CVRD

Saltair Water Treatment Plant Pre-design

Technical Memo #1

Water Treatment Options Study

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Executive Summary

This technical memorandum (TM) No. 1 presents 1) potential drinking water treatment technologies to treat Saltair's supply water from Stocking Lake, and 2) the preliminary design criteria for the new water treatment plant (WTP). The Stocking Lake supply water is historically high in organics, which is a precursor to the formation of chlorination disinfection by-products in the distribution system. Water quality data taken from the distribution system has historically indicated an increasing level of two disinfection by-products, total trihalomethanes (TTHM's) and haloacetic acids (HAAs), over the last four years. In Health Canada's Guidelines for Canadian Drinking Water Quality (GCDWQ), TTHM and HAA guidelines have been set at 0.1 mg/L and 0.08 mg/L, respectively.

A pilot study was previously conducted on the Stocking Lake source water by the Town of Ladysmith. The pilot study indicated that conventional water treatment could remove up to 37% of the organics present in the source water. However, we recommend investigating the potential for a greater removal of organics in order to provide more flexibility to handle deterioration in the source water. As conventional technologies were previously studied, three innovative technologies were considered in this TM: ceramic ultrafiltration membrane (CUF), hollow fibre nanofiltration (HFNF) and integrated treatment of biological and reverse osmosis (Integrated).

Treatment goals

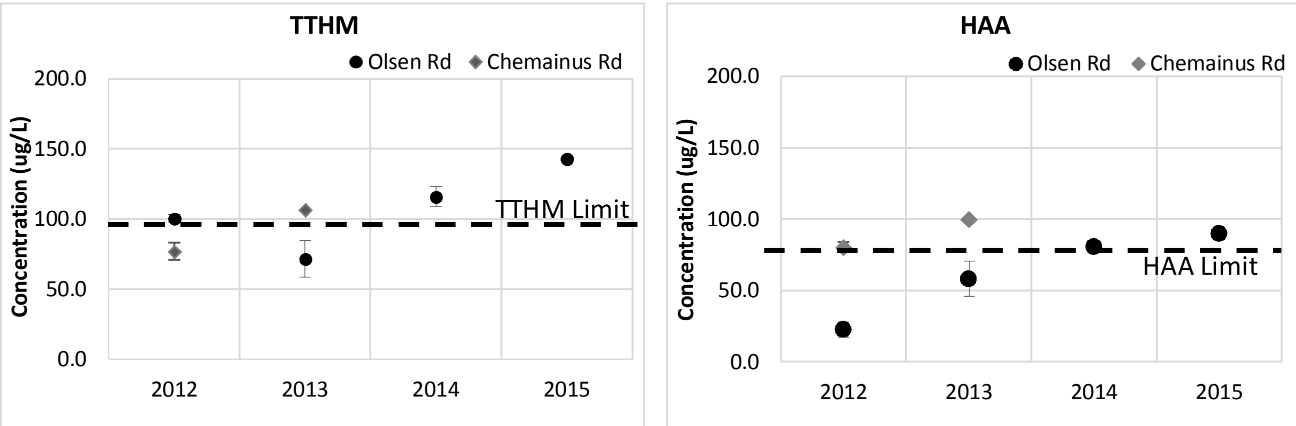
Section 2 of this TM provides a discussion on regulatory requirements and treatment goals. Under the Drinking Water Protection Regulation (DWPR), the Cowichan Valley Regional District (CVRD) must provide potable drinking water that is safe from disease-causing microorganisms, such as viruses, protozoa and bacteria. The Act and Regulation on Vancouver Island are administered by Vancouver Island Health Authority (VIHA) through their mandated "4-3-2-1-0 Drinking Water Treatment for Surface Water Policy". The policy includes the following treatment objectives:

- 4-log (99.99%) reduction or inactivation in viruses. This is normally achieved through the addition of chlorine disinfection with the provision of chlorine contact time.
- 3-log (99.9%) reduction or inactivation in protozoa. Treatment for Giardia and Cryptosporidium is typically through filtration, or UV disinfection, or both. Some inactivation or reduction in Giardia can be achieved through chlorination providing there is sufficient contact time, though this does not apply for Cryptosporidium.
- 2 treatment processes for surface water. A single treatment process may be effective against some microorganisms, but not against others. Combining more than one process for treatment allows for a multi-barrier protection approach against a range of microorganisms.
- 1 NTU turbidity or less. Well-established filtration technologies can consistently reduce turbidity in the water from less than 0.1 to 1 NTU.
- No detectable E. coli, fecal coliforms, and total coliforms. This is typically achieved through disinfection (such as chlorination and/or UV disinfection) or a combination of disinfection and filtration.

All three considered treatment processes would need to maintain the current use of chlorination to provide a multi-barrier approach, virus treatment credits, and secondary disinfection in the distribution system.

Historical Water Quality

Section 3 of this TM provides a discussion on Saltair's source water quality from Stocking Lake. Stocking Lake water typically experiences turbidity <1 NTU and would therefore meet the unfiltered turbidity criteria for water supplies. However, the water has relatively high levels of organics that is causing elevated TTHM and HAA concentrations in distribution system. The concentrations of these disinfection by-products have exceeded the GCDWQ limits of 0.1 mg/L and 0.080 mg/L for TTHM's and HAA's, respectively, in the last 2 years. The trends appear to be increasing since 2012 (Figure ES-1).



a. b.

Figure ES- 1 Historic TTHM and HAA concentrations measured in the distribution system: a) TTHM, b) HAA

System Demands and Flows

Section 4 of this TM reviews the historic population data and provides projections of future water demands. A population growth rate of 1.0% was adopted to project the limited population growth anticipated in Saltair. The future water demand was estimated using the current maximum per capita water consumption rate of 662 lpcd and the future projected population. Based on this, the 20-year projected maximum daily demand (MDD) for Saltair is 22 L/s. This estimate will be used as the design flowrate for the new water treatment plant. Table ES- 1 summarizes the projected 20-year population and water demands for Saltair.

Table ES- 1 Projected Maximum Daily Demand

Year	Population	L/s	m³/day
2016	2,334	18	1,552
2026	2,453	19	1,714
2031	2,710	21	1,802
2036	2,848	22	1,894

Treatment Comparison

Section 5 of this TM provides a discussion on three innovative treatment technologies considered for treating Saltair's water. Table ES- summarizes the process description of the three considered treatment technologies.

Table ES- 2 Innovative Treatment Technologies

Treatment Barrier	Description
Ceramic Ultrafiltration (CUF)	Raw water is pre-screened to remove any coarse particles. Following the screening, coagulant is added at the inlet to the high solids contact reactor (HSCR), where rapid mixing is used for an efficient coagulation process. Coagulation is required for the removal of organics and improved turbidity reduction. From the HSCR tank, water is pumped into the membrane module in a cross flow arrangement. A percentage of unfiltered water remaining in the membrane module is circulated back to the HSCR and produces high concentrate solids, which will then dewatered to a 3% to 10% solids sludge using a de-watering system. Waste volume is anticipated to be 0.3 % of the overall process volume. As such, the produced sludge can be locally stored for off-site disposal by vacuum truck. Therefore, overall treatment efficiency is expected to exceed 99.7%.
Hollow Fibre Nanofiltration (HFNF)	Raw water is pre-screened to remove any coarse particles. Screened water is pumped to the NF fibers in a cross flow arrangement. A small reject stream is continuously wasted from the membrane system as a measure to control solids concentration and optimize permeate quality. This stream is typically ~20% of the WTP flow. The membranes are maintained by frequent backwashing where treated water is applied to the membrane in the reverse filtration direction to dislodge any retained particles from the membrane pores. Backwash flow accounts for ~5% of the total treatment flow and would be free of chemicals.
Integrated Biological and Reverse Osmosis (Integrated)	Raw water is pre-screened to remove any coarse particles. This treatment process then consists of two stages. In the first stage, water flows through a series of biofilters. Bacteria growth is promoted in these filters and the bacteria effectively consume assimilable organic carbon (AOC) and capture colloidal solids. In the second stage, water is pumped through a series of spiral

Treatment Barrier	Description
	wound, reverse osmosis (RO) membranes for the removal of any remaining organic and inorganic contaminants. The treated water is biologically stable water that is free of dissolved organic carbon (DOC) and minerals. pH adjustment is recommended at the end of treatment to reduce the corrosion potential. UV disinfection would be required to meet the 3-log inactivation target for protozoa.

Each of the above treatment processes will be followed chlorine disinfection system to provide 4-log reduction in viruses and to maintain a chlorine residual in the distribution system. As noted above, the Integrated Biological and Reverse Osmosis treatment option will also require UV to provide the 3-log inactivation target for protozoa.

Lifecycle Cost Analysis

In Section 8, a lifecycle cost analysis was performed to provide a comparative life cycle costs for the three technologies introduced in this TM and the DAF/UF option from the previous study. The life cycle analysis was for a 20-year lifespan on the WTP using a 7% interest rate factor. Table 8-1 and Figure 8-1 show comparative results of the life cycle costs analysis.

Table ES- 3 Total Lifecycle Cost Comparison

	Dissolved Air Flotation & Ultrafiltration (DAF + UF)	Ceramic Ultrafiltration (CUF)	Hollow Fibre Nanofiltration (HFNF)	Integrated Biological & Reverse Osmosis (Integrated)
Capital Cost	$6,850,000	$4,600,000	$5,600,000	$5,650,000
20-yr Present Worth	$2,743,846	$1,779,792	$2,012,860	$1,938,702
Total Lifecycle Cost	**$9,593,846**	**$6,379,792**	**$7,612,860**	**$7,588,702**

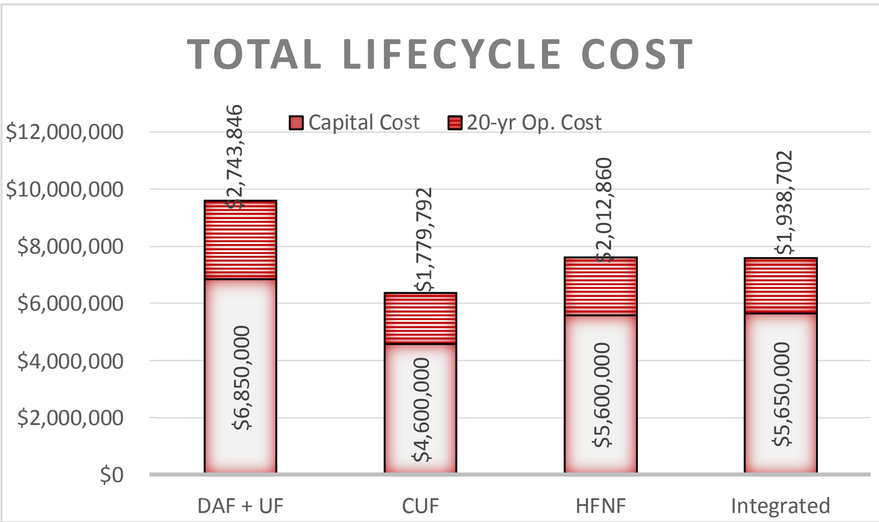


Figure ES- 2 Summary of Comparative Total Lifecycle Costs

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1 Introduction and Project Background

1.1 Project Description

Saltair is located within the Cowichan Valley Regional District (CVRD) on the east coast of Vancouver Island, bordered by Chemainus on the South and Ladysmith on the North. Saltair's sole water supply is Stocking Lake. Water from Stocking Lake flows by gravity to an existing pressure reducing (PRV) station and is disinfected using ultraviolet (UV) light and chlorine. Stocking Lake water generally meets the unfiltered criteria for turbidity for water supplies; however, historical data indicates high organics content in the water and high concentrations of disinfection-by-products in the distribution system.

The Cowichan Valley Regional District (CVRD) was directed by the regulatory authority, Vancouver Island Health Authority (VIHA), to upgrade Saltair's water treatment system to comply with B.C.'s Drinking Water Protection Act (DWPA) and Drinking Water Protection Regulation (DWPR). A multi-barrier treatment approach is recommended to meet VIHA's requirements for the treatment of a surface water source. Opus is assisting the CVRD with the selection and conceptual design for the water treatment upgrade.

Two technical memorandums (TM) are included in Opus's project scope, to separately discuss 1) potential treatment technologies and 2) options to generate and supply power to the treatment plant. This TM No. 1 considers various treatment technologies for Saltair's water supply. Past studies on the treatability of source water were re-assessed and considered in the creation of this TM.

1.2 Project Context and Previous Work

VIHA has directed that the newly upgraded water treatment system be in place by January 31, 2018. The CVRD requested Genivar (2010) to assess suitable technologies to treat Stocking Lake water. The Town of Ladysmith also uses the Stocking Lake supply, and retained Associated Engineering (2015) to also assess suitable technologies to treat this water.

Stocking Lake water quality is generally considered to be of good quality and meets the unfiltered criteria for water supplies for turbidity, with turbidity typically less than 1 NTU. However, high organics content were measured in the raw water, resulting in the downstream formation of disinfection by-products. Both Genivar and Associated Engineering reviewed the challenges in removing organic matter in the raw water through conventional technologies, such as sedimentation, dissolved air flotation (DAF), direct filtration, and ultrafiltration (UF) membranes. Additionally, challenges in footprint requirements and disposal of treatment residuals were also noted in both studies. The following sections summarize the main findings in the two studies.

1.2.1 Genivar Study (2010)

Genivar assessed four different treatment technologies. The treatment technologies considered were: 1) pressure filtration, 2) UF membrane filtration, 3) dissolved air flotation (DAF), and 4) granular activated carbon (GAC). The following paragraphs summarize the descriptions of the different processes considered by Genivar.

Pressure filters use granular media beds to capture and retain particulates in the water. Filter media such as sand, anthracite coal, or dual media of anthracite coal over sand are typical in pressure filter operations. A water treatment coagulant and/or polymer pre-treatment step is often used to enhance the removal of contaminants in the water during filtration. Aluminium sulphate (alum) is an example of a common coagulant used in water treatment. Power consumption is low to moderate, depending on the filter media and the existing head pressure.

UF membrane filtration is a very effective method of removing turbidity from the water. UF works by forcing raw water through a porous tube and physically straining out the contaminants. Due to its relatively high filtration rates and the absence of clarification as a pre-treatment, membrane treatment generally requires a smaller footprint when comparing filtration technologies for turbidity. However, power requirements are typically higher due to the complexity of the process pumps in the system.

DAF followed by mixed media filtration is generally an effective method for treating organics and colour in the water. The process consists of a 3-stage process that includes coagulation/flocculation, followed by a DAF clarification step, and then a filtration step. Following coagulation and flocculation, dissolved air is injected into the flocculated water. Air bubbles attach to the flocs and float the floc particles to the surface. The float is then mechanically skimmed off for disposal in a clarification step. The clarified water is then typically filtered through a mixed media filter. Power requirements for DAF are also high due to the multiple process stages in the system.

GAC treatment is achieved by passing water through a filter bed containing carbon granules. Organic contaminants are adsorped onto the carbon as water passes through it. The efficiency of the treatment is directly proportional to the total volume of carbon present, therefore there is often significant annual media replacement cost. However, power requirements for GAC is comparable to direct filtration.

Genivar concluded that the high capital and annual costs of the above treatment options could not be justified by the achievable improvement in water quality.

1.2.2 Associated Engineering (2015)

Associated Engineering conducted a water treatability study on the multiple water sources for the Town of Ladysmith, including Stocking Lake. The study included both bench-scale tests and pilot tests of the following treatment options:

- Option 1: Coagulation/ flocculation + Sedimentation (ST) + dual media filtration
- Option 2: Coagulation/flocculation + DAF + dual media filtration
- Option 3: Coagulation/flocculation + DAF + UF membranes
- Option 4: Coagulation/flocculation + UF membranes

The study found that Options 1 and 2 above could not satisfy the treatment objectives for organics and colour removal and would not provide reliable protection against protozoa. Options 3 and 4 were able to meet the treatment objectives, and based on the overall organics removal and ease of operation, Option 3 - the DAF and UF membranes combination was recommended. The treated water from DAF and UF membranes system would not require further disinfection beyond chlorination.

The study found that the optimum operational condition for DAF followed by UF was with the addition of 15 mg/L of Poly-Aluminum Chlorides (PACl) and 60 mg/L of soda ash. The pilot study was conducted by GE using these chemical dosages, reduced turbidity to 0.004 NTU, true colour to 5 TCU, total organic carbon (TOC) to 1.1 mg/L and improved UV transmittance to 97%. However, the study also found that the combination of organic material in raw water and coagulants contributed to accelerated fouling rates in the membranes.

Note that although treated true colour value met the *Guidelines for Canadian Drinking Water Quality* (GCDWQ), the overall percent removal of organics was only 37%. If there were to be a deterioration in the raw water quality, disinfection-by-products formation may again become an issue.

The estimated capital cost for a DAF and UF treatment with a design capacity of 125 L/s was $13,300,000. Operating costs were estimated at an average operating flow of 50 L/s and presented in Table 1-1.

Table 1-1 Annual Operating Cost Estimated with Average Flow of 50 L/s

Item	Operating Cost ($/year)
Chemical	$165,000
Power	$27,000
Labour	$100,000
Maintenance and Part Replacement	$51,000
Total	**$343,000**

References

Associated Engineering. (2015). *Town of Ladysmith: Arbutus Water Treatment Plant Phase 2 Pilot-scale Treatability Study*. Vancouver: Associated Engineering.

Cowichan Valley Regional District. (2016, April). Request for Proposal for the Provision of Review of the Saltair Water Source Treatment and Preliminary Design, Including Cost Estimate. *Request for Proposal No. ES-004-16* . Duncan, BC, Canada: Cowichan Valley Regional District.

Genivar. (2010). *Saltair Surface Water Treatment Study*. Duncan: Genivar.

2 Treatment Goals

2.1 VIHA Requirements

British Columbia regulates municipal drinking water quality through its Drinking Water Protection Act (DWPA) and Drinking Water Protection Regulation (DWPR). The Act and Regulation on Vancouver Island are administered by VIHA who mandated that the "4-3-2-1-0" treatment objective for surface water supplies be applied to Stocking Lake. The 4-3-2-1-0 treatment objective includes the following treatment goals:

- 4-log (99.99%) reduction or inactivation in viruses. This is normally achieved through the addition of chlorine disinfection with the provision of chlorine contact time.
- 3-log (99.9%) reduction or inactivation in protozoa. Treatment for Giardia and Cryptosporidium is typically through filtration, or UV disinfection, or both. Some reduction in Giardia can be achieved through chlorination provided there is sufficient contact time, though this does not apply for Cryptosporidium.
- 2 treatment processes for surface water. A single treatment process may be effective against some microorganisms, but not against others. Combining more than one process for treatment allows for a multi-barrier protection approach against a range of microorganisms.
- 1 NTU turbidity or less. Well established filtration technologies can consistently reduce turbidity in the water to <0.1 to 1 NTU.
- No detectable E. coli, fecal coliforms, and total coliforms. This is typically achieved through disinfection (such as chlorination and/or UV disinfection) or a combination of disinfection and filtration.

In addition to the 4-3-2-1-0 approach, the treatment system must also address the high concentrations of disinfection by-products in the treated water, which are related to the high organics concentration in the source water.

2.2 Canadian Drinking Water Standards

Health Canada's Guidelines for Canadian Drinking Water Quality (GCDWQ) provides guideline limits on microbial, chemical, physical, radiological substances in drinking water. In the GCDWQ, health-based limits on a substance are assigned a Maximum Acceptable Concentration (MAC). The GCDWQ also assigns an Aesthetic Objective (AO) to substances that do not cause risk to human health, but will influence consumer acceptance of the water based on factors such as taste, odour and colour. Table 3-1 summarizes the maximum acceptable concentration (MAC) and aesthetic objective (AO) values from GCDWQ that are used as treatment goals in this study. These are consistent with United States Environmental Protection Agency (USEPA) requirements and industry best practice.

Table 2-1: KeyTreatment Objectives

Parameter	MAC	AO
TDS (mg/L)	-	≤ 500
True Colour (TCU)	-	≤ 15
Turbidity (NTU)[1]	1.0/0.3/0.1	-
pH	-	6.5-8.5
Virus Inactivation	>99.99% (4-log)	-
Protozoa Inactivation	>99.9% (3-log)	-

1 Treated water turbidity objective depends on the type of filtration, and is selected based on the expected performance of the filtration technology.

3 Raw Water Source

3.1 Stocking Lake

Stocking Lake is the sole water supply source of Saltair's water system. However, the Stocking Lake watershed is relatively small, encompassing approximately 1.65 km2 of land area. The CVRD, the Town of Ladysmith, TimberWest and the Crown own the lands adjacent to Stocking Lake.

Stocking Lake outflows to Stocking Creek prior to discharging to Stuart Channel. The intake for the source water is a 300 mm DI pipe located at El. 345.2 m at Stocking Lake. The withdrawal licence for Saltair is 925,000 m^3/yr. At the metering hut, raw water is screened through a 5 mm screen and split to two 250 mm PVC pipes to supply Saltair and the Town of Ladysmith. Raw water flows by gravity into a series of three 150-mm pressure reducing valves (PRVs) which reduce the pressure from 2200 kPa to 345 kPa. Raw water is currently disinfected using chlorination and ultraviolet (UV) disinfection. Chlorination is by the injection of 12% sodium hypochlorite. The treated water is stored in an adjacent 750 m3 bolted steel reservoir.

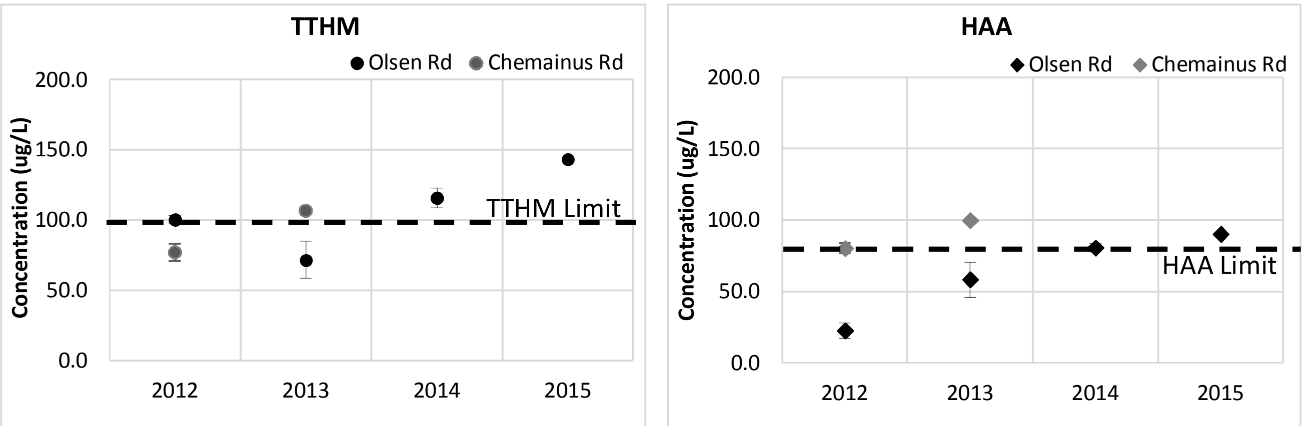
3.2 Water Quality

The CVRD has a sampling program that tests for an extensive list of water quality parameters in the source and the distribution system. The program alternates between testing at the source and in the distribution system on an annual basis. THMs and HAAs (chlorine disinfection by-products or DBP's) are tested on a quarterly basis at Olsen Road and Chemainus Road. A weekly bacteriological sampling program for E. coli and total coliforms occurs at eight dedicated sampling ports throughout the distribution system. The results are submitted to BC's Ministry of Health and available on their website.

The water quality at the Stocking Lake intake chamber is generally good and meets the unfiltered criteria for water supplies for turbidity. There are occasional complaints regarding the taste and odour of domestic water in the Saltair area. TTHM and HAA results have also shown increasing trends in concentration that exceed their respective maximum allowable concentrations (MAC) of 100 µg/L and 80 µg/L (Figure 3-1). Key water quality parameters from the 2012-2015 water sampling program are summarized in Table 3-1.

Table 3-1 Saltair 2012-2015 annual water quality sampling data

Parameter	No. of Samples	Min.	Average	Max.
Intake Chamber				
Turbidity (NTU)	2	0.68	0.74	0.8
pH	2	7	7	7
UV Transmissivity (%)	2	86	87.55	89.1
Total Organic Carbon, mg/L	2	2.89	4.04	5.19
True Colour (TCu)	2	6	6.07	6.13
Tannins & Lignins (mg/L)	2	0.29	0.357	0.424
Parameter	**No. of Samples**	**Min.**	**Average**	**Max.**
Distribution System				
Total Coliform (CFU/100 ml)	22	<1	370	1600
Faecal Coliform (CFU/100 ml)	22	<1	1.86	13
Total Trihalomethanes (mg/L)	68	31.7	105.1	144.5
Haloacetic Acids (mg/L)	108	2.1	55.1	92.2



a. b.

Figure 3-1 Historic TTHM and HAA concentrations measured in the distribution system: a) TTHM, b) HAA

The small number of data samples (2 sample sets) provide a limited representation of the water quality at the intake chamber. However, the elevated presence of TTHM's and HAA's in the distribution system suggests the contribution of organic content in DBP formation. Both TTHM's and HAA's are known carcinogens and have concentrations exceeding the GCDWQ MAC values. In this case, the proposed water treatment process should also include the capability to reduce the organic content to minimize the formation of DBPs. Organics reduction will not only minimize DBP formation but will likely also address odour problems and reduce disinfection requirements.

4 System Demands and Design Hydraulics

The purpose of this section is to establish the design flow rate criteria for the proposed water treatment plant.

4.1 Population and Growth

Saltair's population has declined at an average rate of 0.5% per year between 2001 and 2011based on the 2001 - 2011 Census. The OCP Bylaw 2500 states that limited population growth in the region is expected due to community's intention to protect their limited water resources and pristine rural nature. A nominal 1.0% of population growth was, therefore, assumed to accommodate some growth. With this assumed growth rate, the 2036 projected population of Saltair is 2,848 people. This falls just under the medium projection by LAM & Co. Consulting in their *Regional Population, Housing, and Employment Projections and Industrial Lands Analysis* report to CVRD. Figure 4-1 and Table 4-1 shows the assumed population projection for Saltair.

Table 4-1 Projected population at 1.0% growth rate

Year	Designed Population (1.0% Growth Rate)	LAM & Co	
		Medium	High
2016	2,334	2,352	2,470
2026	2,579	2,639	3,054
2031	2,710	2,795	3,396
2036	2,848	2,960	3,776

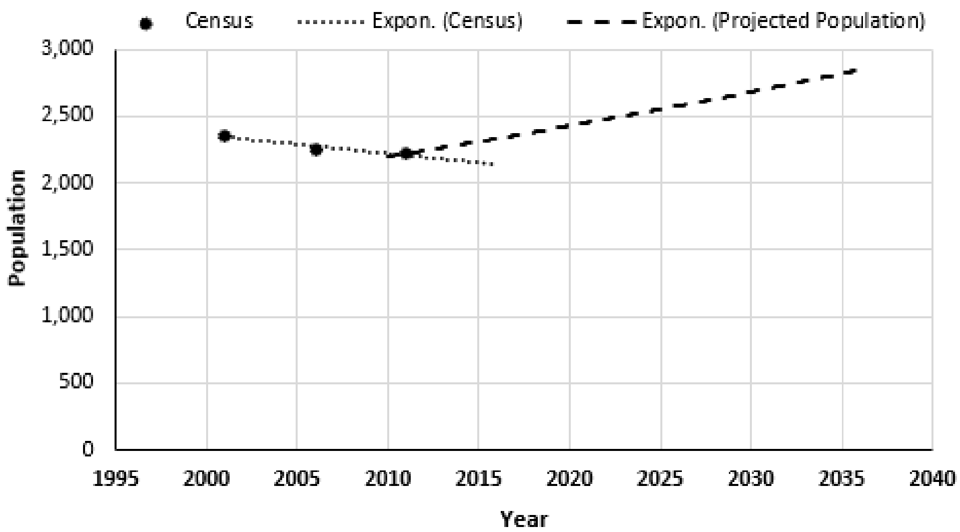


Figure 4-1 Census data and 25-year population projection at 1.0% annual growth rate

4.2 Historical Demands

Figure 4-2 shows the seasonal consumption rate of Saltair between 2005 and 2015, highlighting the average day demand (ADD), maximum day demand (MDD) and peak hour demand (PHD) over that period. There appears to be a seasonal variation of average demand through the year. The highest consumption occurs during summer at an average daily demand of approximately 1,289 m^3/day and the lowest consumption is during winter at an average demand of 661 m^3/day.

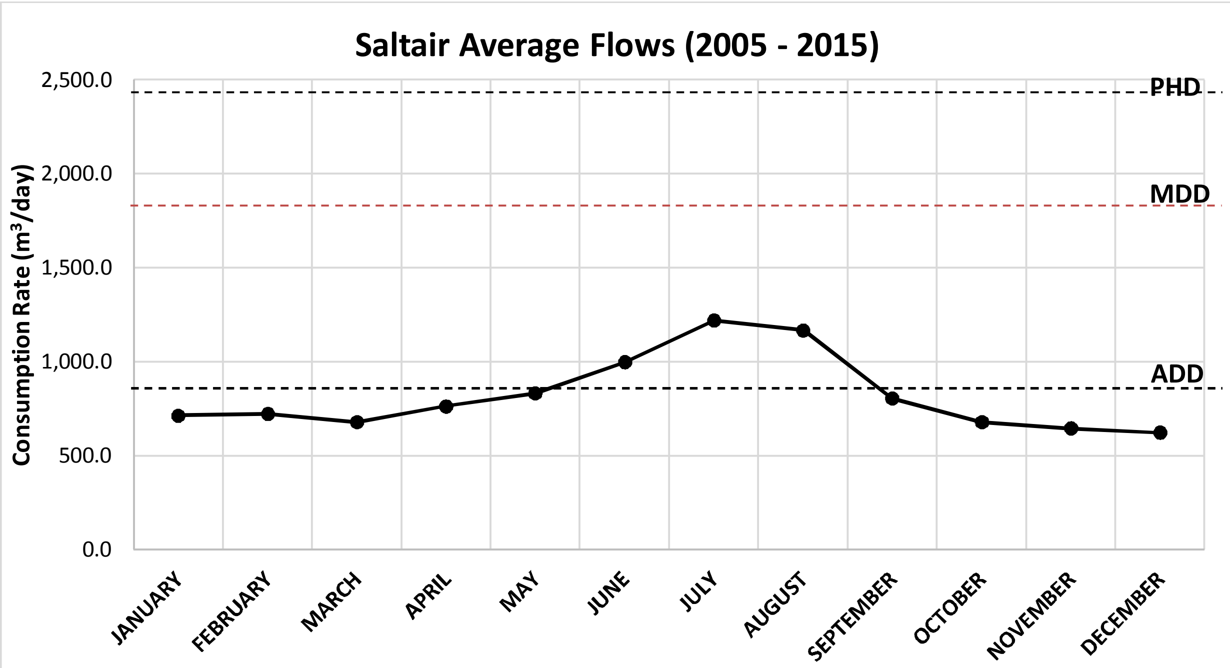


Figure 4-2 Seasonal water demand in Saltair between 2005 and 2015

The annual average day demand remained relatively steady between 2005 and 2015, with an average daily demand (ADD) of 821 m^3/day or 9.5 l/s. Based on the 2011 census data, this equates to approximately 352 litres per capita per day (lpcd). However, there was a declining maximum daily demand (MDD) between 2005 to 2015 from 1,750 to 1,500 m^3/day. Two extreme events were identified in October 2005 and March 2007 and were not used in the analysis. Figure 4-3 shows the flat ADD and declining MDD rates between 2005 and 2015. A peak hour demand (PHD) for Saltair is assumed to be three times the ADD, as per MMCD design guidelines.

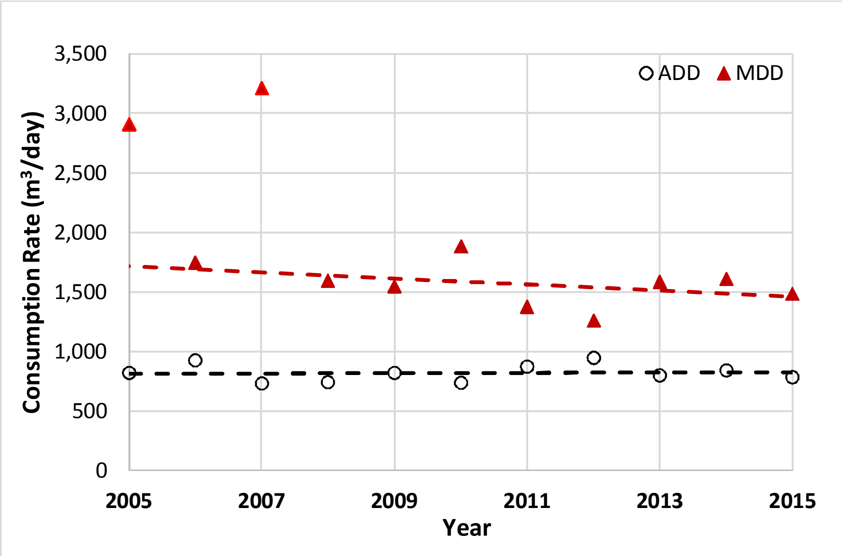


Figure 4-3 Saltair historic daily water consumption between 2005 and 2015

4.3 Projected Demands

The 20-year MDD projection for Saltair is 1,894 m³/day or 22 L/s. The MDDs were calculated based on the projected populations (Section 4.1) and the average of the historic MDD rates (2001-2015) of 662 lpcd. The decision to maintain the average of the historic MDD rates was due to the following two reasons:

- MDD showed a decline from 1,750 to 1,500 m³/day the last 10 years.
- A 1.0% population growth was applied to determine the total population at the end of the 20-year water treatment plant life span, despite the declining trend observed in the census data. This rate would provide an allowance in the water treatment plant capacity for some potential growth.

Table 4-2 summarizes the 20-year projection of Saltair's population and maximum daily demand.

Table 4-2 Projected Maximum Daily Demand

Year	Population	L/s	m³/day
2016	2334	18	1,552
2026	2,579	20	1,714
2031	2,710	21	1,802
2036	2,848	22	1,894

4.4 Hydraulic Design Criteria

Water from Stocking Lake is drawn from the intake chamber located at El. 345.2 m, 0.5 meters below the crest elevation of the dam. Water flows into a meter hut where it is split into two 250-mm PVC watermains to supply the Town of Ladysmith and Saltair. By gravity, water flows into a series of three 150-mm diameter pressure reducing valves (PRVs) where pressure is reduced from 2200 kPa to 345 kPa. In the same building, following the PRVs, water is treated with UV disinfection and chlorine before discharging into the nearby 750 m³ reservoir. The total conveyance distance is approximately 3,358 m from the intake to the PRV/disinfection building. Top water level in the reservoir is 120.38 m. Figure 4-4 shows the hydraulic conditions of Saltair intake water system.

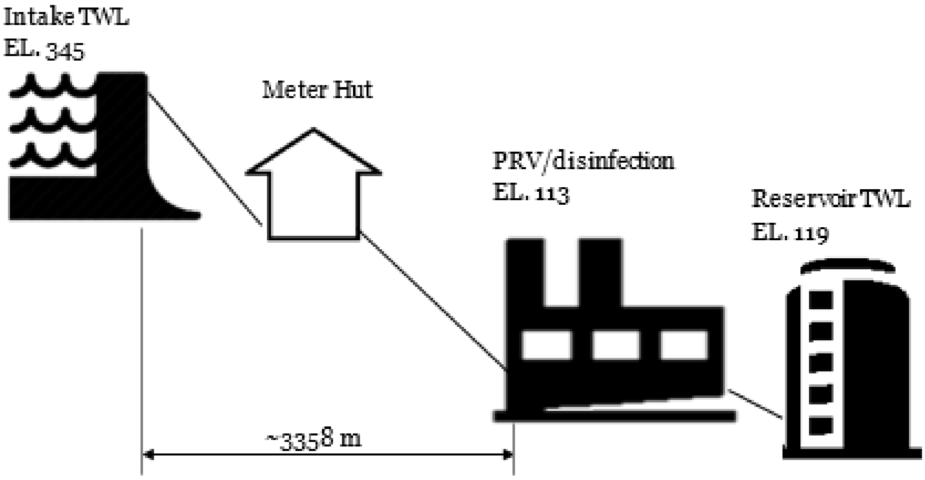


Figure 4-4 Hydraulic profile of Saltair's intake water system

5 Treatment Comparison

5.1 Assessment of Treatment Options

Stocking Lake water is naturally high in organic content, which reportedly results in odour and colour complaints. Additionally, organics are a precursor to DBP's in chlorinated water leading to TTHM and HAA exceedances over the GCDWQ MAC's.

The previous pilot study conducted on Stocking Lake's water using a combined DAF and UF membrane process was able to achieve the GCDWQ objectives, but was limited to a 37% removal of the organic content in the water. This would provide Saltair with a very small buffer for any future changes in water quality. Furthermore, the operation of DAF and UF treatment are relatively complex treatment technologies, requiring an operator with extensive experience in operating both technologies.

Other innovative technologies that focus on organics removal are becoming more readily available. This study will look at the following treatment technologies:

1. Ceramic ultrafiltration membranes;
2. Nanofiltration membranes; and
3. Integrated treatment of biological and membrane filtration.

All three technologies have the potential for achieving high organics and turbidity removal with less dependency on chemical usage than that of DAF and UF filtration. Reductions in residuals waste streams over other technologies are also expected through these technologies. The following sections provide further discussion on the three innovative technologies.

5.2 Ceramic Ultrafiltration Membrane (CUF) Overview

Ceramic ultrafiltration (CUF) is a water treatment technology that combines treatment ideologies from ceramic filtration and membrane ultrafiltration (UF). In ceramic ultrafiltration, the ceramic barrier is manufactured to have a pore size similar to a UF membrane. The ceramic media is typically 100% silicon carbide (SiC), which makes it very resistant to abrasion as well as chemical and biological reactions. The fine UF pore size in the media allows it to reject particles, colloidal material, bacteria, and pathogens. Due to these characteristics, CUF also has the highest operational flow rate (flux) of all UF membrane systems and lowest footprint requirements per volume of water treated. The robust material of the membrane allows it to have a membrane lifespan of 25 years.

The use of ceramic membranes in municipal drinking water application is still is growing as ceramic membrane costs are becoming competitive with polymeric membranes. Presently, there are two operating drinking water ceramic membrane plants located in Delaware and Mississippi, United States, that use a Purifics Ceramic Ultrafiltration system. One other ceramic membrane plant is being designed for the Cache Creek Casino in Brooks, CA using the Kruger Ceramic Membrane (KCM) of Kruger. Two CUF pilot studies are currently in operation, the 180 MLD Choa Chung Kang Waterworks Plant in Singapore and 9.5 MLD City of Watsonville water treatment plant in California.

CUF treatment requires pre-screening of the raw water to remove any coarse particles. Following the screening, coagulant is added at the inlet to the high solids contact reactor (HSCR), where rapid mixing is used for an efficient coagulation process. Coagulation is required for the removal of organics and improved turbidity reduction. A suitable type and dose of coagulant must be determined through a pilot study.

From the HSCR tank, water is pumped into the membrane module in a cross flow arrangement. After passing through the membrane, the filtered water would be disinfected and sent to distribution. A waste stream is generated during membrane cleaning through an automatic maintenance cleaning cycle. A percentage of the waste stream water is circulated back to the HSCR in order to reduce the volume of wastewater and to produce a high concentrate solids, which would then dewatered to a 3% to 10% solids sludge using a dewatering system. Waste volume is anticipated to be 0.3% of the overall process volume, compared to 10% for DAF/ultrafiltration. As such, the produced sludge can be locally stored for off-site disposal by vacuum truck. Overall system efficiency is expected to exceed 99.7%. Figure 5-1 shows a typical process flow diagram of a CUF membrane WTP.

A frequent maintenance cleaning of the CUF is conducted with controlled shock waves through the water and the membrane to dislodge any foulants that are attached. Occasionally, a full maintenance cycle is activated through a combination of heat, high cross-flow flux (similar to a backwash), as well as chemical applications of acid and/or caustic which will scrub and dissolve residual foulants from the membrane. Overall, this chemical waste constitutes less than 0.1% of the total treatment flow. Disposal of this waste can be combined with the waste from the dewatering system and contained for vacuum truck disposal. Alternatively, a neutralization stage can be added to treat the chemical waste which will enable the plant directly discharge to the environment, such as through a rock pit.

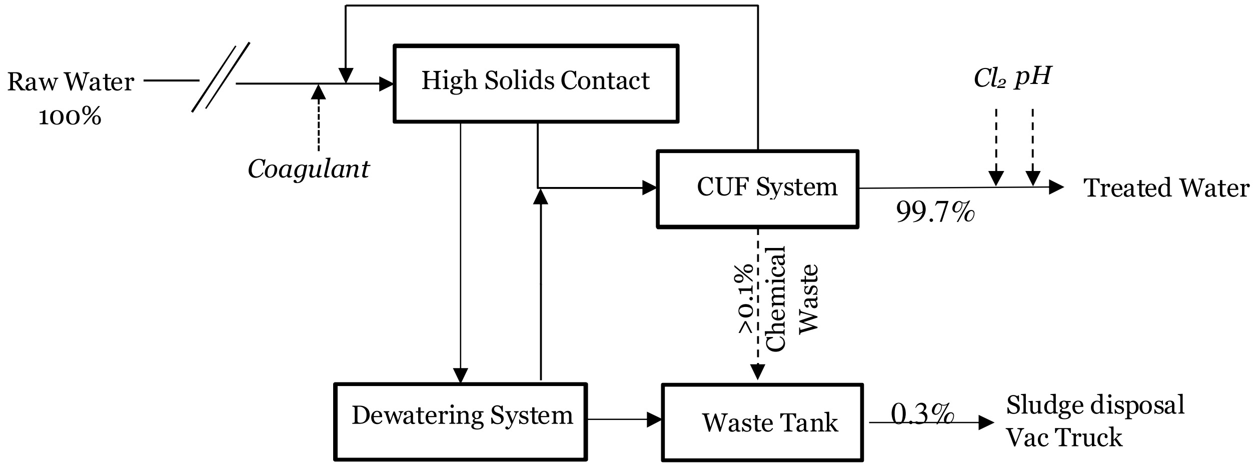


Figure 5-1 Typical process diagram of ceramic ultrafiltration membrane

Post CUF treatment, chlorine disinfection is required to provide 4-log removal of virus and residual for secondary disinfection. However, the amount of chlorine addition is expected to be minimized as the organics present in the water after filtration will be substantially reduced. pH adjsutment would likely be required post-treatment due to the reduction in alkalinity following coagulation.

An example of a North American manufacturer that supplies and installs full-scale CUF water treatment facilities is Purifics. Two full-scale facilities with capacities of 3,800 and 3,300 m^3/day are currently operating in Mississippi and Delaware, respectively. A budget quotation from Purifics was obtained to estimate the CUF capital costs in Section 8.0.

The proposed water treatment system would include the CUF membrane process, chlorine disinfection system, office/lab, chemical room, washroom and electrical room. The water treatment plant's footprint would be approximately 355 m^2. A conceptual layout of the water treatment plant is shown in Figure 5-2, and was developed to provide a comparative cost estimate to the other technologies. The footprint layout for the selected technology would be further developed in the next stages of design. A preliminary estimate of the power requirements for a CUF system were provided by the vendor, and are approximately 0.16 kwh per cubic metre of treated water. The main consumers of power in this process are the pumps used to circulate water continuously between the high solids contact tank and the CUF.

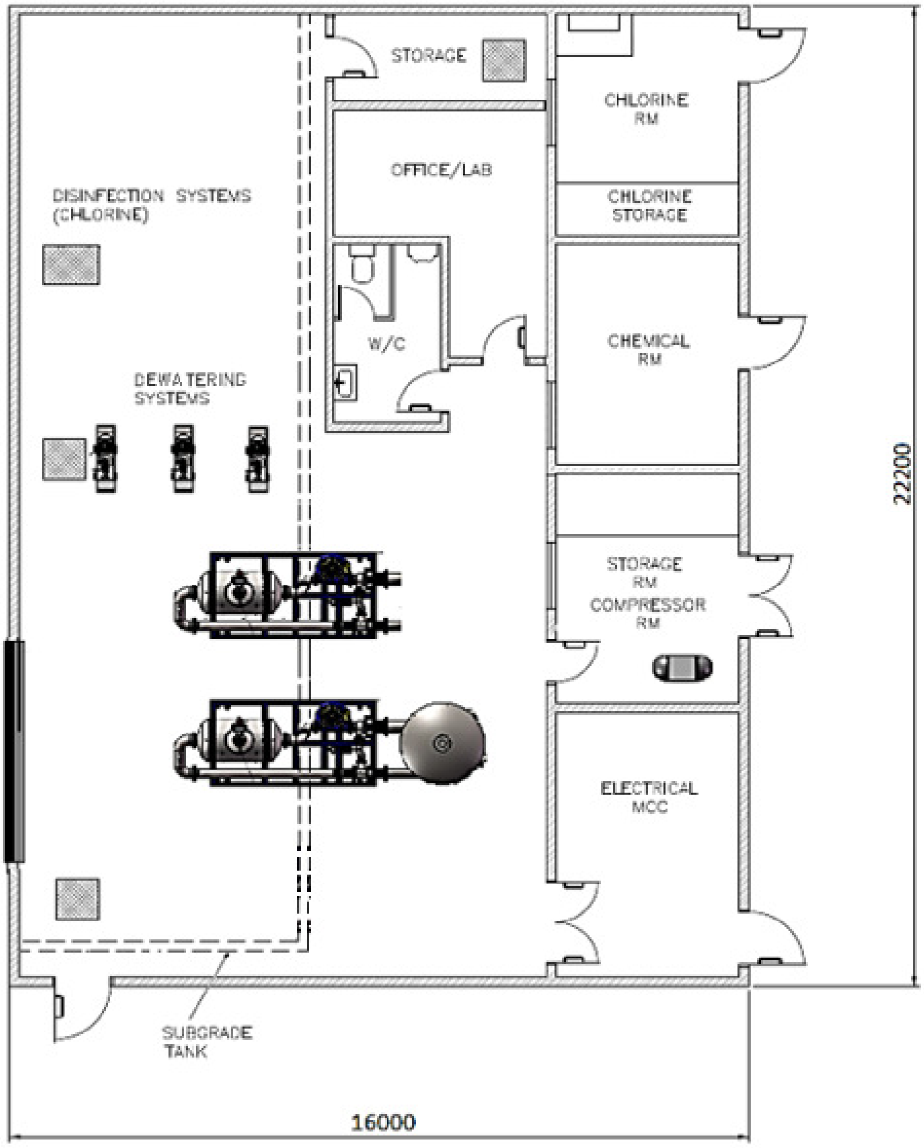


Figure 5-2 Conceptual layout for ceramic ultrafiltration treatment

5.3 Hollow Fibre Nanofiltration Membrane (HFNF) Overview

Nanofiltration (NF) provides a physical treatment barrier treatment with pore size of 1-10 nanometers. The small pore size allows for the removal of large molecular weight organics, suspended solids, and greater than 4-log removal of bacteria and viruses in a one-step process without chemical coagulation. As no chemical alteration is needed, environmental discharge of the waste stream may be viable. NF can treat raw water with turbidities up to 25 NTU down to less than 0.1 NTU, reduce colour to less than 5 TCU, and achieve a typical removal of 80% to 90% of dissolved organic carbon (DOC).

Typically, raw water is pumped to the NF fibres in a cross flow arrangement. A small reject stream is continuously wasted from the membrane system (*feed-and-bleed* operation) as a measure to control retained solids concentration in the system, which otherwise can potentially affect the treated water quality. The reject stream is typically around 5% of the treatment flow. The membranes are maintained by frequent backwashing where treated water is applied to the membrane in the reverse direction to dislodge any retained particles in the membranes. Backwash flow accounts for around 20% of the total treatment flow. Aside from the elevated solids and colour concentrations, the backwash stream is free of chemicals, which potentially allows for a direct environmental discharge.

Periodically, the membranes must be chemically cleaned by immersing the membrane modules in chlorine, sodium hydroxide and/or hydrochloric acid solution. As the cleaning is conducted in the treatment tank, this process is known as Clean-in-Place (CIP). High pH cleaning is typically performed every 3 to 4 days to remove biological matter and oil trapped on the membrane surface. Low pH cleans are typically required every 13 weeks, and it is conducted to remove mineral scales or metal oxides/hydroxides that may also be found in the raw water. This chemical wastes constitutes less than 0.1% of the total treatment flow, and is the only waste stream that requires special handling and disposal. Alternatively, a neutralization stage can be added to treat the chemical waste which will enable the plant directly discharge to the environment with the backwash stream through a rock pit.

The treated water from the NF process would be about 75% efficient, wasting about 25% of the total flow, and have a consistent water quality regardless of the source water turbidity. UV-disinfection is not required as >3-log *Giardia* and *Cryptosporidium* reduction credits are achieved through the NF treatment and verified by daily membrane integrity tests. Chlorine disinfection is required following NF treatment for residual disinfection in the distribution system. It is anticipated that the reduced organics in the water post-filtration would reduce the chlorine demand of the water. Figure 5-3 shows a typical process diagram of a NF system.

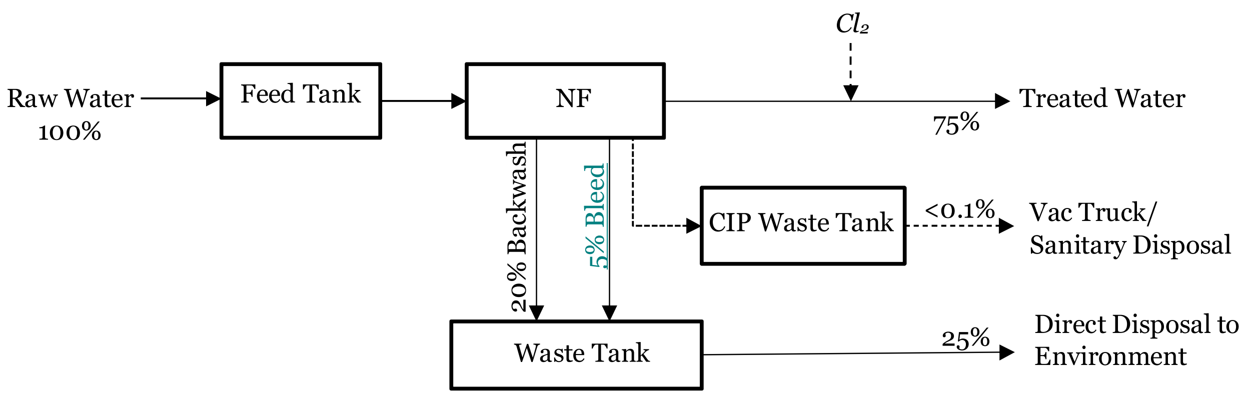


Figure 5-3 Typical Process diagram of nanofiltration membrane system

The proposed WTP would include NF treatment system, staff washroom, chlorine room, office/ lab, storage room, chemical room, a tank area as well as a below-grade contact tank, and electrical room. The building would have an approximate footprint of 500 m^2. A conceptual layout of the water treatment plant is shown in Figure 5-2, and was developed to provide a comparative cost estimate to the other technologies. The footprint layout for the selected technology would be further developed in the next stages of design. Power requirements are based on NF circulation pumps, backwash pumps and forward flush pumps and estimated to be 0.22 kwh per cubic metre of water produced.

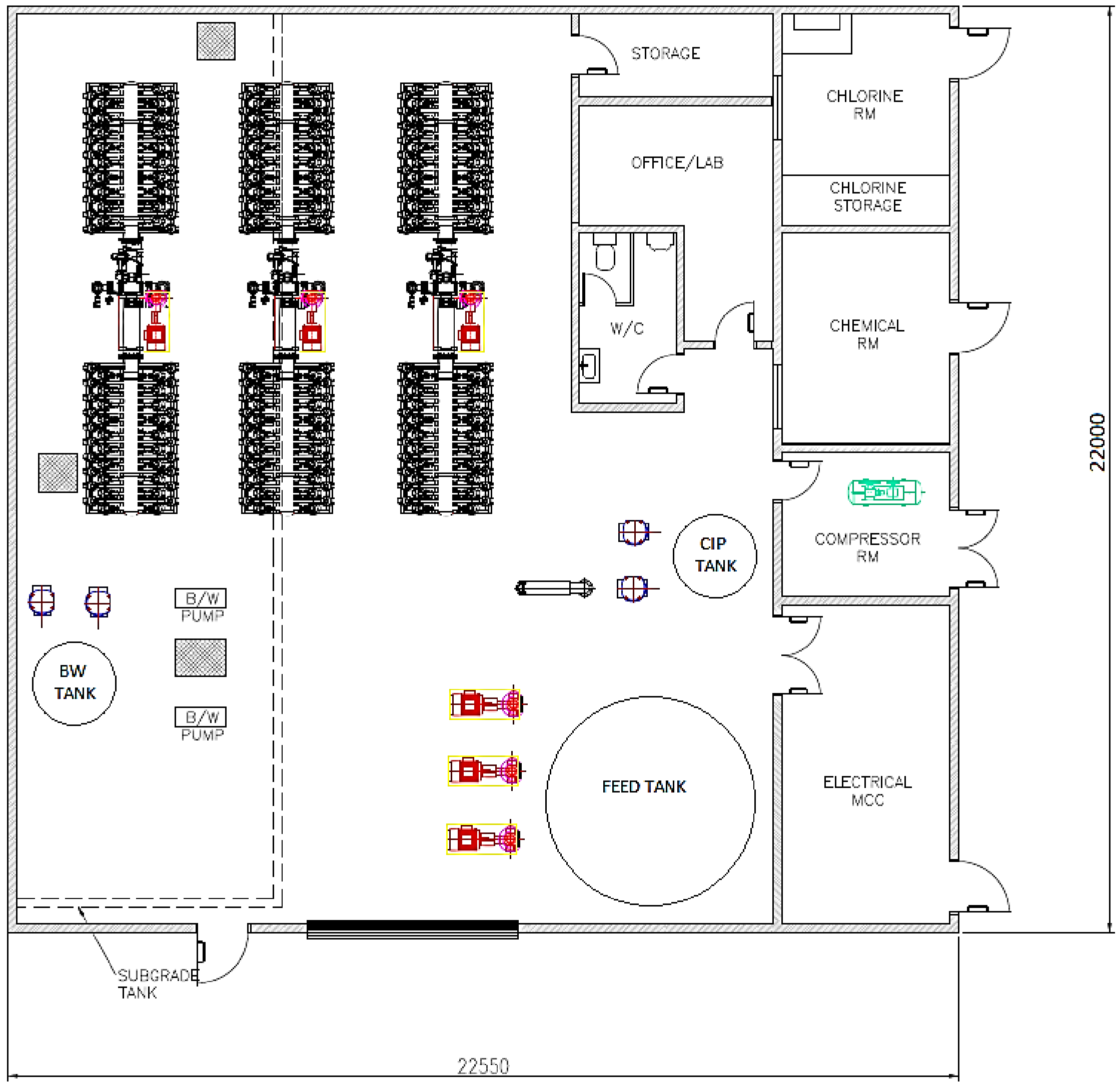


Figure 5-4 Conceptual WTP layout for hollowfibre nanofiltration treatment

5.4 Integrated Biological and Reverse Osmosis (RO) Overview

Reverse osmosis (RO) and NF membranes are susceptible to irreversible fouling from organic contaminates, this is known as biofouling. To reduce membrane biofouling, biological filtration as a pre-treatment step for either RO or NF membranes has become a more common concept in the last decade for drinking water treatment. Pre-treating raw water through a biological filter can effectively eliminate organic compounds that promote biofouling to improve membrane performance.

In the first stage of the treatment process, water flows through a series of biofilter tanks operated under conditions ideal for the colonization of the water treatment bacteria. The bacteria consume a portion of the organics, the assimilable organic carbon (AOC), and remove substances such as iron and ammonium. In the second stage of treatment, water is pumped through a series of tight-woven membranes such as RO or NF for the removal of any remaining organic and inorganic contaminants. The treated water is biologically stable water with reduced organic carbon and minerals. pH adjustment is recommended at the end of treatment to re-mineralize the water. UV disinfection is required due to RO's limitations to verify membrane integrity as a required protection against protozoa. Chlorine disinfection is to follow to provide 4-log removal of viruses and as a protection against bacterial growth in the distribution system.

Since no pre-treatment chemicals are required to operate the biofilters and RO unit, the reject from the RO could potentially be discharged to the environment under permit. However, the biofilters must be periodically backwashed to remove accumulated suspended solids and bio-mass growth. It is anticipated that the biofilters backwash water can be blended with the RO reject for direct discharge to the environment. Additionally, a clean in place (CIP) program will occasionally be required to chemically clean the RO membranes. The spent membrane cleaning chemicals are expected to be stored in a waste tank for periodic disposal by vacuum truck. Figure 5-5 illustrates a typical process diagram of an integrated biological and reverse osmosis system.

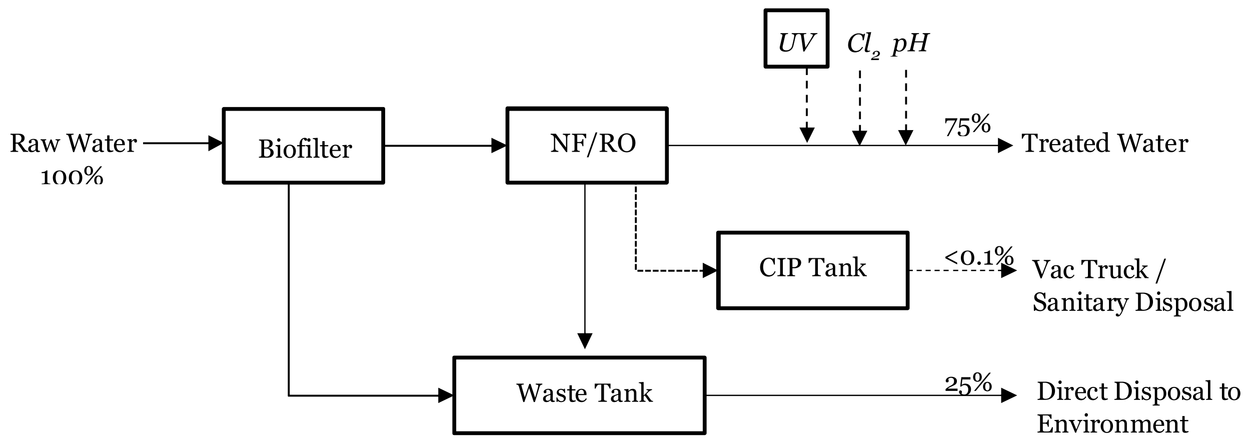


Figure 5-5 Typical Process Diagram of Integrated Biological and Reverse Osmosis Treatment

An example of a Canadian manufacturer that supplies and installs full-scale integrated treatment facilities is Sapphire, with proprietary system known as SIBROM (Sapphire Integrated Biological Reverse Osmosis Membrane). Their system is currently servicing twelve communities in Saskatchewan.

The proposed WTP building would include treatment area (biological tanks and RO membranes), washroom, UV-Chlorine disinfection system, office/lab, storage, below-grade contact tank, chemical room, and electrical room. The total estimated water treatment plant footprint required to include these items is 500 m². A conceptual layout of the water treatment plant is shown in Figure 5-2, and was developed to provide a comparative cost estimate to other technologies. The footprint layout for the selected technology would be further developed in the next stages of Power requirements to operate the SIBROM system is estimated to be 0.3 kwh per cubic metre of treated water based on preliminary estimates from the vendor.

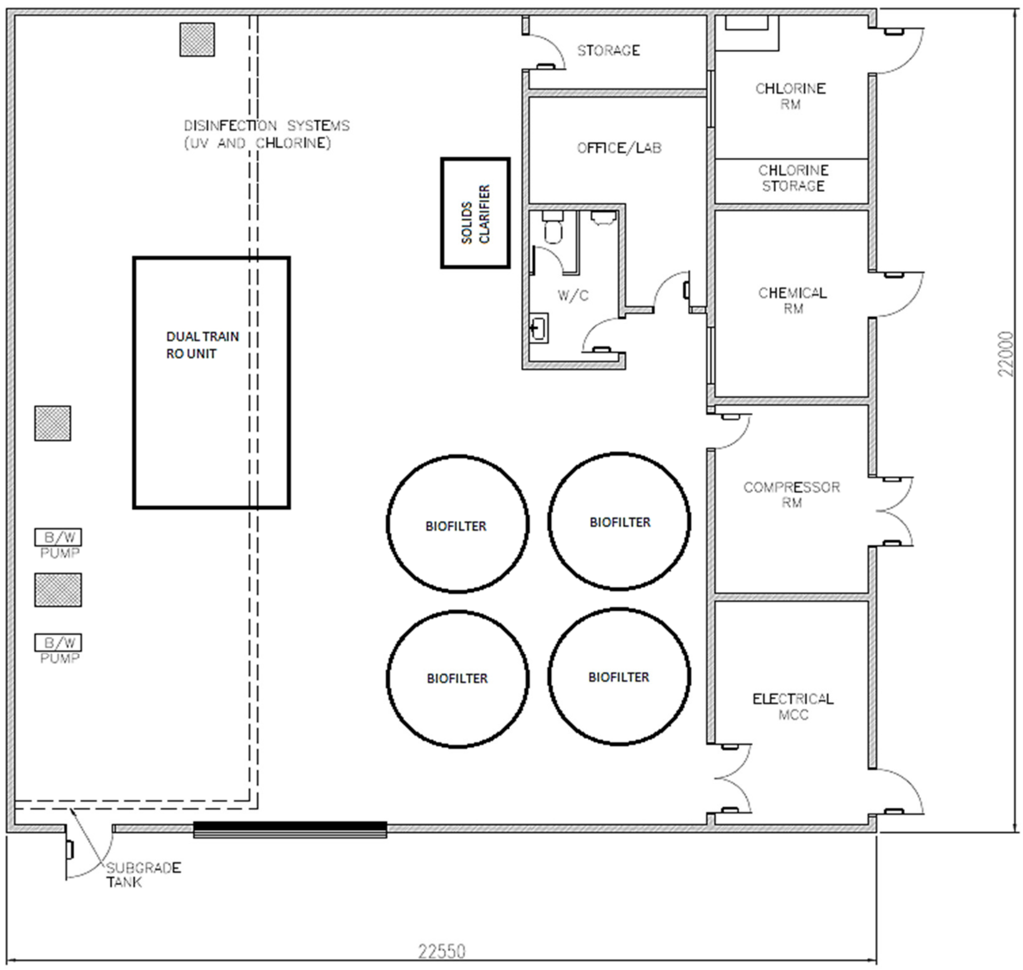


Figure 5-6 Conceptual layout for integrated biological treatment and RO

6 Residuals Handling

The technologies discussed herein offer a number of advantages in residuals production over conventional technologies. Residual handling requirements can be significantly reduced to 0.3% of the total treated water using CUF if a dewatering system is included. The small volume of waste produced can be contained onsite and removed periodically by a vacuum truck. With HFNF and integrated biological and RO treatment, there is the potential for direct waste discharge to the environment as the waste stream is chemical free. In the absence of an accessible watercourse, an on-site soak-away pond or a rock-pit could allow a slow discharge of the waste stream into the ground. Alternatively, a dewatering system could be added as a part of the treatment to reduce liquid waste discharge. In addition to treatment waste handling, a septic tank and field disposal may be required for on-site sewage management.

7 Disinfection

As previously discussed, UV disinfection is only required for the Integrated Biological and Reverse Osmosis option to achieve a 3-log removal of Giardia and Cryptosporidium. For all of the options, chlorine disinfection is required for 4-log virus inactivation and for secondary disinfection to prevent against bacterial growth in the distribution system. To achieve a 4-log reduction of viruses the system must provide a CT of 8 mg/L-min, assuming a minimum water temperature of 50 C.

The current contact time (CT) within the system was estimated to be sufficient at 12.6 mg/L-min using a free chlorine concentration of 0.2 mg/L and a peak hour demand (PHD) of 2.25 m^3/min. The total travel distance from the reservoir tank to the first customer was estimated to be 2-km, with a 300 mm PVC pipe. A baffle factor (BF) of 1.0 was applied for a pipeline flow.

Equation 1

$$CT = \text{Free Chlorine} \times BF \times PHD/V_{eff}$$

Where, V_{eff} is the effective pipe volume and is derived the following:

Equation 2

$$V_{eff} = 0.785 \times D^2 \times L$$

8 Lifecycle Cost Analysis

Preliminary (Class D) construction and operating costs estimates for the different treatment options were developed in Table 8-1 and Table 8-2 to provide a comparative evaluation of the four technologies.

Table 8-1 Comparative constrution cost estimates for the different treatment options

	DAF & Ultrafiltration	Ceramic Ultrafiltration	Nanofiltration	Integrated Biological & RO
Capital Cost	$6,850,000	$4,600,000	$5,600,000	$5,650,000

Table 8-2 Comparative operating cost estimates of the different treatment options

Cost Element	DAF & Ultrafiltration	Ceramic Ultrafiltration	Nanofiltration	Integrated Biological & RO
Chemical Waste	$125,000	$ 50,000 $ 20,000	$ 20,000 $ 0	$ 30,000 $ 10,000
Power	$ 9,000	$ 13,000	$ 15,000	$ 18,000
Parts	$ 50,000	$ 50,000	$120,000	$ 10,000
Labour	$ 75,000	$ 35,000	$ 35,000	$ 50,000
Total	**$259,000**	**$168,000**	**$190,000**	**$183,000**

Cost Element	DAF & Ultrafiltration	Ceramic Ultrafiltration	Nanofiltration	Integrated Biological & RO
20-yr Present Worth	**$2,743,846**	**$1,779,792**	**$2,012,860**	**$1,938,702**

Based on the estimated construction and annual operating costs, a lifecycle cost analysis was calculated over the 20-year lifespan on the plant using a 7% interest rate factor. Table 8-3 and Figure 8-1 compare the lifecycle costs of the considered options.

Table 8-3 Total lifecycle cost comparison

	DAF & Ultrafiltration	Ceramic Ultrafiltration	Nanofiltration	Integrated Biological & RO
Capital Cost	$6,850,000	$4,600,000	$5,600,000	$5,650,000
20-yr Present Worth	$2,743,846	$1,779,792	$2,012,860	$1,938,702
Total Lifecycle Cost	**$9,593,846**	**$6,379,792**	**$7,612,860**	**$7,588,702**

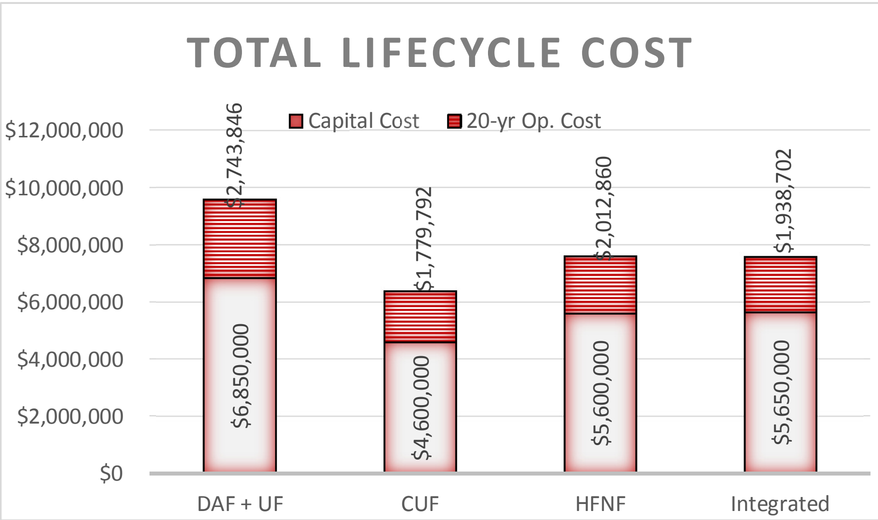


Figure 8-1 Summary of comparative lifecycle costs

9 Summary and Recommendations

A summary of the technologies considered is provided in Table 9-1 below:

Table 9-1 Summary table comparison of the treatment options

Performance Indicator	DAF & Ultrafiltration	Ceramic Ultrafiltration	Nanofiltration	Integrated Biological & RO
System Complexity	Very Complex	Simple	Moderate	Very Complex
Maintenance	High	Low	High	Moderate

Performance Indicator	DAF & Ultrafiltration	Ceramic Ultrafiltration	Nanofiltration	Integrated Biological & RO
Reliability	High likelihood of membrane fouling by coagulant, membrane breakage & repair	Robust and readily available components	High likelihood of frequent membrane breakage & repair	Monitoring ofbackwash, occasional RO clean-in-place
Organics Removal	30% to 50%	65% to 70%	80% to 90%	> 98%
Treated Turbidity	<0.1 NTU	<0.1 NTU	<0.1 NTU	<0.1 NTU
Waste Stream	Sludge waste 10% of total flow for collection	Sludge waste 0.3% of total flow	Direct discharge to environment 25% of total flow	Discharge to environment, plus CIP collection for disposal. 25% of total flow
Disinfection Requirements	Chlorine	Chlorine	Chlorine	UV and Chlorine
Post Treatment	pH adjustment due to coagulation	pH adjustment due to coagulation	No change in water chemistry	pH and alkalinity adjustment
Footprint	580 m²	355 m²	500 m²	500 m²
Capital Cost	$6,850,000	$4,600,000	$5,600,000	$5,650,000
Total Lifecycle Cost	**$9,793,846**	**$6,369,792**	**$7,772,860**	**$7,598,702**

We would recommend further development of the ceramic ultrafiltration (CUF) option for the new water treatment plant. Our recommendation is based on CUF having the lowest estimated total lifecycle cost, least footprint, relatively low system complexity, low residual handling requirements and organics removal capacity. Land availability and permitting requirements will need to be reviewed by CVRD to ensure the feasibility of the project.

Pilot testing of this option would be essential. We recommend that rigorous pilot testing is performed to: 1) confirm the validity of the process to the specific water quality characteristics of the Stocking Lake, 2) confirm design criteria so that the HCSR tank, filtration system, chemical systems, and residuals handling systems are appropriately sized to meet CVRD's requirements, and minimize operational headaches later on. It is anticipated that such pilot testing will need to be performed for 3 to 6 months duration at a total cost of approximately $100,000.

Technical Memorandum 2 builds on the recommended use CUF treatment and discusses the generation and supply of power to the treatment plant. Following the review of Technical Memorandum 1 and 2, meetings will be held with the CVRD will finalize the treatment selection and steps forward for Saltair. The selected treatment will be the basis for the preliminary design and Technical Memorandum No.3.

Appendix: Capital Cost Breakdowns

DAF + Ultrafiltration					
Item No.	**Description or Classification of Work**	**Unit**	**Approx. Qty**	**Unit Price ($)**	**Total Price ($)**
1	**Mob/Demob, Bonding and Insurance**				$75,000
	Subtotal Item 1 - Mob/Demob, Bonding and Insurance				**$75,000**
2	**Earthworks**				
	a) All Siteworks (gravel parking area, access road, site grading and drainage)	L.S.	1	175,000.00	$175,000.00
	b) Import Structural Fill for Building Foundation	m^3	350	$60.00	$21,000.00
	c) Fencing	L.S.	1	$25,000.00	$25,000.00
	Subtotal Item 2 - EARTHWORKS				**$221,000.00**
3	**Concrete**				
	a) Water treatment plant foundation and subgrade tanks	m^3	420	$2,300.00	$966,000.00
	b) Outside sidewalk	m3	10	$150.00	$1,500.00
	Subtotal Item 3 - CONCRETE				**$967,500.00**
4	**Miscellaneous Metalwork and Fibreglass**				
	a) All miscellaneous metalwork and fibreglass for water treatment plant	L.S.	1	$75,000.00	$75,000.00
	Subtotal Item 4 - MISC. METALS & FIBREGLASS				**$75,000.00**
5	**Architectural**				
	a) Pre-engineered building	m^2	660	$1,200.00	$792,000.00
	b) Interior finishing	L.S.	1	$125,000.00	$125,000.00
	Subtotal Item 5 - ARCHITECTURAL				**$917,000.00**
6	**Outside Piping**				
	a) New watermain and appurtenances (allowance)	LS	1		$150,000.00
	Subtotal Item 6 - OUTSIDE PIPING				**$150,000.00**
7	**Mechanical**				
	a) Mechanical piping and equipment	LS	1	$300,000.00	$300,000.00
	Subtotal Item 7 - MECHANICAL				**$295,000.00**
8	**Plumbing**				
	a) Plumbing work	L.S.	1	$30,000.00	$30,000.00
	Subtotal Item 8 - PLUMBING				**$30,000.00**
9	**Heating and Ventilation**				
	a) HVAC work	L.S.	1	$75,000.00	$75,000.00
	Subtotal Item 9 - HVAC				**$75,000.00**
10	**Corrosion Protection and Painting**				
	a) Architectural	L.S.	1	$20,000.00	$20,000.00
	b) Mechanical piping and equipment	L.S.	1	$20,000.00	$20,000.00
	Subtotal Item 10 - CORROSION PROTECTION & PAINTING				**$40,000.00**

DAF + Ultrafiltration						
Item No.		**Description or Classification of Work**	**Unit**	**Approx. Qty**	**Unit Price ($)**	**Total Price ($)**
11		**Electrical**				
	a)	Electrical MCC	L.S.	1	$400,000.00	$400,000.00
	b)	MCC control section	L.S.	1	$200,000.00	$200,000.00
	c)	Instrumentation	L.S.	1	$75,000.00	$75,000.00
	d)	All other associated electrical work (conduits, cables, etc.)	L.S.	1	$125,000.00	$125,000.00
		Subtotal Item 11 - ELECTRICAL				**$800,000.00**
12		**Treatment Equipment**				
	a)	Package Treatment Plant: DAF/UF	L.S.	1	$1,200,000.00	$1,200,000.00
	b)	Chlorination System	L.S.	1	$25,000.00	$25,000.00
	c)	Caustic Feed System	L.S.	1	$20,000.00	$20,000.00
	d)	Coagulant Feed System	L.S.	1	$20,000.00	$20,000.00
	e)	Polymer Feed System	L.S.	1	$20,000.00	$20,000.00
	f)	Gravity thickener	L.S.	1	$300,000.00	$300,000.00
	g)	Start-up, testing and commissioning	L.S.	1	$30,000.00	$30,000.00
		Subtotal Item 12 - TREATMENT EQUIPMENT				**$1,615,000.00**
		SUBTOTAL ITEMS 1 though 12				**$5,265,500.00**
		CONTINGENCY (20%)				**$1,053,100.00**
		ENGINEERING (10%)				**$526,500.00**
		TOTAL (EXCLUDING GST)				**$6,845,150.00**
					SAY	**$6,850,000**

Ceramic Ultrafiltration				
Description or Classification of Work		**Approx. Qty**	**Unit Price ($)**	**Total Price ($)**
Mob/Demob, Bonding and Insurance				$75,000
			Subtotal Item 1 - Mob/Demob, Bonding and Insurance	**$75,000**
Earthworks				
a)	All Siteworks (gravel parking area, access road, site grading and drainage)	1	120,000.00	$120,000.00
b)	Import Structural Fill for Building Foundation	200	$60.00	$12,000.00
c)	Fencing	1	$20,000.00	$20,000.00
			Subtotal Item 2 - EARTHWORKS	**$152,000.00**
Concrete				
a)	Water treatment plant foundation and subgrade tanks	270	$2,300.00	$621,000.00
b)	Outside sidewalk	10	$150.00	$1,500.00
			Subtotal Item 3 - CONCRETE	**$622,500.00**
Miscellaneous Metalwork and Fibreglass				
a)	All miscellaneous metalwork and fibreglass for water treatment plant	1	$50,000.00	$50,000.00
			Subtotal Item 4 - MISC. METALS & FIBREGLASS	**$50,000.00**
Architectural				
a)	Pre-engineered building	355	$1,000.00	$355,000.00
b)	Interior finishing	1	$65,000.00	$65,000.00
			Subtotal Item 5 - ARCHITECTURAL	**$420,000.00**
Outside Piping				
a)	New watermains and appurtenances			$150,000
			Subtotal Item 6 - OUTSIDE PIPING	**$150,000.00**
Mechanical				
a)	Mechanical piping and equipment	1	$150,000.00	$150,000.00
			Subtotal Item 7 - MECHANICAL	**$150,000.00**
Plumbing				
a)	Plumbing work	1	$25,000.00	$25,000.00
			Subtotal Item 8 - PLUMBING	**$25,000.00**
Heating and Ventilation				
a)	HVAC work	1	$55,000.00	$55,000.00
			Subtotal Item 9 - HVAC	**$55,000.00**
Corrosion Protection and Painting				
a)	Architectural	1	$12,000.00	$12,000.00
b)	Mechanical piping and equipment	1	$12,000.00	$12,000.00
			Subtotal Item 10 - CORROSION PROTECTION & PAINTING	**$24,000.00**

Ceramic Ultrafiltration				
	Description or Classification of Work	**Approx. Qty**	**Unit Price ($)**	**Total Price ($)**
Electrical				
a)	Electrical MCC (VFDs in vendors scope)	1	$250,000.00	$250,000.00
b)	MCC control section	1	$175,000.00	$175,000.00
c)	Instrumentation	1	$100,000.00	$100,000.00
d)	All other associated electrical work (conduits, cables, etc.)	1	$100,000.00	$100,000.00
			Subtotal Item 11 - ELECTRICAL	**$625,000.00**
Treatment Equipment				
a)	Package Treatment Plant: ZLD CUF + DeWRS	1	$1,100,000.00	$1,100,000.00
b)	Chlorination System	1	$25,000.00	$25,000.00
c)	Caustic Feed System	1	$20,000.00	$20,000.00
d)	Start-up, testing and commissioning	1	$30,000.00	$30,000.00
			Subtotal Item 12 - TREATMENT EQUIPMENT	**$1,175,000.00**
	SUBTOTAL ITEMS 1 though 12			**$3,523,500.00**
	CONTINGENCY (20%)			**$704,700.00**
	ENGINEERING (10%)			**$352,350.00**
	TOTAL (EXCLUDING GST)			**$4,580,550.00**
			SAY	**$4,600,000**

Nanofiltration (HFNF)				
Description or Classification of Work		**Approx. Qty**	**Unit Price ($)**	**Total Price ($)**
				OPTION A
Mob/Demob, Bonding and Insurance				$75,000
			Subtotal Item 1 - Mob/Demob, Bonding and Insurance	**$75,000**
Earthworks				
a)	All Siteworks (gravel parking area, access road, site grading and drainage)	1	140,000.00	$140,000.00
b)	Import Structural Fill for Building Foundation	250	$60.00	$15,000.00
c)	Fencing	1	$25,000.00	$25,000.00
			Subtotal Item 2 - EARTHWORKS	**$180,000.00**
Concrete				
a)	Water treatment plant foundation and subgrade tanks	300	$2,300.00	$690,000.00
b)	Outside sidewalk	10	$150.00	$1,500.00
			Subtotal Item 3 - CONCRETE	**$691,500.00**
Miscellaneous Metalwork and Fibreglass				
a)	All miscellaneous metalwork and fibreglass for water treatment plant	1	$60,000.00	$60,000.00
			Subtotal Item 4 - MISC. METALS & FIBREGLASS	**$60,000.00**
Architectural				
a)	Pre-engineered building	496	$1,000.00	$496,000.00
b)	Interior finishing	1	$70,000.00	$70,000.00
			Subtotal Item 5 - ARCHITECTURAL	**$566,000.00**
Outside Piping				
a)	New watermains and appurtenances (allowance)			$150,000.00
			Subtotal Item 6 - OUTSIDE PIPING	**$150,000.00**
Mechanical				
a)	Mechanical piping and equipment	1	$100,000.00	$140,000.00
			Subtotal Item 7 - MECHANICAL	**$140,000.00**
Plumbing				
a)	Plumbing work	1	$25,000.00	$25,000.00
			Subtotal Item 8 - PLUMBING	**$25,000.00**
Heating and Ventilation				
a)	HVAC work	1	$60,000.00	$60,000.00
			Subtotal Item 9 - HVAC	**$60,000.00**
Corrosion Protection and Painting				
a)	Architectural	1	$15,000.00	$15,000.00
b)	Mechanical piping and equipment	1	$15,000.00	$15,000.00
			Subtotal Item 10 - CORROSION PROTECTION & PAINTING	**$30,000.00**

Nanofiltration (HFNF)				
	Description or Classification of Work	Approx. Qty	Unit Price ($)	Total Price ($)
Electrical				
a)	Electrical MCC (VFDs in vendors scope)	1	$250,000.00	$250,000.00
b)	MCC control section	1	$175,000.00	$175,000.00
c)	Instrumentation	1	$50,000.00	$50,000.00
d)	All other associated electrical work (conduits, cables, etc.)	1	$100,000.00	$100,000.00
			Subtotal Item 11 - ELECTRICAL	**$575,000.00**
	Treatment Equipment			
a)	Package Treatment Plant: NF	1	$1,700,000.00	$1,700,000.00
b)	Chlorination System	1	$25,000.00	$25,000.00
c)	Start-up, testing and commissioning	1	$30,000.00	$30,000.00
			Subtotal Item 12 - TREATMENT EQUIPMENT	**$1,755,000.00**
	SUBTOTAL ITEMS 1 though 12			**$4,307,500.00**
	CONTINGENCY (20%)			**$861,500.00**
	ENGINEERING (10%)			**$430,750.00**
	TOTAL (EXCLUDING GST)			**$5,599,750.00**
			SAY	**$5,600,000**

Biofilter + RO + UV				
Description or Classification of Work		**Approx. Qty**	**Unit Price ($)**	**Total Price ($)**
Mob/Demob, Bonding and Insurance				$75,000
			Subtotal Item 1 - Mob/Demob, Bonding and Insurance	**$75,000**
Earthworks				
a)	All Siteworks (gravel parking area, access road, site grading and drainage)	1	140,000.00	$140,000.00
b)	Import Structural Fill for Building Foundation	250	$60.00	$15,000.00
c)	Fencing	1	$25,000.00	$25,000.00
			Subtotal Item 2 - EARTHWORKS	**$180,000.00**
Concrete				
a)	Water treatment plant foundation and subgrade tanks	300	$2,300.00	$690,000.00
b)	Outside sidewalk	10	$150.00	$1,500.00
			Subtotal Item 3 - CONCRETE	**$691,500.00**
Miscellaneous Metalwork and Fibreglass				
a)	All miscellaneous metalwork and fibreglass for water treatment plant	1	$60,000.00	$60,000.00
			Subtotal Item 4 - MISC. METALS & FIBREGLASS	**$60,000.00**
Architectural				
a)	Pre-engineered building	496	$1,000.00	$496,000.00
b)	Interior finishing	1	$70,000.00	$70,000.00
			Subtotal Item 5 - ARCHITECTURAL	**$566,000.00**
Outside Piping				
a)	New watermains	168	$250.00	$150,000.00
			Subtotal Item 6 - OUTSIDE PIPING	**$150,000.00**
Mechanical				
a)	Mechanical piping and equipment	1	$100,000.00	$190,000.00
			Subtotal Item 7 - MECHANICAL	**$190,000.00**
Plumbing				
a)	Plumbing work	1	$25,000.00	$25,000.00
			Subtotal Item 8 - PLUMBING	**$25,000.00**
Heating and Ventilation				
a)	HVAC work	1	$60,000.00	$60,000.00
			Subtotal Item 9 - HVAC	**$60,000.00**
Corrosion Protection and Painting				
a)	Architectural	1	$15,000.00	$15,000.00
b)	Mechanical piping and equipment	1	$15,000.00	$15,000.00
			Subtotal Item 10 - CORROSION PROTECTION & PAINTING	**$30,000.00**

Biofilter + RO + UV				
	Description or Classification of Work	**Approx. Qty**	**Unit Price ($)**	**Total Price ($)**
Electrical				
a)	Electrical MCC (VFDs in vendors scope)	1	$250,000.00	$250,000.00
b)	MCC control section	1	$175,000.00	$175,000.00
c)	Instrumentation	1	$50,000.00	$50,000.00
d)	All other associated electrical work (conduits, cables, etc.)	1	$100,000.00	$100,000.00
			Subtotal Item 11 - ELECTRICAL	**$575,000.00**
	Treatment Equipment			
a)	Package Treatment Plant: SIBROM	1	$1,550,000.00	$1,550,000.00
b)	UV Disinfection System	2	$65,000.00	$130,000.00
c)	Chlorination System	1	$25,000.00	$25,000.00
d)	Start-up, testing and commissioning	1	$30,000.00	$30,000.00
			Subtotal Item 12 - TREATMENT EQUIPMENT	**$1,735,000.00**
	SUBTOTAL ITEMS 1 though 12			**$4,337,500.00**
	CONTINGENCY (20%)			**$867,500.00**
	ENGINEERING (10%)			**$433,750.00**
	TOTAL (EXCLUDING GST)			**$5,638,750.00**
			SAY	**$5,650,000**

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