4 are based on the assumption that the water wells will be discontinued. Since the bulk water rate in the District of Oak Bay is significantly less than the water rates in the District of Saanich and other municipalities, it is proposed to use a water rate of $0.72 /m^3 when estimating revenues from the sale of reclaimed water.

5.4 Business Case and Market Considerations

A summary of capital cost, O&M cost and revenues based on a reclaimed water rate of $0.72/m^3 is shown in Table 5.4. The use of reclaimed water will cause a corresponding drop in the usage of potable water. The CRD sells potable to the municipalities at a rate of $0.544/m3. The net profit/loss from the sale of reclaimed water is the difference between the sales of reclaimed water and the revenues lost from the sale of potable water. As indicated in Table 5.4, if the reclaimed water is sold at $0.72/m^3 there would be a net operating loss when taking into account the lost revenues from the sale of treated water. In order to cover the operating expenses and avoid a loss, reclaimed water should be sold at the same rate as potable water.

Table 5.4 – Summary of Cost and Revenues

	Capital Cost	Annual O&M Cost	Revenues from the sale of reclaimed water ($0.72/m^3)	Lost revenues from sale of treated water CRD ($0.543/m^3)	Operating Loss
Option 1	$3,721,900	$70,500	$103,000	$77,700	- $45,200
Option 2	$7,190,300	$102,400	$167,000	$126,000	- $61,400
Option 3	$9,777,000	$128,400	$194,400	$146,600	- $80,600
Option 4	$11,544,000	$141,500	$226,800	$171,000	- $85,700

Discussions were held with the three golf courses located within 5 km of the proposed SENOB plant. The golf courses did not express an interest in using reclaimed water for effluent for various reasons including (1) one golf obtains two-third of their irrigation water needs from wells, (2) negative public perception, (3) concerns that sodium in the reclaimed water could affect the quality of the greens, (4) public health danger posed by players walking on wet grass that has been recently irrigated with reclaimed water.

The other significant marker consideration would be to enter into long term agreement with potential customers of reclaimed water. Considering the high capital cost of a reclaimed water system coupled with no net revenues, agreements with a duration of 10 years or more should be negotiated with the customers.

Section 6 Triple Bottom Line Analysis for Effluent Reclamation

6.1 Methodology

CRD has adopted the Triple Bottom Line (TBL) evaluation approach to provide the basis for selection of the preferred alternative. By understanding the economic, environmental and social implications of the alternatives that are reflective of the community values, the most long term sustainable decisions can be made.

Economic impacts are the direct costs to a public agency that are traditionally associated with an economic analysis. Capital costs and reclaimed water revenues are considered as well as ongoing operations and maintenance costs. Environmental costs are the environmental implications of an agency's actions that customers place value on. Examples include reduction in suspended solids discharge to the ocean resulting from the diversion of effluent to irrigation with reclaimed water. Social costs, like environmental costs, are indirect costs to the community. An example of this is the inconvenience of traffic delays caused by construction. The utility does not directly pay for the "cost" of traffic but its customers place a value on avoiding unnecessary traffic delays.

This chapter outlines the triple bottom line analysis that was used to evaluate the four options for a reclaimed water system in the area surrounding the proposed SENOB plant. A complete listing of impacts included in the model sorted by the three categories is provided in Table 6.1.

TABLE 6.1: Impacts Evaluated for Triple Bottom Line Analysis

Criteria Group	No.	Criteria Categories	Measure Description
Economic	**EC-01**	Capital Costs	Construction cost and markup for soft costs adjusted to midpoint of construction
	EC-02	Capital Costs Eligible for Grants	Not available at this time
	EC-03	Loss of Water Revenue	Loss of water revenue by local municipality
	EC-04	Present Worth of Net O&M Costs	O&M costs
	EC-05	Flexibility for Future Expansion	Cost to upsize piping to allow for future expansion of reclaimed water piping
	EC-06	Flexibility to Accommodate Future Regulations	Additional space needed versus available to meet potential regulations
Environmental	**EN-01**	Carbon Footprint	Tons of eCO_2 created
	EN-02	Water Reuse Potential	Potential demands in megaliters per year
	EN-03	Power (energy) usage	kilowatt hours per year consumed
	EN-04	Transmission Reliability	Risk cost of pump station and distribution piping failure
	EN-05	Reduction Pollution Discharge	Reduction in pollutants discharged to ocean by reuse of effluent
	EN-06	Non-renewable Resource Use	Gallons of diesel consumed per year
	EN-07	Terrestrial effect	Restoration of forest habitat disturbed by reservoir construction
Social	**SO-01**	Impact of Property Values	Perception of lost value to current property owners abutting properties to be irrigated with reclaimed water
	SO-02	Construction Disruption	Cost of traffic inconvenience due to construction
	SO-03	Public and Stakeholder Acceptability	Lost time due to public disapproval
	SO-04	Loss of Beneficial Site Uses	Loss of park land due to storage tank construction
	SO-05	Cultural Resource Impacts	Risk cost of a cultural site find

6.2 Placing Value on Factors

6.2.1 Economic Impacts

EC-01 Capital Costs

Capital costs measure the construction cost and soft costs for each option escalated to the midpoint of construction. Data input included the estimated construction cost and a 2011 midpoint of construction. Assumptions included an inflation rate of 3%. The scoring for capital costs was scaled based on the NPV of costs for all three options with an NPV of $8 million worth three points, higher NPVs worth fewer points, and lower NPVs worth more.

EC-02 Capital Costs Eligible for Grants

This impact was intended to measure the value of grants to offset construction costs but at this time, insufficient information is available to adequately account for this impact.

EC-03 Utility Revenue Implications

The construction of a reclaimed water distribution system will reduce water consumption resulting in loss of revenues from the sale of water by the municipalities. The annual cost of lost utility revenues was calculated by multiplying the potential annual reclaimed water consumption by the local area municipality water rate. A qualitative 1 to 5 score was scaled based on the cost of lost utility revenue as shown below.

EC-03 Scoring:	
1	Over $250,000
2	$200,000 to $250,000
3	$150,000 to $200,000
4	$100,000 to $150,000
5	Less than $100,000

EC-04 Present Worth Costs

Present worth included annual expenditures for operations and maintenance (O&M) and for replacement and refurbishment (R&R) projects. Data input included annual O&M and R&R costs. Assumptions included a 3% rate of inflation for each annual cost. The scoring was scaled based on the annual costs, with an annual cost of $3.9 million worth 3 points, a higher annual cost worth fewer points, and lower annual costs worth more.

EC-05 Flexibility for Future Expansion

This impact was intended to measure the flexibility of each option to allow for expanding the reclaimed water distribution system. To measure this, the additional cost of upsizing the distribution piping of each option to the potential maximum demand was calculated. The cost for additional piping cost was scored using the following scale.

EC-05 Scoring:	
1	More than $750,000
2	$500,000 to $750,000
3	$250,000 to $500,000
4	0 to $250,000
5	No cost

6.2.2 Environmental Impacts

EN-01 Carbon Footprint

The energy consumption for pumping reclaimed water into the distribution system was calculated and the greenhouse gas produced was estimated on the basis of 0.000072 g CO_2e/kw-hr. Scoring was based on the cost of carbon dioxide emitted (assuming $25 per tonne) using the following scale.

EN-01 Scoring:	
1	More than $4,500
2	$,3500 to $4,500
3	$2,500 to $3,500
4	$1,500 to $2,500
5	Less than $1,500

EN-02 Water Reuse Potential

Water reuse potential was a measure of potable water that could be replaced by reclaimed water. The potential volume of reclaimed water produced, a $0.72/cubic meter cost of water, and a 0.38% growth rate were the data inputs. A 3% inflation in water costs was assumed. The NPV for each option was calculated and compared using the following scale.

EN-02 Scoring:	
1	Less than $2 million
2	$2 to $4 million
3	$4 to $6 million
4	$6 to $8 million
5	More than $8 million

EN-03 Power (Energy) Use

This impact compared the electrical energy usage for each option. Data input included annual power consumption and a $0.08/kW-hr cost of power. Assumptions included a 3% rate of inflation for power costs. The NPV for electrical costs was calculated for each option and then scaled as follows.

EN-03 Scoring:	
1	More than $250,000
2	$200,000 to $250,000
3	$150,000 to $200,000
4	$100,000 to $150,000
5	Less than $100,000

EN-04 Transmission Reliability

This impact measure the relative risk carried for each option in terms of a conveyance failure. Data inputted was the volume of reclaimed water pumped and the length of piping. Each option was compared by multiplying the volume pumped by the distance pumped. A $0.25 risk cost per ML-km/day was assumed and a NPV was calculated. The following 1 to 5 score scale was used.

EN-04 Scoring:	
1	More than $250,000
2	$200,000 to $250,000
3	$150,000 to $200,000
4	$100,000 to $150,000
5	Less than $100,000

EN-05 Pollution Reduction

Pollution reduction measured the mass volume of total suspended solids (TSS) in the effluent that is diverted from the ocean by reusing reclaimed water. TSS concentration and average dry weather design flows were included as data input. A $1/kg cost for solids discharged was assumed and a NPV was calculated. The following 1 to 5 scale was used to compare the three options.

EN-05 Scoring:	
1	More than $60,000
2	$45,000 to $60,000
3	$ $30,000 to $45,000
4	$15,000 to $30,000
5	Less than $15,000

EN-06 Non-Renewable Resource Use

This impact measured diesel fuel consumption during construction and operations. Diesel consumption during construction was assumed to be 2% of construction costs and diesel consumption during operations was assumed to be 2% of O&M costs. Therefore, data inputted was construction costs and O&M costs. A 3% inflation rate was assumed and a NPV was calculated for each option. The options were scored using the scale below.

EN-06 Scoring:	
1	More than $250,000
2	$200,000 to $250,000
3	$150,000 to $200,000
4	$100,000 to $150,000
5	Less than $100,000

EN-07 Terrestrial Habitat Impacts

This measure was intended to measure the impact that the storage reservoir would have on existing terrestrial habitats assuming that the plant is constructed in the forested area of Haro Woods. The area required for the storage tanks was calculated and relative 1 to 5 score was given based on the potential mitigation cost for the area impacted assuming that a 15 m strip around the reservoir would have to be replanted with trees. The following scale was used.

EN-07 Scoring:	
1	More than $65,000
2	$50,000 to $65,000
3	$35,000 to $50,000
4	$20,000 to $35,000
5	Less than $20,000

6.2.3 Social Impacts

SO-01 Impact on Property Values

Lost values for existing private properties are not expected but a perception of lost value constitutes a social cost. This impact was measured by assuming that the parcels that are abutting each site irrigated with reclaimed water would be perceived to lose 1% of an assumed average value of $500,000. The societal impact was calculated by multiplying the number of parcels that were impacted by $5,000 and scored as shown below.

SO-01 Scoring:	
1	More than $1 million
2	$750,000 to $1 million
3	$500,000 to $750,000
4	$250,000 to $500,000
5	Less than $250,000

SO-02 Construction Disruption

Traffic during construction can be particularly noisome to neighboring residents and businesses. To measure this disruption, the volume of traffic potentially impacted by reclaimed water storage construction was estimated by using traffic counts at nearby intersections for each site. These traffic counts came from CRD's 2005 evaluations. The number of construction trips was calculated by estimating one construction trip per day for every $2,500 of construction budget. The traffic count was multiplied by the daily construction traffic at each site and a plant construction disruption cost was calculated assuming a $1 cost per trip delayed, a 1% probability of delay due to construction and a 6 month construction period.

For conveyance construction, the number of kilometers of pipe was used to estimate the number of trips delayed. The conveyance construction cost was calculated by multiplying the length of pipe by the traffic count as well as assuming a $2 cost per trip delayed, a 50% probability of delay, and a 4 month construction schedule. The plant and conveyance construction disruption costs were added together and a qualitative 1 to 5 score was then given as shown below.

SO-02 Scoring:	
1	More than $500,000
2	$375,000 to $500,000
3	$250,000 to $375,000
4	$125,000 to $250,000
5	Less than $125,000

SO-03 Public and Stakeholder Acceptability

Delays caused by public disapproval could be costly during the construction period. A delay was assumed for each site for each option and the construction cost was delayed by that number with a 3% inflation rate. A 25% probability of delay was assumed at each site and thus the risk of delay costs were compared for each option using the following scale.

SO-03 Scoring:	
1	More than $80,000
2	$60,000 to $80,000
3	$40,000 to $60,000
4	$20,000 to $40,000
5	Less than $20,000

SO-04 Loss of Beneficial Site Use

The construction of storage tanks for reclaimed water may preclude the use of the site as an open space or park land. To measure this impact, the number of hectares of potential park or open space lost due to plant siting was estimated and an assumption of a $1,000,000 per hectare incremental value for using the site as a park instead of a treatment facility was assumed. The scale used to compare options is presented below.

SO-04 Scoring:	
1	More than $50,000
2	$30,000 to $40,000
3	$20,000 to $30,000
4	$10,000 to $20,000
5	Less than $10,000

SO-05 Cultural Resource Impacts

A cultural resource find would cause additional cost and delay to site construction. The probability of a cultural find for each site and the resulting delay were estimated along with the estimated construction cost. An assumed 3% inflation rate was used to quantify the delay cost of a cultural find. By multiplying the delay cost by the probability of a find, the risk cost of a cultural find was calculated for each option and compared using the following scale.

SO-05 Scoring:	
1	More than $25,000
2	$15,000 to $20,000
3	$10,000 to $15,000
4	$5,000 to $10,000
5	Less than $5,000

Table 6.2 **Triple Bottom Line Analysis for Reclaimed Water**

Criteria Group	No.	Criteria Categories	Measure Description	Weight	Option Results 1	2	3	4
Economic	EC-01	Capital Costs	construction cost and markup for soft costs adjusted to midpoint of construction	8	5.0	3.0	2.3	1.9
	EC-02	Capital Costs Eligible for Grants	Not available at this time	-				
	EC-03	Utility Revenue Implications	Loss of water revenue by local municipalities	1.33	4	3	2	1
	EC-04	Present Worth of O&M costs	O&M costs	8	5	3	3	2
	EC-05	Flexibility for Future Expansion	Cost to upsize piping to allow for future expansion of reclaimed water piping	1.33	1	2	3	4
				Economic Subtotal (100 pts max)[1]:	**83**	**55**	**45**	**40**
Environmental	EN-01	Carbon Footprint	Tons of eCO2 created	2.86	4	3	2	2
	EN-02	Water Reuse Potential	Potential demands in megaliters per year	2.86	2	4	4	5
	EN-03	Power (energy) usage	kilowatt hours per year consumed	2.86	4	3	2	2
	EN-04	Transmission Reliability	Risk cost of pump station and distribution piping failure	2.86	5	3	2	2
	EN-05	Reduction in Pollution Discharge	Reduction in pollutants discharged to ocean by reuse of effluent	2.86	2	3	4	5
	EN-06	Non-renewable Resource Use	Gallons of diesel consumed per year	2.86	4	3	2	1
	EN-07	Terrestrial Habitat Effect	Restoration of forest habitat disturbed by reservoir construction	2.86	5	4	2	1
				Environmental Subtotal (100 pts max):	**74**	**66**	**51**	**51**
Social	SO-01	Impact of Property Values	Perception of lost value to current property owners abutting properties to be irrigated with reclaimed water	4	5	4	1	1
	SO-02	Construction Disruption	Cost of traffic inconvenience due to construction	4	4	3	1	1
	SO-03	Public and Stakeholder Acceptability	Lost time due to public disapproval	4	4	3	1	1
	SO-04	Loss of Beneficial Site Uses	Loss of park land due to storage tank construction	4	5	4	2	1
	SO-05	Cultural Resource Impacts	Risk cost of a cultural site find	4	5	4	3	3
		`		**Social Subtotal (100 pts max):**	**92**	**72**	**32**	**28**
				TOTAL SCORE (300 pts max):	**249**	**193**	**129**	**122**

Section 7 Discussions and Recommendations

7.1 Summary of Reclaimed Water Options

Four options were investigated for a reclaimed water distribution system in the vicinity of the SENOB plant. Most of the demand for reclaimed water is for irrigation and most of the existing irrigation systems that would use reclaimed water are using spray irrigation. These include parts of the campus of the University of Victoria, adjacent schools and institutions and golf courses. Reclaimed water could also be used for toilet flushing in future institutional buildings on the campus of the University of Victoria.

Storage and Disinfection

Because these areas are open to the public, high quality filtered and disinfected reclaimed water would minimize health risks. The proposed SENOB plant will consist of a state-of-the-art ultrafiltration membrane bioreactor (MBR) plant. This process produces the highest effluent quality in terms of suspended solids and BOD of all the treatment processes. Also, the small pore sizes of the ultrafiltration membrane remove a large proportion of micro-organisms. One of the biggest issues facing the use of reclaimed water for spray irrigation is the current requirements of the Municipal Sewage Regulation to provide a minimum of 2 days of storage time. However as indicated in the MSR Policy Intentions Paper, this requirement will be eliminated provided the plant is designed with multiple units such that the effluent requirements can be met with one unit out of service. To ensure that the effluent is properly disinfected, it is proposed to provide a chlorine contact time with a minimum detention time of 90 minutes and to provide two barriers by adding UV disinfection prior to chlorination.

In addition to the chlorine contact chamber, equalization storage will be needed since irrigation takes place at night between 10:00 PM and 6:00 AM. Current nighttime sewage flows are lower than the combined peak irrigation demand for the University of Victoria and golf courses. The equalization storage would follow the chlorine contact chamber.

Also as discussed in Part B of the report, equalization storage is proposed in order to extract heat from effluent during the early morning period when low flows occur at the time of peak heating demand. Equalization storage would provide a benefit in the summer during nighttime peak irrigation demand and in the winter during early morning peak heating demand.

System Configuration

Following treatment and storage, high lift pumps would pump the reclaimed water into a separate purple pipe distribution system. There is a difference in elevation of approximately 27 metres between the sewage treatment and the plateau where the University and adjacent golf course is located. As a result, the high lift pumps motor size exceeds 100 HP. The reclaimed water distribution system is designed to provide a pressure of 275 kPa at the point of use.

Option 1 has the smallest capital cost because it services customers located near the proposed plant, namely the University of Victoria and surrounding institutions, and includes 2 km of piping Equalization storage is not required with Option 1. Option 2, which includes a golf course adjacent to the University, requires 4.3 km of piping and an equalization tank. Options 3 and 4 both include 6.5 km of piping in order to service the Cedar Hill golf course and require larger pumps and reservoirs.

Revenues

The reclaimed water system straddles two municipalities with different pricing for large water users. The incentive pricing of $0.72/m^3 that was proposed earlier is lower than the water rate of $1.05/m^3 in Saanich but is higher that the bulk water rate of $0.55/m^3 in Oak Bay. This factor mitigates against extending the reclaimed water system into the Municipality of Oak Bay since it would reduce revenues from reclaimed water by 30%. In order for the revenues to cover the operating and maintenance expenses, reclaimed water should be sold at a roughly the same price as potable water.

Triple Bottom Line Assessment

A value-based triple bottom line evaluation has been completed. Equal total weighting has provided a value for social, environmental and economic factors. The results of the TBL indicate the following relative scores:

Table 7.1 – Summary of Triple Bottom Line

	Option 1	Option 2	Option 3	Option 4
Economic	83	55	45	40
Environmental	74	66	51	51
Social	92	72	32	28
Total	249	193	128	119

Option 1 offers the lowest capital cost and equalization storage is not required. Options 2, 3 and 4 require significantly more piping and larger pumps.

7.2 Conclusions – Reclaimed Water Reuse

Reclaimed water has been used in many other jurisdictions including California and Arizona where water resources are limited. In these areas reclaimed water is a viable option to offset irrigation water demands. There is also a long history of using reclaimed water for spray irrigation in the BC Interior in communities such as Kamloops, Vernon and Osoyoos. On Vancouver Island, reclaimed water is used for irrigation at the Morningstar golf course near Parksville. In many instances use of reclaimed water is driven by a shortage of water resources and climatic conditions.

In the Greater Victoria area the irrigation season is short at approximately 4-5 months. In the District of Saanich, where the University of Victoria gets is water, the rate is $1.05/ m^3. However the District of Oak Bay bulk water rate to golf courses is $0.55/m^3. This bulk water rate does not provide any incentive for current users to consider the use of reclaimed water by potential users. Policy changes and education programs would be required to promote the use of reclaimed water. When the current and proposed MSR regulatory and public health requirements are considered for the situation at UVic grounds, there is limited area that can be irrigated.

All four options provide for varying volume of reuse of reclaimed water mainly by the use of spray irrigation in urban areas. Public acceptability needs to be established and starting with Option 1, which provides for irrigation on the University of Victoria campus and adjacent institutions, would provide the opportunity for a demonstration project and public education.

The capital cost of a reclaimed water supply and distribution system to supply the University of Victoria and adjacent institution is estimated at $3.9 million. This amount does not include the work on private property to extend the reclaimed water lines to connect with the irrigation system. There are several reasons why the capital costs are high:

- The reclaimed water must be pumped in separate pipelines over a 30 m difference in elevation.
- The length of the transmissions mains ranges from 2 km for Option 1 to 6.5 km for Options 3 and 4 adding to the cost;
- The regulation specifies that for all areas, direct public contact with reclaimed water must be minimized. The regulation also spells out there shall be no direct contact between the reclaimed water and any persons on parks, playground and school grounds. As a result of these restrictions, the irrigable area of the campus by approximately by two-thirds so only one third of the campus can be considered for irrigation and this significantly reduces the water demand and potential revenues.

A reclaimed water system would provide social and environmental benefits such as promoting public awareness of water conservation and reducing the effluent discharge into the ocean during the summer months. There are no financial benefits since the annual revenues will only cover the annual O&M and the corresponding loss of revenues from the sale of treated water. This assumes that reclaimed water is sold at the same price as potable water. If reclaimed water is sold at a lower price, there would be an annual operating loss. None of the capital cost of the water reclamation system would be recovered by the revenues.

PART B

Section 8 Examples of Heat Recovery Systems

The following are examples of a district energy systems and /or heating system using heat from extracted from treated effluent.

Okanagan College

There are existing operating systems and projects that utilize treated effluent water as a source for heat pumps. One such example is Okanagan College's Clearwater system, designed by Stantec in 2002.

Okanagan College's KLO Campus is located in Kelowna, BC, and was retrofitted with a heat pump heating system that utilizes treated effluent water from the adjacent City of Kelowna Wastewater Treatment Facility. The "Clearwater" system was first operational in 2003/2004, and is used to provide about 40% of the peak heating demand for the campus.

The Clearwater system utilizes a small fraction of the available City of Kelowna wastewater flow. About 600 US Gallons Per Minute (USGPM) of treated effluent water are drawn from a pipeline that flows at approximately 13,000 USGPM, thus lowering the temperature of the discharged effluent by only 0.47°F. The heat pumps in the Clearwater system provide heat to approximately 400,000 ft2 of campus buildings, and distributes that heated water through existing underground insulated district heating piping.

Kelowna Wastewater Treatment Maintenance Building

A second example of treated effluent heat recovery utilizing heat pump technology is the City of Kelowna's Wastewater Treatment Facility new Maintenance Building. The new building is targeting LEED™ Silver registration, and one of the main components of the facility's energy reduction system is the heating and cooling systems that utilize heat pumps connected to treated effluent water.

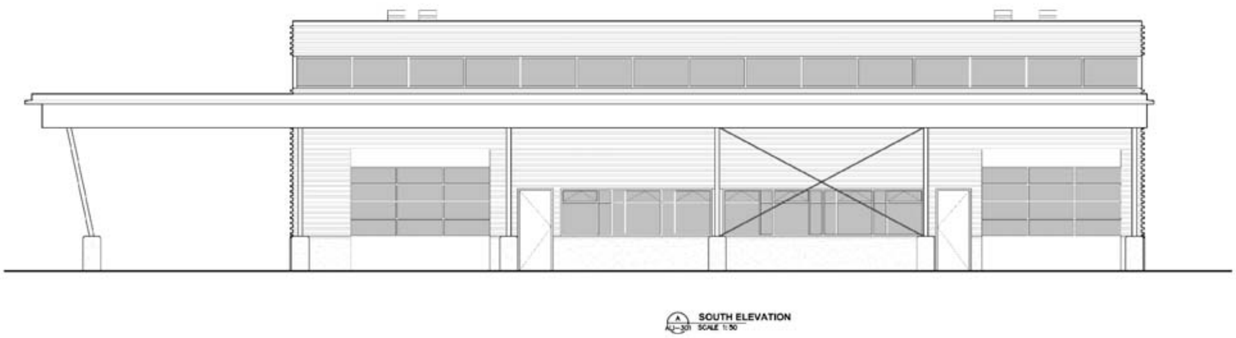


Image: Rendering of the City of Kelowna WWTF Maintenance Building

Okanagan Centre for Learning

A third example of treated effluent heat recovery is Okanagan College's new Centre for Learning. This new facility is targeting LEED™ Gold registration, and incorporates a heat pump heating and cooling system that is connected to receive treated effluent water from the City of Kelowna's Wastewater Treatment Facility. The Centre for Learning building has been operating since mid 2009.

The Okanagan College Clearwater system is an example of an "ambient" temperature district heating system. The Clearwater system currently has two main usage points or customers. The main usage is through the College's Central Heating Plant Building that houses the heating boilers and heat pumps for the main campus, and the second usage is for the new Centre for Learning Building, where new heat pumps and treated effluent heat exchangers are installed.

The ambient distribution system utilizes purple pigmented non-potable AWWA C900 Class 150 PVC piping with push on bell and spigot joints. C900 piping is commonly utilized in municipal water works distribution piping, although it is coloured bright blue for that application. Piping for distribution of the treated effluent water is pigmented with purple dyes, and is marked "Non-potable" along the spine of the piping, with the spine turned upward in the trench during underground installation to ensure that it cannot be mistaken for potable water piping during later excavation.

The purple PVC piping is installed in the same manner as conventional water works piping, utilizing common excavation, installation and backfilling methods, and is installed below the frost level without external insulation.

The treated effluent water is piped to utility customers using the C900 piping, where a heat exchanger separates the treated effluent water from the customer's closed loop piping systems.

Whistler Athlete's Village

The Whistler Athlete's Village district energy system consists of a two pipe closed loop energy system operating at ambient temperature and using heat extracted from the Whistler WWTP as the primary source of energy. The secondary source of energy consists of natural gas boiler. The source of gas would be either the landfill or natural gas. The secondary source is required to maintain the capacity of the DES when the effluent flow and temperature are inadequate.

The district energy system is designed to provide 70% of the peak building load. Electric duct heaters will be installed within the buildings to provide standby heat and will also be sized to meet approximately 70% of the peak building load. As such, the electric duct heaters would more than adequately supplement the DES to meet both peak demand and any upset operating conditions. The supplemental heat provided by the duct heaters will only be required for short periods during the coldest weather. The system also has back up natural gas fired boilers which can be used to provide additional supplemental heat as necessary to the loop.

Saanich Peninsula STP Thermal Energy Recovery

The proposed district energy sharing system will be a dual pipe closed loop with the supply water temperature into the loop between 11^{0}C and 30^{0}C. Plate heat exchangers located at the sewage treatment plant will inject heat into the system. The effluent will be pumped through the primary side the heat exchangers and the liquid will be circulated into the system using VFD controlled water pumps.

Each building that is connected to the system will require a heat pump to increase the water temperature. The heat pumps at each point of use will be located either in separate enclosures within the building if the mechanical room is large enough. The heat pumps will be integrated with the existing systems so that, should the heat pump system fail, the existing mechanical systems within the buildings would keep operating effectively.

The main users for the recovery heat will be the Panorama Recreation Centre and the Saanich Peninsula sewage treatment plant. These will have externally located metal enclosures containing heat pumps. Pumping and controls will be arranged such that both heat sources complement each other. If the rink refrigeration system can produce warmer water than the effluent, then part of the DES will be allowed to rise in temperature to improve the efficiency of the nearby heat pumps. The system may be extended into residential areas at a later date.

Section 9 Heat Analysis

9.1 District Heating Using Effluent

District heating using secondary effluent has been practiced at a number of locations in Europe and is now being considered by some municipalities in North America. One of the main drivers of the use of reclaimed heat in Europe has been higher power and energy costs than is the case in North America. The assessment of using reclaimed heat is specific for every situation and must be investigated for the local conditions and circumstances for where it is being considered. If reclaimed heat can be used it has the potential to provide significant carbon offsets in comparison to the use of natural gas.

9.2 Available Heat & Heat Demand at University of Victoria

The existing average daily sewage flow at the proposed Saanich East/North Oak Bay SENOB sewage treatment plant is 9.6 ML/d. Based on this flow, the total annual heat available is 146,346 GJ/yr. Heat losses through a transmission system operating at 82^{0}C are estimated at 8% leaving 134,638 GJ of available heat for the entire year. It should be noted however that the majority of the heat demand will be required in the winter heating season and domestic hot water on a year-round basis. The sewage flows are projected to increase substantially to 16.6 ML/day for 2030 and 17.2 ML/day for 2065. This increases the year-round available heat to 253,056 GJ and 262,203 GJ respectively. The amount of saleable heat is estimated at 70% of the available heat since space heating is not required for the summer months though domestic hot water, which sources from the University's district heating system (DHS), is required year-round at UVic.

Table 9.1 – Estimated Saleable Heat from SENOB STP (GJ/yr)

Year	Total Annual Heat Available	Estimated Saleable Heat	Demand
2009	146,346	94,250	211,762
2030	253,056	162,970	243,500*
2065	262,203	168,800	280,000*

* Assuming status quo consumption practices with growth projections

The estimated heat available from treated effluent is based on the following assumptions:

- The minimum temperature of treated effluent of 12 C. This is based on temperature data from the CRD Saanich Peninsula sewage treatment facility.
- Allowable minimum temperature of effluent of 5 C prior to ocean discharge.

The University of Victoria is one the largest potential customers for heat in the Greater Victoria area. In addition, there are several schools and institutions in the vicinity of the University of

Victoria, which are potential customers for a district energy system. Based on existing boiler capacity, the heat demand for space heating and domestic hot water at the University of Victoria is 203,360 GJ/yr. This estimation from boiler power is confirmed by gas bill data indicating gas consumption at 211,762 GJ/yr. When this demand is compared with the estimated saleable heat shown in Table 9.1, it can be seen that based on current sewage flows, the saleable heat is less than 50% of the existing annual demand. At the estimated 2030 sewage flow, the available heat is approximately 67% of the demand. Because of the limited supply of heat, long conveyance distances and proportionally small demand, it is proposed not to consider the heat demand of adjacent schools and institutions.

A more critical detailed analysis has been performed on the flow data and "heating power" demand. This was undertaken due to concerns over the significant diurnal variations in the amount of heat that may be available from wastewater throughout the day. The hour to hour variations in sewage flow and therefore the available heat are shown in Figure 9.1. As can be seen, sewage flows from midnight until 8:00 am are low, with the lowest flow occurring around 5 AM. This limits the supply of heat at a critical time in the early morning where major building heating systems begin to ramp up to satisfy the major occupancy demand.

Figure 9.1 also shows the hourly variations in heat demand for the DHS for the entire UVic campus. The heating systems go into set-back mode between the hours of 8pm - 5am. This is when demand is at its lowest. At approximately 5 – 6 am, there is a sharp spike in demand as the boilers ramp-up to heat the buildings for the students and staff arriving between 7 and 9 am. The system reaches a daytime equilibrium and then drops in the evening. Unfortunately, the morning peak heating demand occurs while the sewage flows are still low. This situation is the reverse to what would be optimal, where supply would lead demand.

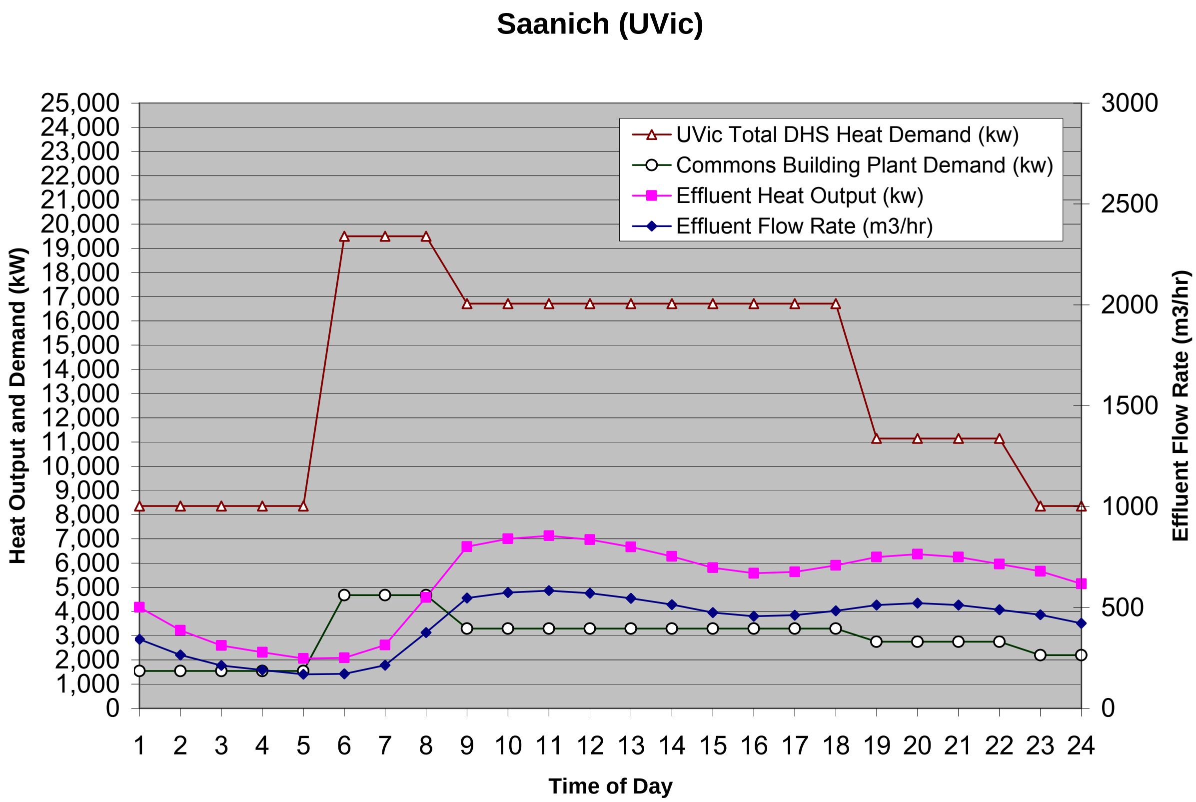


Figure 9.1 – Hourly Supply / Demand Relationship for the University of Victoria (2009)

Even at the 2030 average day flow of 16.6 ML/d, the heat output from treated effluent would be approximately 8,000 KW. This is still insufficient to meet the heat demand of the UVic campus and would only be capable of providing about 50% of the base daytime demand.

As discussed in subsequent sections, the proposed approach is to examine options to service a portion of the campus' heat demand. The heat demand for space heating and domestic hot water is normally provided by 4 boilers in a central heating plant located in the Engineering Laboratory building (No. 4 boiler room). All the buildings on campus except smaller residential buildings are connected to a district heating system. There are three older boiler rooms on campus. One of these boiler plants, the Commons Building, is fired during the coldest period of the year to supplement the newer No. 4 boiler room.

The existing UVic main boiler plant for the district heating system operates at a temperature of 230^{0}F. It is our understanding that the system is designed to operate at a temperature of 200^{0}F, but is operated at a higher temperature to prevent premature damage in the boilers. The Campus central heating system schematic is attached as Appendix A. It is noted that most conventional heat pump systems are only able to boost heat to 176^{0}F with a coefficient of performance of 3. As a result, it will not be possible to use the heat from the effluent to serve the main UVic District heating system without consuming an inordinate amount of electricity. UVic does however have some other boilers in some of the older buildings which could consider the use of reclaimed heat from effluent. The system which could be considered is the No.2 Boiler room in the Commons Building. The buildings previously served by this boiler could be disconnected from the central heating system and connected to the heat reclamation system which operates at a lower temperature. This is further described in Section 9.3

9.3 Proposed Arrangement for the University of Victoria

As indicated above, an average of approximately 5,000 KW of heating power is available from the sewage at current 2009 flows. However, the heat output drops to 2,000 KW between 6:00 and 7:00 am which is also the time when the heat demand spikes. In order to provide a more consistent and reliable utility, a number of supply options would be available including:

- Heat extraction from sea water
- Gas fired back-up boilers
- Solar thermal collectors
- Building heat reclaim
- Geo-thermal, and
- Effluent storage tanks

It is beyond the scope of this report to examine, in detail, the extraction of heat and the feasibility of other sources than sewage or treated effluent. It is proposed that the additional heat needed to make up for low sewage flows would come from a storage tank. As discussed in Part A of this report, storage of effluent will be required for the reuse of reclaimed water as irrigation demand occurs between 10:00 PM and 6:00 AM when flows are lowest. The equalization storage needed to meet the irrigation demand in the summer could also be used to meet the heat demand in the fall, winter and spring heating and non irrigation months, and for the small demand for domestic hot water in the summer. In order to extract additional heat from storage, the heat equalization storage tank should be sized to make up the deficit in available heat from 5:00 AM to 9:00 AM. A storage tank with a volume of 1.540 m^3 would provide a source of heat for the early morning. This volume could be combined with the storage tank needed for chlorine contact for the irrigation system noted earlier in the report. This arrangement would function well in the winter when there is no demand for irrigation water.

It is proposed to supply heat extracted from effluent to the portion of the central heating system that can be valved off and supplied from the No. 2 boiler room located in the Commons Building. This would include the following buildings: The Commons, Student Union Building, Craigdarroch residences (David Thompson, Emily Carr, Margaret Newton, Arthur Currie) and the Lansdowne residences (See Figure 9.2 and the full schematic included in Appendix A).

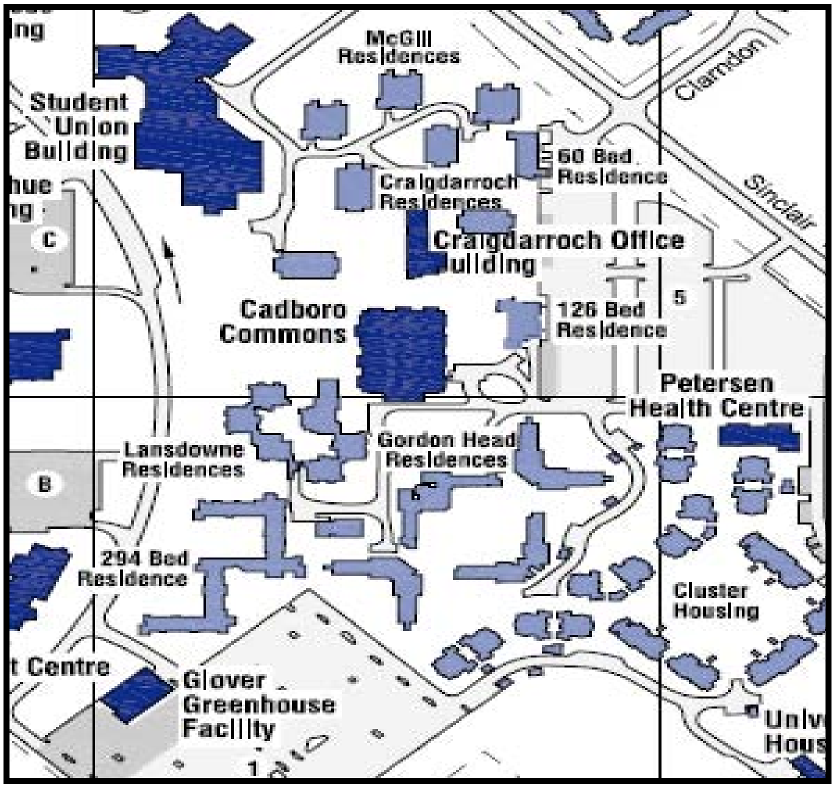


Figure 9.2 – Proposed portion of UVic DHS supplied from effluent heat

There is a benefit in connecting at the Commons building plant. The distance from the proposed SENOB wastewater treatment plant is considerably shorter and simpler than to the main plant in the Engineering Lab Wing. There would be less disruption, road works and conveyance costs, less transmission heat loss in the lines, and a better match between supply and demand magnitudes. In other words, the installation would be less expensive and a more consistently reliable heat utility would be provided. The proposed route of the heat supply loop from the treatment plant to the Commons Building is shown on Figure 9.3.

SEAL	BY	DATE	No.	REVISION	ENG.	No.	DATE	ISSUE
						1		

Making a difference...together

Capital Regional District | Environmental Services			
DESIGNED	G.C.	SURVEYED	–
DRAWN	S.S	DATE	12/11/09
SCALE HORIZONTAL	1:10,000	CHECKED	G.C.
SCALE VERTICAL	–	APPROVED	S.S.

CORE AREA WASTEWATER TREATMENT PROJECT

HEAT RECOVERY CONCEPT PLAN FOR UNIVERSITY OF VICTORIA

CONTRACT NUMBER	DRAWING NUMBER	ISSUE	SHT. No.
149009002	Fig 9.3	X	4 OF 4

There is also an additional benefit to connecting at the Commons Building plant. Besides the reduced conveyance costs, the Commons plant is connected to the remainder of the University's district heating system by an 8 inch diameter pipe loop. In the summer, when space heating demand is low, the available heat from effluent could instead be used to provide domestic hot water heating. Based on preliminary DHW demand calculations and boiler power demand in the McKinnon building, it appears there is enough heat available from wastewater to serve both DHW and heat for the swimming pool in the McKinnon building. This would permit the University to shut down the 4000 KW natural gas fired boiler in the main ELW plant that they currently run all summer to serve the domestic hot water and McKinnon pool demand. This would have a positive impact on their green house gas footprint as well.

The storage tank would be used to store effluent from the previous day. Heat would then be extracted during the night and the early morning to provide heat the peak heating demand. This is shown schematically in Figure 9.4

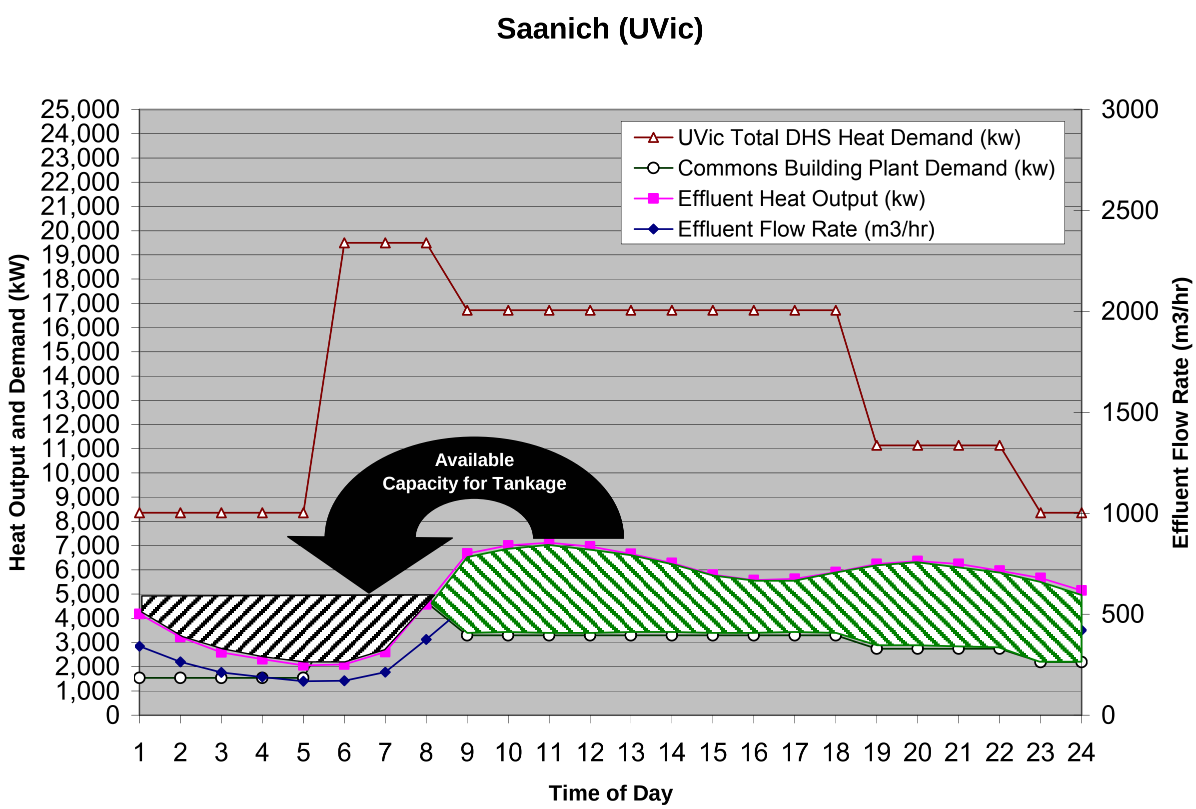


Figure 9.4 – Consistent Heat Supply vs. Daily Capacity for Tankage

Based on the boiler power in the Commons Building of approximately 5000 KW, there is a better match between supply and demand if this portion of the campus DHS is only considered for connection only. As can be seen from Figure 9.4, an average of approximately 5000 KW is shown for existing flows. This would be the peak demand that could be satisfied with any consistency including the heat from the storage tank capacity.

The highest hot water temperature that can be supplied from heat pump devices is 80 C (176 F) without major reductions in the coefficient of performance (COP). This will have a major impact on the amount of heat that may be delivered from the existing heating equipment in these older buildings. The Campus boilers serving the main UVic DHS currently run at 230 F so a significant amount of the campus cannot be considered for use of reclaimed heat from effluent except during the shoulder seasons.

Due to the curve-linear heat transfer relationship that exists for heating equipment, any reduction in system temperature impacts the amount of heat delivered significantly. The amount of heat, however, would be sufficient for most of the shoulder season. During the coldest winter days, the boilers may need to be fired to meet the demand from the 7 residence buildings. Further testing of the system will be required to confirm both the effects of the lower temperature water on heat supply to the buildings and to see how much of the shoulder heating season the wastewater heat extraction can cover.

9.4 Cooling Demand

Building cooling can be accomplished by exhausting heat to the effluent. The University of Victoria has a policy against providing any new building cooling systems on campus. Most of the larger older buildings do not have central cooling systems. There are, however, over 210 individual air conditioning units and heat pumps of various capacities on campus. Most of these systems are smaller individual units that are used for various uses such as: space cooling, cryogenic freezers and lab refrigeration. In order to connect all these individual systems together, it would be necessary to create a separate district cooling loop. Also, newer buildings with separate/disconnected cooling systems are at significant distances from each other, which would imply significant capital cost needed for a conveyance system installation.

The domestic hot water tanks in most buildings are connected to the University's district energy system. Therefore in summer, the boiler plants must keep running in order to supply DHW in the buildings. To provide cooling using effluent, there would have to be either a parallel cooling distribution system installed or to remove all the DHW tanks from the district energy system. Either of these options would be costly and could not be justified. Cooling demand in Victoria's mild summer climate is also significantly less than heating; approximately a 70/30 split so this makes it impractical to provide cooling using effluent since it would be necessary to build a separate cooling water distribution system throughout the campus to connect the individual air conditioning units and heat pumps. Such a system would be very expensive to construct and significant modifications would be required within existing buildings to implement this scheme.

Section 10 Alternative for Heat Extraction Methods

10.1 In-pipe Heat Exchanger (Rabtherm Product)

The extraction of heat from raw sewage using heat exchangers built into the conveyance piping was investigated. This included gravity mains, forcemains or treated effluent outfall pipes using the Rabtherm® product. This option could be considered where new pipelines must be built as part of the overall program and where the routing of such pipelines makes use of the recovered heat viable in adjacent buildings. This product consists of a pipeline with the heat exchanger tubing built into the pipe wall. Currently this patented product must be imported from Europe, however, the North American representative has indicated that it could be manufactured in Canada using imported parts. Due to the high cost of this piping system, the use of this in pipe heat exchanger would be limited to newly constructed mains.

There is one significant limiting factor to the cost vs. heat extraction business metric for this product. The heat potential in raw sewage is constrained by the temperature to which it can be dropped. For the wastewater treatment process, the temperature of the raw sewage can only be reduced to 10 ºC before biological sewage treatment processes are impacted. Since treated effluent is at the end of the sewage treatment process, its temperature can be reduced to near seawater temperature levels of 5 ºC before it is discharged to the outfall. This 5 ºC temperature difference has a significant effect on both the size of the Rabtherm heat exchange system and on the amount of heat that can be extracted from the wastewater. The in-pipe heat exchanger is shown on Figure 10.1. The heat exchanger tubing is built into the pipe wall with separate inlet and outlet connections for each 5 m long section of pipe.

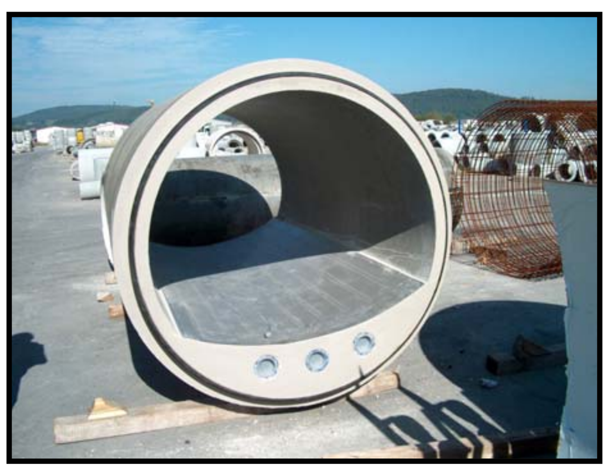


Figure 10.1 – Rabtherm, Forcemain Heat Exchanger

If a 600 mm diameter heat exchange pipe was installed in the 700 m long land portion of the new outfall for the SENOB plant, the amount of extractable heat would be 4,700 KW. With a 900 mm pipe, the amount of extractable heat would 7,000 KW. The cost of material alone is estimated at $3.1 million for the 600 mm pipe and $4.2 million for the 900 mm pipe. This cost does not include the dual parallel heat conveyance pipes that have to be installed in the same trench as the heat extraction pipe and the installation cost. Because of the high cost of this product, it is recommended to carry out heat exchange using other proven and locally available types of heat exchanger products as discussed in the next section

10.2 Direct Heat Exchangers

There are various options available for direct heat exchange to closed loop piping systems from treated effluent, seawater, and groundwater. Potential options include brazed plate, plate & frame, tube in tube coiled helical, and shell and tube heat exchanger technology. Each heat exchanger technology has various characteristics that make them either more or less suitable for duty in various functions of the proposed heat distribution system. Each technology is discussed in the sections below.

10.2.1 Brazed Plate Heat Exchangers

Plate and frame heat exchangers are a sandwich of very thin plates of stainless steel that have a thin layer of brazing alloy fitted between each plate during manufacturing. The raw assembly of loose plates are stacked together, and “sintered” or fused together at high temperature in a combination oven/hydraulic press. The resulting assembly is very light in weight for a given output and arguably the most compact of all heat exchangers.

High internal velocities result from the closely spaced thin plates, with a high heat transfer rate. These heat exchangers can be utilized with fluids that contain suspended solids, as their high internal scouring velocities promote continuous cleaning. Brazed plate heat exchangers cannot tolerate coarse suspended solids such as sand or marine organisms, as the plate tolerances are so small that the exchanger will clog quickly.

This product is limited by the quality of the treated effluent including suspended solids. For the SENOB plant, it is proposed to construct an ultra-filtration MBR plant which will produce a high quality effluent with turbidity that approaches drinking water quality. The main drawback of brazed plate heat exchangers using treated effluent systems, however, is that the high pH and high amount of entrained oxygen in the effluent will accelerate the corrosion of the brazing alloy that forms the bond between plates. Life expectancy is about 5-6 years for treated effluent applications. They have excellent usage as a customer’s heat exchanger, due to their suitability in closed loop systems that are treated with corrosion inhibitors, pH monitored, and with no oxygen present.

The image above has been reprinted from Mueller, www.muel.com.

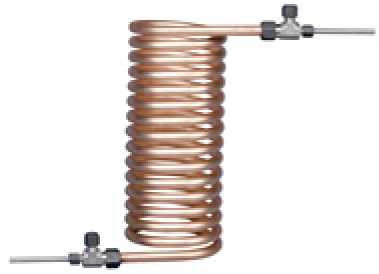
10.2.2 Plate and Frame Heat Exchangers

Plate and frame heat exchangers are characterized by their multiple plate configuration, gaskets between plates, frame/header assembly, compact size (relative to conventional shell/tube configurations), availability in a wide variety of plate and header metallurgy for different applications, availability in double wall atmospheric vented construction for leak detection, and ability to be disassembled in the field for cleaning and gasket replacement. This use of this product is limited by suspended solids. The ultra-filtration MBR plant, however, would eliminate this problem.

Biofouling from organisms found in effluent can be an issue with plate and frame exchangers, including the supply and return pipelines. Products are available that prevent biofouling. One such product is from Blame Worldwide Services. Their product provides both anti-fouling and anti-corrosion protection through the generation of trace amounts of copper ions and the dissipation of trace aluminum hydroxide into the pipeline system. The Blume system will be discussed in further detail below, in the "Heat Exchanger Cleaning Options" section of this report. The image above has been reprinted from Mueller, showing their Accu-Therm models, www.muel.com.

10.2.3 Tube in Tube Heat Exchangers

Another product available for heat exchange are the helical or coiled "tube-in-tube" models shown in the photos below. Their high scouring velocity could make them usable for heat exchange between the treated effluent and closed loop systems. Provided that large enough models are available, the high scouring velocity is of particular benefit for the treated effluent side of the heat exchangers. The treated effluent will contain micro-organisms that can foul heat exchange surfaces. Also of interest is their availability in a variety of metallurgy options, and thus the ability for construction in corrosion resistant options for treated effluent duty.



The images above have been reprinted from Sentry Equipment Corp. www.sentry-equip.com

10.2.4 Shell and Tube Heat Exchangers:

Shell and tube heat exchangers are characterized by their outer shell and inner tube bundle construction, complete with headers. They typically require substantially more floor space than other heat exchanger technologies, both because they are long and narrow, but also because the tube bundles are removable from one end of the exchanger. Usually, the space that a shell and tube exchanger requires for tube bundle removal must be incorporated into the building or space in which the exchanger is installed, and the length required for the total installation is twice the operating length of the exchanger. Their main advantage is that they are the easiest of all the heat exchangers to clean and maintain, when the heat exchanger is handling a fluid with suspended solids. Shell and tube heat exchangers are available in a wide variety of metallurgy options, and thus can easily be adapted to treated effluent heat recovery usage.

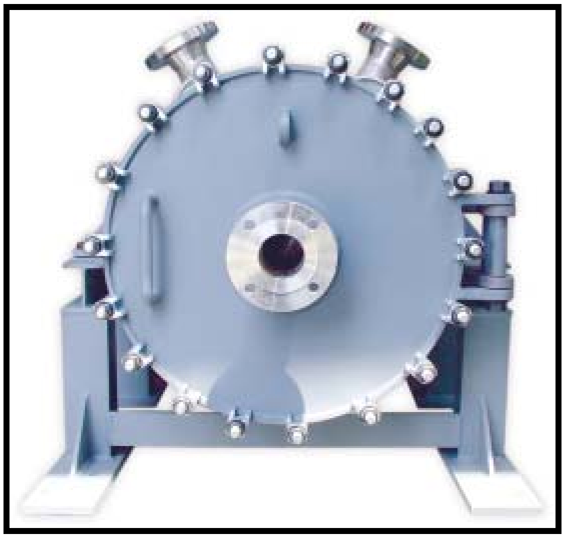
The preliminary cost estimates are based on shell and tube heat exchanger. The final selection of the heat exchanger should be carried out at the time of detailed design.

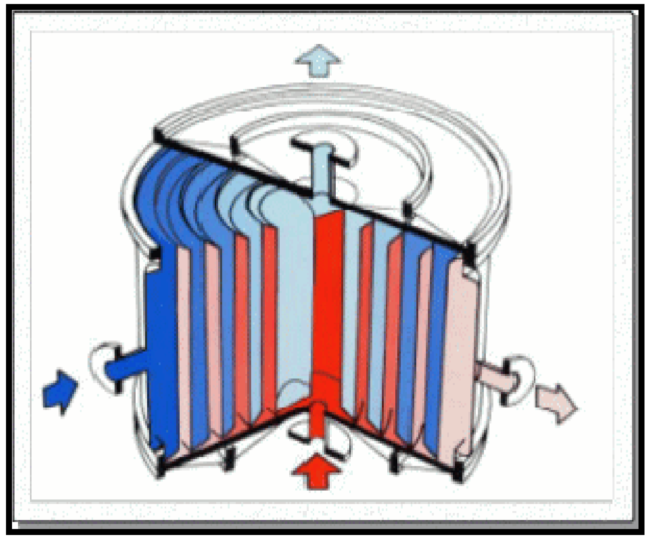
Figure 10.2 Diagram and Photos of Shell and Tube Heat Exchangers

Courtesy of Logichem Process Engineering, www.heatexchangers.co.za.

10.2.5 Spiral Heat Exchangers:

Spiral heat exchangers (SHE) are configured using helical (coiled) tubes. In general, the device consists of a pair of flat surfaces that are coiled into two channels in a counter-flow arrangement. Each of the channels has a long curved path which are connected at the outer arms of the spiral to the loop.





Main advantages of the SHE is its highly efficient use of space and anti fouling characteristics. As well, a notable tradeoff is capital cost vs operating cost. A compact SHE has a smaller footprint and thus lower capital cost to house it. SHE's can therefore be oversized to lower pressure drop, lower required pumping energy and have higher thermal efficiency.

SHEs are often used in heating fluids which contain solids. Other heat exchangers have a tendency to foul in such environments. The SHE uses a "self cleaning" mechanism, whereby fouled surfaces cause a localized increase in fluid velocity, thus increasing the drag friction on the fouled surface. This helps dislodge small blockages and keep the heat exchanger clean. "The internal walls that make up the heat transfer surface are often rather thick, which makes the SHE very robust and durable in demanding environments." They units are also easily cleaned, opened easily so any foulant can be removed with pressure washing.

The SHE is suited for applications such as digester heating, heat recovery and effluent cooling. For most applications SHEs are smaller than other types of heat exchangers.

10.2.6 Heat Exchanger Cleaning Options

Heat exchangers can be prone to fouling from suspended solids and bacteria in the treated effluent. Treated effluent heat exchangers will require either manual cleaning, some form of automatic cleaning system or an anti-fouling system to maintain heat transfer efficiency for reduction of manual cleaning by maintenance staff. It is recommended that the treated effluent be piped through the tubes and not the shell side of the exchanger. There are options available for "online timed" interval cleaning of the heat exchanger internal tube surfaces:

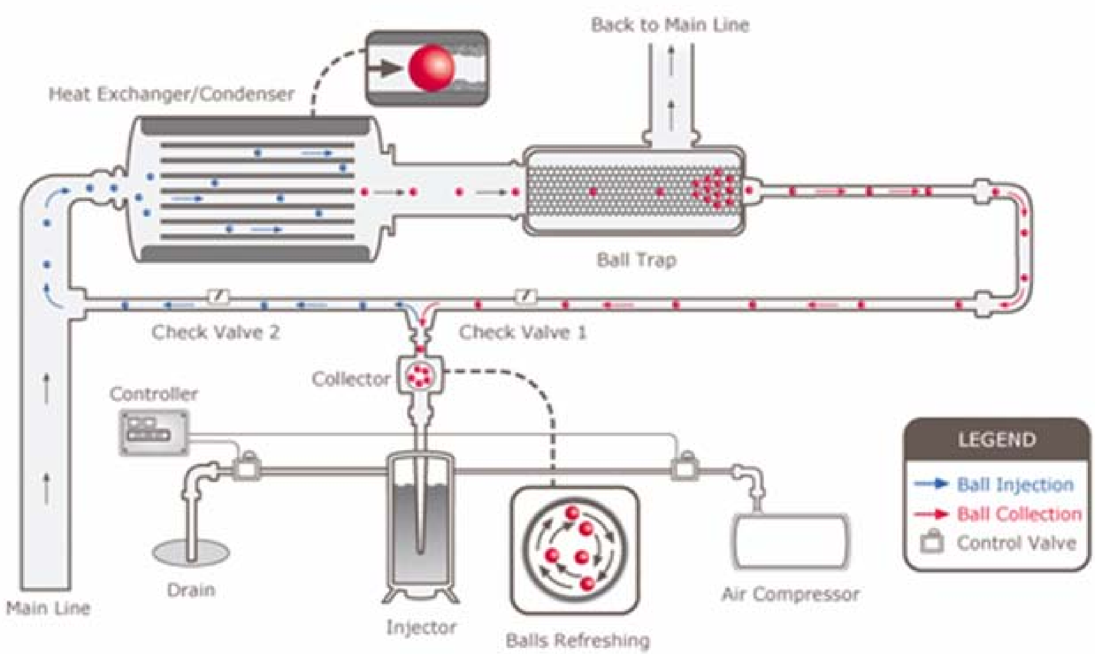
- One such cleaning system manufactured by CQM Tech is called "ATCS Ecodenser". The ATCS system works by injecting foam balls into the fluid stream periodically, and automatically collecting and cleaning the balls for repeated automatic usage. A more detailed description of this system follows.

- Blume Worldwide manufactures an anti-corrosion/anti-fouling system specifically for seawater systems and undersea structures such as offshore oil platforms. It is recommended that an anti-corrosion and anti-fouling system be fitted to the seawater heat exchangers for this project.

It should be noted that both the Blume and ATCS systems will not eliminate maintenance from the treated effluent heat exchangers entirely, however these automatic systems do have the potential to reduce maintenance substantially, and keep internal heat exchanger surfaces clean enough to promote maximum heat transfer efficiency.

How ATCS Works

The CQM ATCS is installed on the chiller's condenser and keeps tubes clean without human intervention. The system periodically injects into the tubes sponge balls that are slightly larger in diameter then the tubes themselves. The natural pressure head pushes the balls through the tube, which is thus rubbed clean. The balls are then trapped in the outlet of the heat exchanger, where they are prepared for the next cleaning cycle.



Section 11 Alternatives for Heat Supply System

11.1 General

In this study, 3 principal types of district heat distribution systems are evaluated:

Option 1: Ambient temperature distribution system (up to 20 ºC)

Option 2: Moderate temperature distribution system (80 ºC)

Option 3: Low temperature distribution system (35 ºC)

These district heating systems would generally consist of the following components:

1. Heat exchangers – to transfer heat from the treated effluent to a clean liquid in a district heating loop;
2. Water pumping – a first set of pumps to flow effluent through the heat exchangers and then a second set of pumps to flow the clean fluid though the district heating loop;
3. Heat pumps – the temperature of the clean liquid has to be "lifted" to the requirements of the building heating system in order to be useful for the end customer;
4. Distribution piping – to distribute the clean heating liquid from the wastewater treatment plant to the end users;
5. Various treatment, expansion and buffer tanks, and
6. Direct Digital Control (DDC) System.

The following system component options have been identified and are further discussed in Section 11.2 to 11.4.

Components	Option 1 – Ambient Temp. Distribution System (up to 20 C)	Option 2 – Moderate Temp. Distribution System (80 C)	Option 3 – Low Temp. Distribution System (35 C)
Heat exchangers	At sewage treatment plant and end user's facility	At sewage treatment plant and end user's facility	At sewage treatment plant and end user's facility
Water pumps	At sewage treatment plant	At sewage treatment plant	At sewage treatment plant
Heat pumps	At end user's facility	At sewage treatment plant	First lift heat pump at STP and second heat pump at point of use
Distribution piping	Non insulated pipe - PVC or HDPE	Insulated welded steel pipe	Insulated PVC or HDPE

11.2 Option 1 – Ambient Temperature System (Up to 20^{0}C)

Option 1 is shown schematically in Figure 11.1 and consists of an ambient temperature system that will provide the Owner of the district energy system (DES) with the ability to meter utility customer's usage in both heating and cooling modes or heating only, if a customer chooses this option.

With this option, a closed loop distribution piping consisting of 450 mm diameter non-insulated pipe system would be required. Utility customers could draw water from the DES utility and water would be fed to a heat exchanger(s) in each building. Customers could in turn use heat pumps for both heating and cooling within their facilities, and the customers heat pumps would be connected on the load side of the heat exchanger. The heat exchangers in each customer's building would serve two purposes:

- As a means to separate the DES closed loop treated water from the customer's hydronic heating and cooling systems in order to ensure that any customer issues with maintaining their water chemistry does not impact CRD's systems.
- As a means to separate the DES systems from systems with a higher operating pressure. For example, customers with high buildings might exert a higher than anticipated static pressure on the DES distribution systems if there were no heat exchangers fitted to the piping network. The benefit of separating higher pressure systems from the DES results from being able to utilize pipeline components with lower pressure ratings where possible.

System Basics:

This option is termed a "net-metering" solution. Thus, it is expected that customers with differing heating and cooling load profiles would connect to the same network of closed loop piping, and the DES closed loop utility would allow energy sharing between buildings that simultaneously require heating and cooling.

For example, a transit repair shop connected to the utility might have a large makeup air heating requirement, with a heating load from the makeup air that might occur at any ambient temperature below 15 degrees Celsius. Nearby, a large office building may have many interior areas with no interaction to the envelope of the building, and resulting heating/cooling load variations with weather, time of year, and solar effects. The interior spaces of the large office building would normally be filled with people, lighting and computers that would require cooling year round, independent of outside temperature, and would thus be rejecting heat either from heat pump or central chiller operation.

Conventional stand alone HVAC systems for each building would dictate that the transit repair shop systems be designed to utilize natural gas fired equipment for makeup air heating, while the nearby office building would be operating a cooling tower or closed circuit fluid cooler almost year round in order to reject heat from the interior spaces. With an energy sharing utility, energy can be transferred between customers. Each utility customer would require their buildings to be fitted with a heat pump, either water to air or water to water type. It is anticipated that the best candidates for a water source heat pump system are those with existing hydronic (fluid based) heating and cooling systems within their facilities.

Facilities with rooftop packaged, or unitary equipment are not anticipated to be potential customers due to the high costs of system retrofit. However, it should be noted that as CO2 emissions penalties legislated by the BC Provincial Government grow over time, a treated effluent utility coupled with heat pumps fed from renewable hydroelectric power may become more attractive to potential customers, both for reasons of economics and for environmental stewardship. During periods of low cooling load operation, customer bypass valves can be used on the load side of customer heat exchangers to potentially provide chilled water directly from the customer heat exchanger, by operating the seawater exchanger to provide chilled water.

System Operation:

As mentioned above, the proposed system type is a closed circuit utilizing tap water treated with corrosion inhibitors as a heat transfer fluid. Water would be circulated amongst all buildings connected to the utility, and temperature of the closed loop would be monitored and adjusted by automatic temperature control systems. Common water source heat pumps have the ability to operate within a wide temperature range at their water inlet, of approximately 2 C to 25 C in heating mode, and between 15.5 C and 32 C in cooling mode. Therefore, it is expected that the closed loop utility would operate in a temperature range between 5 C and 25 C during all conditions. Automatic valves, recirculation valves and temperature controls on the utility heat exchanger and customer connection would ensure that the fluid temperature at the inlet to each customer heat pump would be maintained within an optimum range.

If return water temperature at any point in the system moved near to the limits of either 5 C or 25 C operating range, automatic controls would use a combination of additional flow and the addition or rejection of energy to the loop via the treated effluent to maintain proper closed loop operating temperatures.

The DES would meter water usage with both flow meters and accurate temperature measuring devices in order to bill the customers for usage. The added advantage of a “closed loop net-metering solution” is that separate customers demanding both heating and cooling simultaneously can be charged for their usage, while the DES only energy cost is for circulating the fluid to the customers. Two or more customers “share” energy. The potential impact of eliminating natural gas usage from combustion for heating, while sharing energy with a customer that is simultaneously requiring cooling is significant. The only penalty of this approach is that pumping energy is needed for fluid transfer between customers, and heat pump energy is required for heating.

System Advantages:

- Can be expanded to an energy management system;
- Heating and cooling capability with a single pipe;
- Conveyance loop does not require welded steel insulated pipe; pipe is cheaper; and
- Essentially no transmission heat loss.

System Disadvantages:

- More costly for end customer to connect since a heat pump is required at each point of use and may require costly building modifications to expand the mechanical room to accommodate the heat pumps;
- Conveyance is more difficult with larger pipe with cost implications;
- Will need backup boiler for coldest winter months; and
- May need very expensive “single lift” heat pump to achieve required DHS temperatures.
- There will be higher electrical usage at the end user’s plant. This may trigger the need for improved electrical infrastructure such as transformers and improved distribution network.

11.3 Option 2 – Moderate Temperature System (80ºC)

This is the classic type of DHS that runs at higher temperatures incorporating an insulated distribution loop and a simple heat exchanger at the end customer's facility. This system is shown schematically in Figure 11.2.

System Basics:

The system consists of heat exchangers and heat pumps at the wastewater treatment plant, which extract heat from the treated effluent. The heated water is then pumped through an insulated closed loop piping system to the University where it can be extracted to the existing DHS. This extraction at the University is accomplished with a simple low maintenance heat exchange system, incorporating pumps and heat exchangers.

System Operation:

The closed loop transmission fluid temperature would be increased in 2 stages. The first stage would be through heat pumps or chillers to accomplish the first lift to 35 ºC. The second lift would be through modular heat pumps to raise the fluid temperature to 80 ºC. This 80 ºC water would then be transmitted through an insulated 350 mm diameter closed loop pipe to the Commons Building to charge the residential portion of the University's DHS.

The two temperature lifts would be controlled by a direct digital control system with temperature meters on supply and return lines in order to optimize the coefficient of performance (COP) between heat output and required electrical power. As well, calibrated temperature and flow meters would be employed to measure consumption so that the University could have accurate consumption and billing information.

System Advantages:

- Simpler end customer hook up: At the end customer's facility, only heat exchangers, pumps and controls would be installed. Heat pumps would not be required at the end users facility as the district loop water has already been lifted to the required temperature. Less equipment means less initial capital cost for the end customer and therefore greater incentive to connect;
- End customer does not need to find copious amounts of space in existing mechanical rooms to house heat pumps and related equipment.=;
- Less maintenance and lower initial capital cost for end customer to get connected;
- Maintenance of heat pump equipment is centralized at the sewage treatment plant – this is an ongoing incentive for the end customer;

- Due to the presence of the insulated pipe loop, a fully modulating back-up boiler could be located at the wastewater treatment plant and maintained centrally. The moderate or higher temperature water from the back-up boiler could boost system capacity and be transmitted to the University to accommodate more of the shoulder/winter season demand;

- End customers do not have to pay direct capital costs for heat pumps at their facility or pay hydro costs for extracting heat at their facility with heat pumps, and

- The pipe diameter for the transmission loop is smaller than for the ambient system. This reduces conveyance costs.

System Disadvantages:

- There will be higher heat losses in the conveyance pipe at this elevated temperature Heat loss in conduction is proportional to the square of the Temperature (i.e. $Q_{loss}\ \alpha\ T^2$);

- There will be a lower coefficient of performance (COP) from the heat pumps at higher temperatures, and

- There is no ability to both heat and cool at the same time with this system unless a second insulated loop is installed to solely carry cooling water. Installation of a second loop would have a significant effect on conveyance costs. With the mild summer temperatures in Victoria and UVic's ban on mechanical cooling, this option does not appear financially viable or worthwhile.

11.4 Option 3 "Low" Temperature System (35ºC)

The 35ºC low temperature system is similar to the 80 ºC system above, but with minor differences that affect the conveyance cost, transmission losses and end customer operations. See attached system schematic on Figure 11.3.

System Basics:

This is a lower temperature system than the 80 ºC system above, but it carries more heat capacity per fluid volume in the distribution pipe than the ambient system. Since temperatures are lower, a less expensive plastic pipe can be used for the distribution loop instead of welded steel. The distribution pipe still requires insulation; however transmission losses due to the lower fluid temperature are significantly reduced.

The heat extraction and first temperature lift of the distribution loop is conducted at the sewage treatment facility and 35 ºC water is then pumped through the loop. The end customer must then conduct the final temperature lift with a heat pump located within their facility. Operating parameters can then be controlled by the end user to satisfy their specific heating system(s) needs of operating temperatures and demand.

System Operation:

The system operation is similar to the 80 ºC loop, however the second temperature lift occurs in a different location; at the end users facility.

The fluid carried in the closed 450 mm diameter transmission loop is increased to 35 ºC in a single stage. Then a second lift is conducted at the end customer's facility to 80 ºC. Chillers accomplish the first lift, pump convey the 35 ºC fluid to the end users facility where the second lift is provided by modular heat pumps to raise the fluid temperature to 80ºC.

The temperature lifts, which occur in separate locations, would be controlled by separate direct digital control systems. The system the end users facility, located before the customer's heat pumps, would employ calibrated temperature and flow meters to measure consumption so that the University could have accurate consumption and billing information.

System Advantages:

- The system would incur less transmission losses than with the 80 ºC system;
- There is lower conveyance and pumping costs due to more heat capacity in fluid and smaller diameter pipe;
- The end customer has more control over temperature and COP with control over both the heat exchanger and the heat pump, and
- The insulated plastic transmission pipe should be more economical than the welded steel pipe of the 80 ºC system.

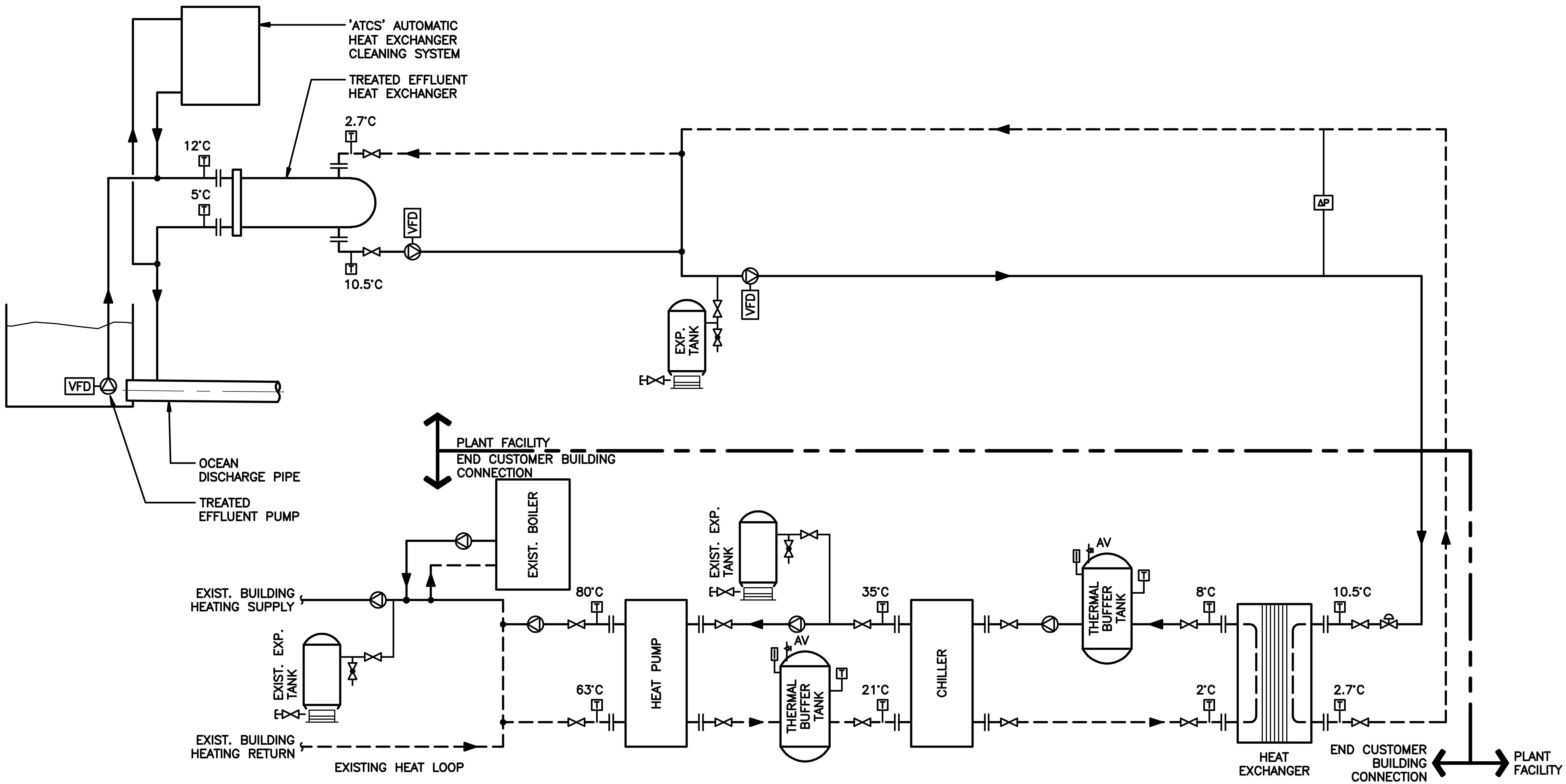
System Disadvantages:

- The cost of the insulated transmission pipe is likely more expensive than the ambient pipe. The conveyance of the larger ambient pipe my have significance however;
- There is more heat loss in the low temperature system transmission pipe than for the ambient system;
- A better COP could be achieved in early shoulder seasons than in the higher temperature system, and

The ability to heat and cool at the same time is reduced as the system would require a second (expensive) insulated distribution loop. Having the end user's DHW system connected to the DHS makes cooling in summer not feasible.

- There will be higher electrical usage at the end user's plant. This may trigger the need for improved electrical infrastructure such as transformers and improved distribution network.

- For this option, significant direct digital control systems with feedback loops would need to be installed in the wastewater plant and in the end users plant. This will nearly double the controls cost and impact operations and maintenance.



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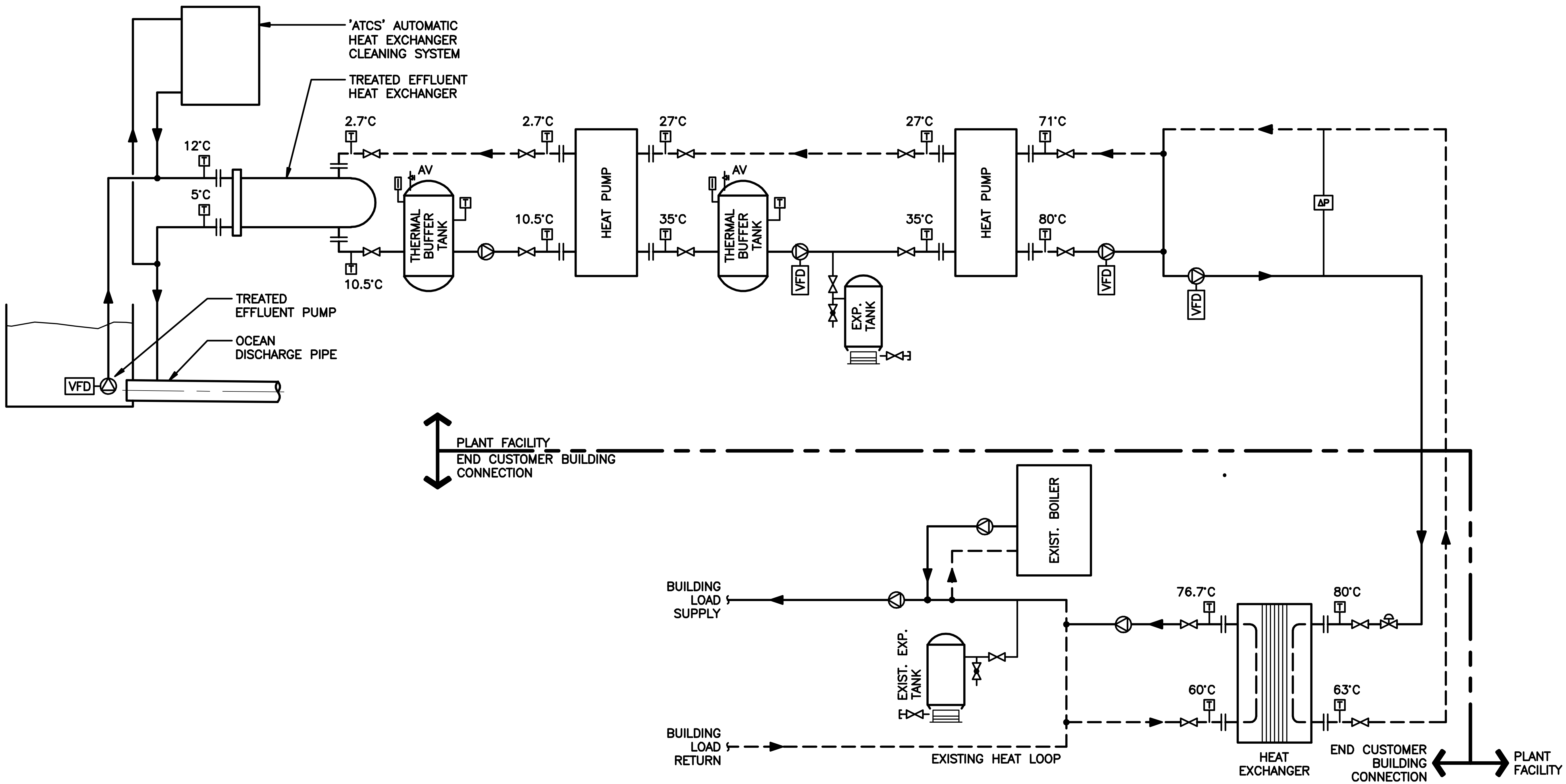
CORE AREA WASTEWATER TREATMENT PROJECT

HEAT RECOVERY – AMBIENT TEMPERATURE WATER LOOP – UNIVERSITY OF VICTORIA OPTION 1

CONTRACT NUMBER	DRAWING NUMBER	ISSUE	SHT. No. OF
149009002	Fig 11.1	X	1 OF 3



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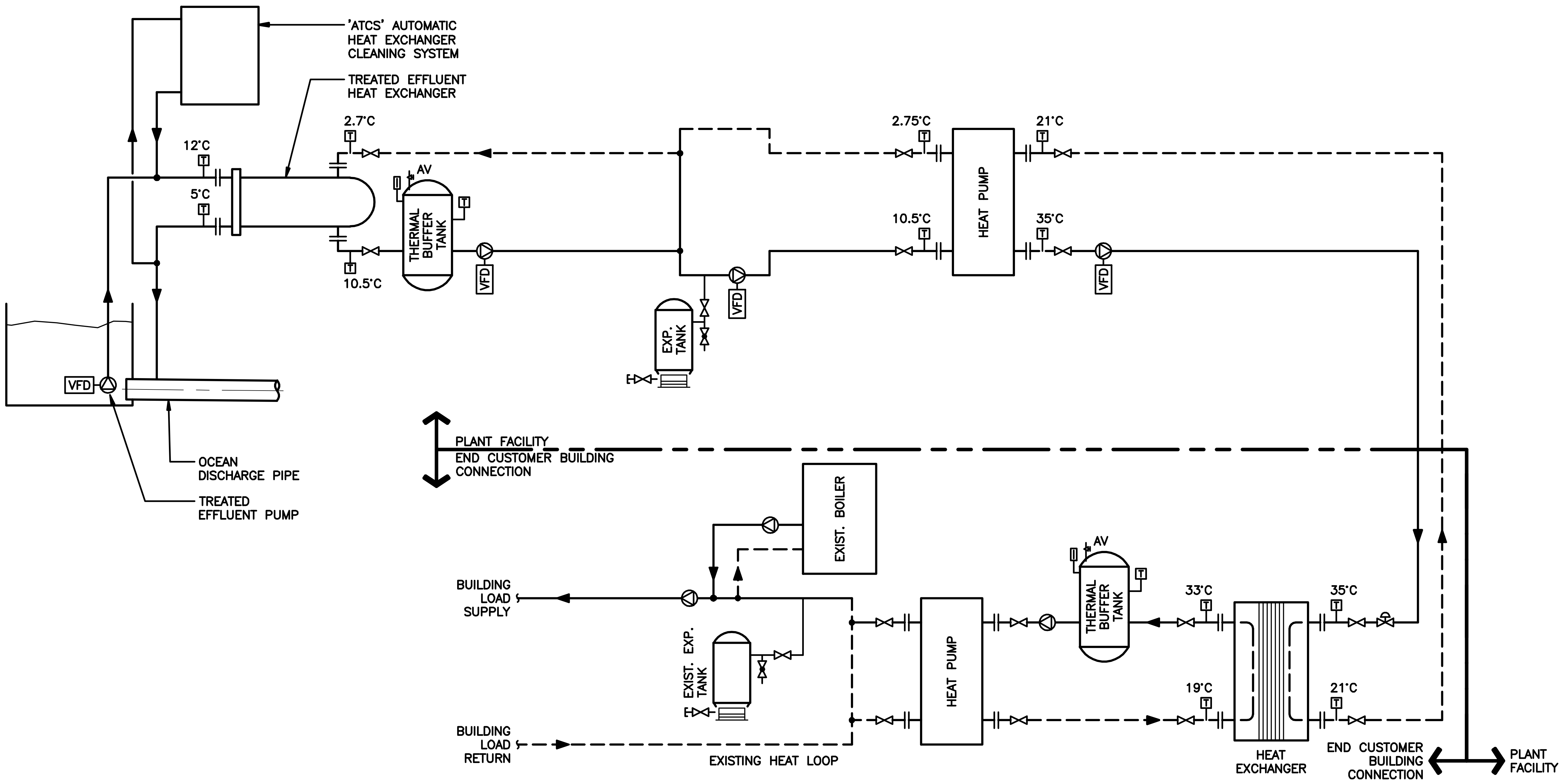
CORE AREA WASTEWATER TREATMENT PROJECT

HEAT RECOVERY – AMBIENT TEMPERATURE WATER LOOP
– UNIVERSITY OF VICTORIA OPTION 2

CONTRACT NUMBER	DRAWING NUMBER	ISSUE	SHT. No.
149009002	Fig 11.2	X	2 OF 3



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CORE AREA WASTEWATER TREATMENT PROJECT

HEAT RECOVERY – AMBIENT TEMPERATURE WATER LOOP – UNIVERSITY OF VICTORIA OPTION 3

CONTRACT NUMBER 149009002 DRAWING NUMBER Fig 11.3 ISSUE X SHT. No. 3 OF 3

Section 12 Opinion of Probable Cost

12.1 Cost Basis

To enable completion of the triple bottom line assessment and to obtain an initial indication of capital cost for each of options 1, 2 and 3, cost estimates were prepared for each option. The basis of the estimates includes the following:

Direct Cost

- Capital construction cost
- Design and construction contingency costs at 25% of construction cost

Indirect Cost

- Engineering at 15% of direct cost
- Administration and miscellaneous at 6% of direct cost

Financing Cost

- Interim financing at 4% of direct and indirect cost
- Inflation to midpoint of SENOB construction 2% per annum to 2011 (4%)

Furthermore the following assumptions have been made in estimating the cost of the major components:

- Heat distribution piping from sewage treatment to the University of Victoria point of use is sized on the heat available at the 2065 average day design flow of 17.2 ML/d. The rationale is that buried pipes should be sized for the 50-year available heat.
- Heat exchangers, heat pumps, water pumps and equalization storage are based on the existing available heat of 5,000 KW which in turn is based on the current sewage flow of 10 ML/d.
- As sewage flows increase to the projected 2030 flow of 16.6 ML/d, additional heat can be extracted from the treated effluent. The additional heat extraction equipment and the expansion of the storage tank would be done in a second phase in order to increase the available heat from 5,000 to 8,000 KW. The cost of the equipment to be installed in a second phase is not included.

12.2 Capital Cost

	Component	Option 1 – Ambient Temp. (up to 20 C)	Option 2 – Moderate Temp. (80 C)	Option 3 – Low Temp. (35 C)
1	Heat pumps at STP	-	$1,400,000	$350,000
2	Heat exchangers and water pumping system at STP	$880,000	$1,502,000	$1,154,000
3	Buildings at STP to house equipment (water pumps, etc, heat pumps, heat exchanger)	$423,000	$1,575,000	$1,170,000
4	Equalization storage	$665,000	$665,000	$665,000
5	Closed Loop Distribution piping L= 3200 m			
	Option 1 - 450 mm dia PVC pipe non-insulated	$2,354,000	-	-
	Option 2 - 350 mm welded steel insulated pipe c/w 50 mm insulation	-	$2,130,000	-
	Option 3 - 350 mm HDPE insulated pipe c/w 50 mm insulation	-	-	$2,032,000
6	Heat pumps at point of use	$1,400,000	-	$1,050,000
7	Building addition at point of use to house heat pumps	$1,386,000	-	$864,000
8	Pumping system at point of use (UVic)	$1,030,000	$220,000	$650,000
	Sub total - Items 1 to 11	$8,138,000	$7,492,000	$7,935,000
9	Design and construction contingencies (26%)	$2,115,900	$1,947,900	$2,063,000
	Sub total - Items 1 to 13	$10,253,900	$9,439,900	$9,998,000
10	Other cost; engineering, project management, financing, etc (28%)	$2,871,100	$2,643,100	$2,799,000
	TOTAL ESTIMATED COST	**$13,125,000**	**$12,083,000**	**$12,797,000**

12.3 Operations and Maintenance Cost

	Component	Option 1 – Ambient Temp. (up to 20 C)	Option 2 – Moderate Temp. (80 C)	Option 3 – Low Temp. (35 C)
1	Annual power cost based on $0.08/kwh	$892,780	$848,915	$880,100
2	Labour cost	$80,000	$80,000	$80,000
3	Equipment and buildings maintenance and repairs	$56,309	$51,667	$50,468
4	Distribution system and storage maintenance and repairs	$16,605	$15,373	$14,834
5	Vehicle allowance and miscellaneous	$10,000	$10,000	$10,000
	TOTAL ESTIMATED COST	**$1,055,694**	**$1,005,955**	**$1,035,402**

12.4 Projected Revenues

The following assumptions were made when estimating projected revenues from the sale of heat:

- In order to mitigate the low night time and early morning sewage flows, a storage tank will be provided to ensure the minimum heat supply is 5,000 KW.
- An incentive price of $10/GJ for the sale of heat generated by effluent.
- The average daily sewage flow will increase from 10 ML/d to 16.6 ML/d by 2030 thus allowing an

The projected annual revenues from the sale of heat are as follows:

	Option 1 – Ambient Temp. (up to 20 C)	Option 2 – Moderate Temp. (80 C)	Option 3 – Low Temp. (35 C)
Annual revenues based on 2009 available heat	$1,110,000	$1,021,200	$1,065,600
Annual revenues based on projected 2030 available heat	$1,840,000	$1,692,800	$1,766,400

Section 13 Triple Bottom Line Analysis for Heat Recovery

13.1 Carbon Footprint Analysis

A carbon footprint analysis was performed as a part of the evaluation of the environmental impacts of the three alternatives, Options 1, 2 and 3. A carbon footprint measures the amount of greenhouse gas (GHG) released or stored as a result of a process or activity. A detailed description of the carbon footprint analysis methodology can be found in the September 16, 2009 report by Stantec Consulting and Brown and Caldwell titled "*Core Area Wastewater Treatment Assessment of Wastewater Treatment Options 1A,1B and 1C.*"

The emission factors used to calculate the GHG emissions/savings associated with the heat recovery project as follows:

- Heat pumps and water pumps for district heating 0.000072 tonne/kWhr (electricity)
- Saleable heat for district heating offset 0.0503 tonne CO_2/GJ (based on natural gas)

In addition, there are one-time emissions associated with construction activities as follows:

- Concrete 0.272154 tonne CO_2/m^3
- Steel (re-bar, piping, equipment 0.0032 tonne CO_2/tonne product
- Excavation 0.000981 tonne CO_2/m^3

The estimated annual carbon footprint in tones of CO_2 associated with each heat recovery system option based on current available heat is summarized in Table 13.1. The value of carbon credit based on $25 and $50 per tonne of CO_2 is shown in Table 13.2.

Table 13.1 – Summary of GHG Emissions for Heat Recovery System Options (Tonnes of CO_2)

	Option 1 – Ambient Temp. (up to 20 C)	Option 2 – Moderate Temp. (80 C)	Option 3 – Low Temp. (35 C)
Power for heat pumps and conveyance (pumping)	803	792	792
Saleable heat for district heating	- 5584	- 5137	- 5360
Total annual emissions	- 4781	- 4345	- 4568

Table 13.2 - Value of Carbon Credit

	Option 1 – Ambient Temp. (up to 20 C)	Option 2 – Moderate Temp. (80 C)	Option 3 – Low Temp. (35 C)
Based on \$25/tonne of CO_2	\$119,525	\$108,625	\$114,200
Based on \$50/tonne of CO_2	\$239,050	\$217,250	\$228,400

13.2 Triple Bottom Line Methodology

This chapter outlines the triple bottom line analysis that was used to evaluate the four options for a reclaimed water system in the area surrounding the pro posed SENOB plant. A complete listing of impacts included in the model sorted by the three categories is provided in Table 13.3.

TABLE 13.3: Impacts Evaluated for Triple Bottom Line Analysis

Criteria Group	No.	Criteria Categories	Measure Description
Economic	EC-01	Capital Costs	Construction cost and markup for soft costs adjusted to midpoint of construction
	EC-02	Capital Costs Eligible for Grants	Not available at this time
	EC-03	Present Worth of Net O&M costs	O&M costs
	EC-04	Flexibility for Future Expansion of District Energy System	Cost of additional equalization storage needed to overcome low available heat at night.
Environmental	EN-01	Carbon Footprint	Tons of CO2 created and/or saved
	EN-02	Power (energy) usage	Cost of KWhr per year consumed by district energy system equipment
	EN-03	Heat losses in distribution system	Cost of energy losses in distribution system in MJ/d
	EN-04	Heat Transmission Reliability	Risk cost of equipment and distribution piping failure
	EN-05	Non-renewable resource use	Amount of diesel consumed per year
	EN-06	Terrestrial habitat impact	Restoration of forest habitat disturbed by storage construction
Social	SO-01	Construction Disruption	Cost of traffic inconvenience due to construction
	SO-02	Disruption on private property and customer acceptability	Construction cost on private properties
	SO-03	Loss of Beneficial Site Uses	Loss of park land due to storage tank construction
	SO-04	Cultural Resource Impacts	Risk cost of a cultural site find

13.2.1 Economic Factor

<u>EC-01 Capital Costs</u>

Capital costs measure the construction cost and soft costs for each option escalated to the midpoint of construction. Data input included the estimated construction cost and a 2011 midpoint of construction. Assumptions included an inflation rate of 3%. The scoring for capital costs was scaled based on the NPV of costs for all three options with an NPV of $12 million worth three points, higher NPVs worth fewer points, and lower NPVs worth more.

EC-02 Capital Costs Eligible for Grants

This impact was intended to measure the value of grants to offset construction costs but at this time, insufficient information is available to adequately account for this impact.

EC-03 Present Worth O&M Costs

Present worth included annual expenditures for operations and maintenance (O&M), and for replacement and refurbishment (R&R) projects. Data input included annual O&M and R&R costs. Assumptions included a 3% rate of inflation for each annual cost. The scoring was scaled based on the annual costs with an annual cost of $1 million worth 3 points, a higher annual cost worth fewer points, and lower annual costs worth more.

EC-04 Flexibility for Future Expansion

This impact was intended to measure the flexibility for each option to allow for expansion of the heat recovery system. To measure this, the cost of providing additional building space and the number of buildings to be expanded in order increase the supply of heat available at the 2030 flow rate of 16.6 ML/d was estimated.

EC-04 Scoring	
1	More than $2.5 million
2	$2 to 2.5 million
3	$1.5 to 2 million
4	$1 to 1.5 million
5	Less than $1 million

13.2.2 Environmental Factors

EN-01 Carbon Footprint

The details of the carbon footprint calculation are presented in Section 13.1. Scoring was based on the annual value of offsets for equivalent tonnes of carbon dioxide emitted (assuming $25 per tonne) using the following scale.

EN-01 Scoring:	
1	Less than -$3 million
2	-$3.5 million to -$4 million
3	-$3.5 million to -$4 million
4	-$4 million to -$4.5 million
5	More than -$4.5 million

EN-02 Power (energy) Use

This impact compares the electrical energy usage for each option. Data input included annual power consumption and a $0.08/kW-hr cost of power. Assumptions included a 3% rate of inflation for power costs. The NPV for electrical costs was calculated for each option and then scaled as follows:

EN-02 Scoring:	
1	More than $1.25 million
2	$1 to $1.25 million
3	$0.75 to $1 million
4	$0.5 to $0.75 million
5	Less than $0.5 million

EN-03 Heat Losses in Distribution Piping

Some of the heat extracted from the effluent will be lost in the transmission lines between the heat exchange at the sewage treatment and the point of use. The NPV of the loss in revenues resulting from heat losses was estimated. The following1 to 5 score was used.

EN-03 Scoring:	
1	More than $1.5 million
2	$1 to $1.5 million
3	$0.5 to $1 million
4	Less than $0.5 million
5	No loss

EN-04 System Reliability

This impact measures the relative risk carried for each option in terms of system complexity. The number of water pumps and heat pumps required varies for each option. The complexity of each option was compared by multiplying the of number water pumps by the number of heat pumps. A $15,000 risk cost per unit was assumed. The following 1 to 5 score scaled was used.

EN-04 Scoring:	
1	More than $100,000
2	$75,000 to $100,000
3	$50,000 to $75,000
4	$25,000 to $50,000
5	Less than $25,000

EN-05 Non-Renewable Resource Use

This impact measured diesel fuel consumption during construction and operations. Diesel consumption during construction was assumed to be 2% of construction costs and diesel consumption during operations was assumed to be 2% of O&M costs. Therefore, data inputted was construction costs and O&M costs. A 3% inflation rate was assumed and a NPV was calculated for each option. The options were scored using the scale below.

EN-05 Scoring:	
1	More than $1.75 million
2	$1.5 to $1.75 million
3	$1.25 to $1.5 million
4	$1 to $1.25 million
5	Less than $1 million

EN-6 Non-Renewable Resource Generated

Non-renewable resource generated measured the available heat to sell for each option after taking account the heat lost in the transmission. The sale price for heat was assumed at $10 per GJ. The NPV based on annual revenue for each option was calculated and scores were given based on the following scale.

EN-6 Scoring:	
1	Less than $5 million
2	$5 to $15 million
3	$15 to $25 million
4	$25 to $35 million
5	More than $35 million

EN-07 Terrestrial Habitat Impacts

This measure was intended to measure the impact the equalization reservoir would have on existing terrestrial habitats assuming that the plant is constructed in the forested area of Haro Woods. The area required for the storage tanks was calculated and relative 1 to 5 score was given based on the potential mitigation cost for the area impacted, assuming that a 15 m strip around the reservoir would have to be replanted with trees. The following scale was used.

EN-07 Scoring:	
1	More than $25,000
2	$20,000 to $25,000
3	$15,000 to $20,000
4	$10,000 to $15,000
5	Less than $10,000

13.2.3 Social Impacts

SO-01 Construction Disruption

Traffic during construction can be particularly noisome to neighboring residents and businesses. To measure this disruption, the volume of traffic potentially impacted by the district energy system construction was estimated by using traffic counts at nearby intersections for each site. These traffic counts came from CRD's 2005 evaluations. The number of construction trips was calculated by estimating one construction trip per day for every $2,500 of construction budget. The traffic count was multiplied by the daily construction traffic at each site and a plant construction disruption cost was calculated assuming a $1 cost per trip delayed, a 1% probability of delay due to construction and a 12 month construction period.

SO-01 Scoring:	
1	More than $500,000
2	$375,000 to $500,000
3	$250,000 to $375,000
4	$125,000 to $250,000
5	Less than $125,000

SO-02 - Disruption on Private Property and Customer Acceptability

In order to connect to the heat recovery system, equipment and piping may be required at the site of each potential customer. Depending on the option for the distribution system, the equipment at each point of use could include heat exchangers and heat pumps. In many cases, the existing mechanical rooms have to be expanded to allow construction of this work adding to the cost of the system. The cost of this one-time expense of work on the property of the University of Victoria was estimated and a qualitative 1 to 5 score was given as shown below.

SO-02 Scoring:	
1	More than $4 million
2	$3 to $4 million
3	$2 to $3 million
4	$1 to $2 million
5	Less than $1 million

SO-03 Loss of Beneficial Site Use

The construction of buildings on private property to accommodate heat pumps and other equipment may preclude the use of the site for other types of use. To measure this impact, the space lost due to building footprint was estimated and an assumption of a $1,000,000 per hectare incremental value for using the site for heat recovery instead of a treatment facility was assumed. The scale used to compare options is presented below.

SO-03 Scoring:	
1	More than $200,000
2	$150,000 to $200,000
3	$100,000 to $150,000
4	$50,000 to $100,000
5	Less than $50,000

SO-04 Cultural Resource Impacts

A cultural resource find would cause additional cost and delay to site construction. The probability of a cultural find for each site and the resulting delay was estimated along with the estimated construction cost. An assumed 3% inflation rate was used to quantify the delay cost of a cultural find. By multiplying the delay cost by the probability of a find, the risk cost of a cultural find was calculated for each option and compared using the following scale.

SO-04 Scoring:	
1	More than $60,000
2	$45,000 to $60,000
3	$30,000 to $45,000
4	$15,000 to $30,000
5	Less than $15,000

13.3 Results

The results of the triple bottom line analysis is summarized in Table 13.4 and shown graphically in Figure 13.1. The discussion of the results can be found in Section 14.

Figure 13.1 – Triple Bottom Line Analysis for a Heat Recovery System at the University of Victoria

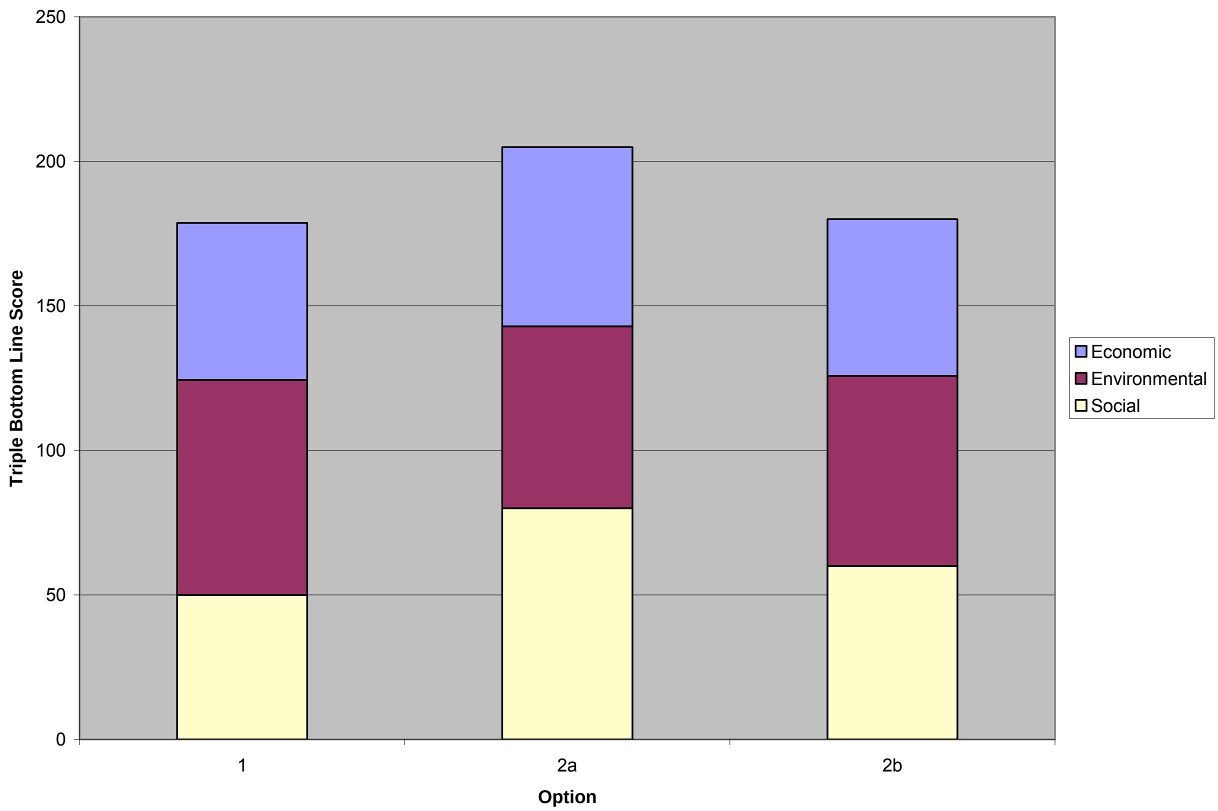


Table 13.1 **Triple Bottom Line Analysis for Heat Extraction**

Criteria Group	No.	Criteria Categories	Measure Description	Weight	Option Results 1	Option Results 2a	Option Results 2b
Economic	**EC-01**	Capital Costs	Construction cost and markup for soft costs adjusted to midpoint of construction	9	2.8	3.0	2.9
	EC-02	Capital Costs Eligible for Grants	Not available at this time	-			
	EC-03	Present Worth of O&M costs	O&M costs	9	2.8	3.0	2.9
	EC-04	Flexibility for Future Expansion	Cost and number of additional buildings to accommodate future equipment	2	2	4	1
			Economic Subtotal (100 pts max)[1]:		**54**	**62**	**54**
Environmental	**EN-01**	Carbon Footprint	Tons of eCO2 created/saved	2.86	3	2	3
	EN-02	Power (energy) usage	Heat energy replacing natural gas	2.86	3	3	3
	EN-03	Heat loss in distribution piping	Loss of revenues	2.86	5	3	4
	EN-04	System Reliability	Number of water pumps and heat pumps	2.86	4	3	3
	EN-05	Non-renewable Resource Use	Gallons of diesel consumed per year	2.86	4	4	3
	EN-06	Non-renewable Resource Generated	Net sale of heat	2.86	3	3	3
	EN-07	Terrestrial and Inter-tidal Effect	Habitat areas potentially disturbed	2.86	4	4	4
			Environmental Subtotal (100 pts max):		**74**	**63**	**66**
Social	**SO-01**	Operations Traffic in Sensitive Areas	Cost of traffic inconvenience during operations	5	3	3	3
	SO-02	Disruption on Private Property and Customer Acceptability	Construction cost of work on private property	5	1	5	2
	SO-03	Loss of Beneficial Site Uses	Cost of area required on private property for heat pumps and building	5	2	5	4
	SO-04	Cultural Resource Impacts	Risk cost of a cultural site find	5	4	3	3
			Social Subtotal (100 pts max):		**50**	**80**	**60**
			TOTAL SCORE (300 pts max):		**179**	**205**	**180**

Section 14 Analysis of Results and Conclusions

14.1 Market Considerations

For the Saanich East / North Oak Bay WWTP, there is principally a single customer; the University of Victoria, so technical requirements and the design will be guided by the University's DHS requirements. More than 80% of the demand in this area comes from the 4 boiler plants of the University. The remaining 20% is scattered principally amongst smaller schools and recreation centers that range in distance from the district heat conveyance line from 0.5 km to 4 km away.

Temperature, capacity and reliability are important issues from all customers. The potential customers have stated, with respect to reliability and connect-ability of a district energy system that: "…making the ability to connect to the system as attractive as possible for the end users is of utmost importance".

This is true for the University as our surveys and meetings have indicated they have concerns about compatibility with their DHS which currently operates at a 230 ºF supply temperature which is much higher than what can be provided by conventional heat pumps (176F).

The three options that were analyzed for extracting and conveying the heat from the treated effluent to the University of Victoria vary based on the temperature of the water that is conveyed to the point of use:

- Option 1 will provide low grade heat at ambient temperature of 10^0C to 20^0C. This requires that heat pumps be installed at the University.
- Option 2 will provide heat at moderate temperature of 80^0C. This is a readily usable product that does not require heat pumps at the customer's locations.
- Option 3 will provide heat at a lower temperature of 35^0C. This will also require heat pumps be installed at the University.

The central boiler system for the University operates at temperatures of 105^0C to 115^0C (220^0F to 240^0F) and the suitability of the product to be sold to the customer increases with its heat content. From the customer's point of view, Option 2 would be the preferred option. Since the supply temperature of Option 2 is lower than the current boiler operating temperature and because the supply of heat from effluent will not meet the entire demand, it is proposed to supply heat only to a portion of the campus and to supplement the heat provided from the effluent with the existing boilers.

14.2 Triple Bottom Line Assessment

The difference in capital and in O&M costs between the three options under consideration is not significant. The capital cost Options 2 is lower mainly because of the economies of scale resulting from having all equipment and the heat pumps at one location. Another factor is the lower cost of the transmission line from the sewage treatment plant to the campus since hotter water requires a smaller pipe and the added cost of insulation does not offer the larger pipe size

However, Option 2 has a lower environmental score because of the heat losses in the transmission main. These heat loss estimated at 4% will result is a corresponding reduction in the amount of saleable heat and a higher energy consumption. The main drawback of Options 1 and 3 is the need to construct a new building on campus in order to house the heat pumps and other equipment at the point of use. The need to construct facilities on private property could result in significant disruption as well as the loss of land. This could also affect the marketability of the heat recovery system.

14.3 Conclusions

The design of the existing central heating plant at the University of Victoria limits the amount of heat that can be feasibly extracted for beneficial reuse. Connecting to the main boiler plant (No. 4 boiler room) is not possible because the existing boiler system operates temperatures that are higher that can be provided by a district energy system using heat extracted from treated effluent. As an alternative to connecting to the main boiler plant, the buildings served by the boiler No.2 plant can be considered for effluent heat reclamation. Also is would be possible to meet the domestic hot water demand for the entire campus during the summer months when space heating is not required. There is however considerable cost associated with the implementation of such a system. There are several reasons why the costs are so high:

- The heated water must be pumped in separate pipelines over a 30 m difference in elevation between the site of the proposed WWTP plant on Arbutus Road and the campus.

- The heat extracted from the effluent is low grade heat which has a temperature of 12 C. Following heat exchange between the effluent and clean water, the water temperature has to be boosted twice with heat pumps in order to achiever the minimum useful temperature of 80 C. The power consumption of the heat pumps is significant and this increases operating costs substantially;

- Even at 80 C, this is lower than the operating temperature the campus district heating system which is in the range of 105-115C. As a result, the use of extracted heat is limited to supplying domestic hot water in summer and space heating in the shoulder seasons. During the colder winter months, boilers will have to be fired up in order to meet the demand for space heating;

- The peak demand for heat occurs early in the morning and this corresponds to the lowest flow rate of the day. In order to supplement the low available heat, equalization storage is proposed since the life expectancy of boilers will be severely reduced by frequent stop and start cycles. (Boilers are designed to stay on for extended periods of times and not daily off-on cycles);

- Even with equalization storage, the amount of available heat from treated effluent represents only 25% of the morning peak demand for the campus based on existing sewage flows of 10 ML/d, and

- The existing sewage flow at the proposed SENOB plant averages 10 ML/d. This is significantly lower than the 2030 design flow of 16.6 ML/d. The amount of available heat is proportionally reduced.

The capital costs for the recovery of heat at the proposed SENOB wastewater treatment plant for reuse on the campus of the University of Victoria are significant and are summarized as follows:

- Option 1 – Ambient temperature system $13,125,000
- Option 2 – Moderate temperature system (80C) $12,083,000
- Option 3 – Low temperature system (35C) $12,797,000

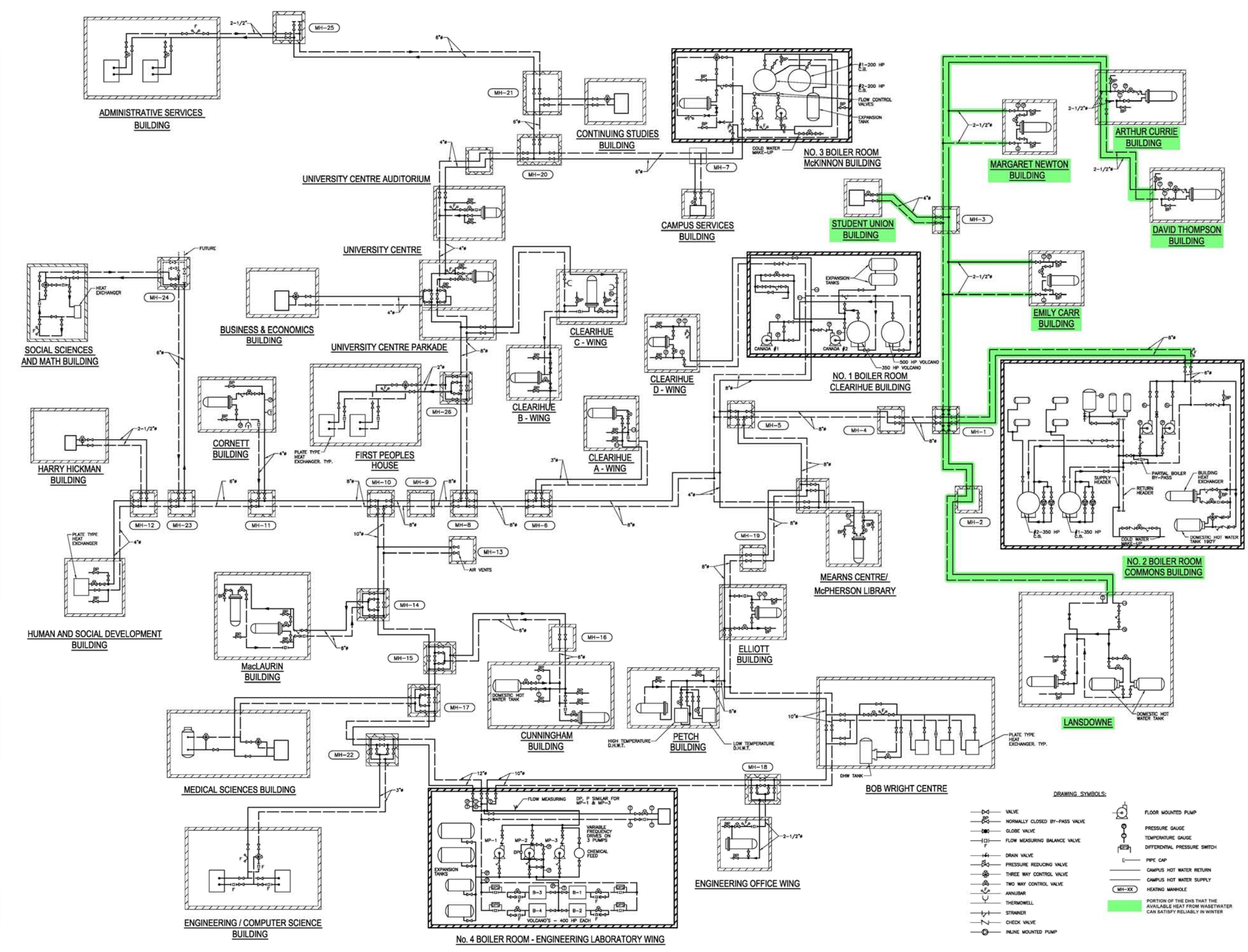
Based on the Triple Bottom Line analysis, Option 2 would be the preferred option for a heat extraction and supply system. On the basis of Option 2, the operating and maintenance costs and the revenues generated by the recovery of heat are summarized in a follows:

- Operating and maintenance cost $1,006,000
- Revenues $1,021,000
- Net operating revenues $15,000
- Value of carbon credit based on $25/tonne of CO_2 $108,000
- Value of carbon credit based on $50/tonne of CO_2 $217,000

The carbon credit associated with the use of heat extracted from sewage has a value of $108,000 per year based on $25 per tonne of CO_2 and $217,000 if the value of carbon doubles to $50/tonne.

The proposed SENOB plant should be designed in such a manner that the footprint and piping connections required for the infrastructure needed for resource recovery are provided. This would allow the implementation of resource recovery either now or in the future. Heat recovery for the new buildings at the SENOB WWTP could be considered as it is likely this system could be implemented economically.

Implementing a heat extraction system for the University of Victoria would be as a result of a policy decision since the economic analysis of heat extraction has indicated the payback period is beyond the life expectancy of the equipment.



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PROJECT

UNIVERSITY OF VICTORIA CAMPUS HEATING REPORT

Victoria
British Columbia

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