WHISKEY CREEK
WATER SERVICE AREA

WATER TREATMENT OPTIONS

SEPTEMBER 2014

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Consulting Engineers

Parksville, BC

Serving Vancouver Island since 1987

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September 10, 2014

Regional District of Nanaimo
6300 Hammond Bay Road
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Attention: **Gerald St. Pierre, P.Eng., PMP**
Project Engineer - Water and Utility Services

Re: Regional District of Nanaimo
Whiskey Creek Water Service Area – Water Treatment Options

Koers & Associates is pleased to submit three (3) hard copies and one (1) electronic copy of our final report entitled, "Whiskey Creek Water Service Area – Water Treatment Options". Comments provided by the RDN have been incorporated into this report.

The report provides recommendation on future water treatment processes and how to implement them, while adhering to Island Health's 4-3-2-1 Surface Water Treatment Objectives. The report entailed a detailed review of the available water quality analysis reports and conceptual water treatment processes.

Should you have any questions regarding our report, please do not hesitate to contact us.

Yours truly,

KOERS & ASSOCIATES ENGINEERING LTD.

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA K.R. DOLL # 37152
Sept 10/14

Ken Doll, PEng
Project Engineer

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA C. L. DOWNEY
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Enclosures

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1.0 INTRODUCTION

1.1 AUTHORIZATION

On June the 16th, 2014, the Regional District of Nanaimo authorized Koers & Associates Engineering Ltd. to review the Whiskey Creek's surface water supply and to assess viable water treatment processes that would enable the Whiskey Creek to achieve compliance under Island Health's 4-3-2-1 surface water treatment objectives.

1.2 SCOPE OF WORK

The scope of work is to include:

- Review the existing infiltration collection and treatment system and comment on any potential upgrades/changes.
- Collect required raw water data for high turbidity and colour events, analyze, and provide options and recommendations for treatment processes.
- Investigate and recommend options for detailed design and construction methodologies in order to bring the recommended treatment option online as quickly as possible. This should include investigation of both packaged treatment and stick-built building options.
- Ensure treatment options meet the Island Health 4-3-2-1 Drinking Water Treatment for Surface Water Policy.
- Consult with Island Health to confirm the acceptance of the recommended treatment solutions.
- Ensure recommended building, distribution, and treatment solutions meet the latest MMCD standards.
- Provide Class C Engineering, Construction, and Lifecycle cost estimates for the recommended option(s), including power usage, operations and maintenance requirements, land use considerations, and any storage/distribution system upgrades required.
- Provide a complete report that includes of all the above items as a final deliverable.

2.0 BACKGROUND

2.1 HISTORY AND OWNERSHIP

The Regional District of Nanaimo took over ownership and operation of the Whiskey Creek water system in 2012 in response to the request from the majority of the owners of properties that the water system services. It was developed in the 1970's and was initially operated by the subdivision developer, Westerlea Estates Ltd. It presently has 123 connections, all residential properties, with an estimated service population of approximately 300 people.

2.2 SURFACE WATER SOURCE

Crocker Creek is subject to high turbidity and colour spikes following significant rainfall events and during the spring when creek flows are higher. While the current water treatment system (polymer addition followed by sand filtration) is able to reduce the turbidity and colour, there have been times when the acceptable limits are exceeded and a water quality advisory is issued. Also, historic water quality testing performed by the RDN at Crocker Creek has indicated elevated iron and manganese, which on occasion exceeded the aesthetic objective limit in the Guidelines for Canadian Drinking Water Quality.

2.3 WATER SYSTEM OPERATING CONDITIONS

The RDN's 2014 operating permit issued by Island Health includes four conditions.

Condition 1 requires the water system owner to provide a residual level of disinfectant within the water distribution system. It is recommended that the level of residual disinfectant measured at any point within the distribution system be at least 0.2 mg/L, measure as free chlorine. The maximum residual disinfectant concentration, shall not exceed 4.0 mg/L, or as combined chlorine shall not exceed 3.0 mg/L anywhere in the distribution system. This does not apply in situations where watermains are being super chlorinated during their installation, repair or routine maintenance.

Condition 2 requires that trihalomethance (THM) testing be conducted in a quarterly basis at the point in the distribution system with the highest potential THM levels. The maximum acceptable concentration (MAC) for THMs in drinking water is 0.100 mg/L based on a locational running annual average of a minimum of quarterly samples.

Condition 3 requires the water system owner to ensure the persons operating the water system are certified to operate, maintain or repair the drinking water system at the level of system classification, as classified by the Environmental Operators Certificate Program (EOCP).

Condition 4 requires the water system owner provides a finished water quality using technology that will achieve the following performance standard:

- 4-log removal/inactivation of viruses,
- 3-log removal/inactivation of Giardia cysts and Cryptosporidium oocysts,
- provide two treatment processes and
- produce finished water with less than 1 NTU turbidity.

2.4 WATER LICENCES AND DAILY CONSUMPTION

Water is withdrawn from Crocker Creek under two water licences issued by the provincial government as listed in Table 1. There are a total of eight water licences issued on Crocker Creek.

Table 1 – RDN Crocker Creek Water Withdrawal Licences

Licence No.	Priority Date	Daily Withdrawal Limit	
		m^3/day	(lps)
C039791	Nov 16, 1970	95	(1.1)
C045726	Feb 22, 1973	198	(2.3)
	Combined Total:	**293**	**(3.4)**

It is reported in the Whiskey Creek Water Service Area Annual Report 2012 that the system water demand varied from approximately 0.34 m^3 per day per household (42 m^3/day total system demand) in the fall and winter months to 0.59 m^3/day per household (72 m^3/day total system demand) in the summer. The peak flow through the existing water treatment plant is reported to be 210 m^3/day (2.43 lps).

2.5 EXISTING WATER SUPPLY SYSTEM

The water system is supplied by Cocker Creek through an infiltration gallery consisting of two 150 mm diameter 6 m long perforated pvc pipes, underneath 1.05 m (3 ½ ft) of graded sand layers. The pipes are connected to a concrete clear well. The water is withdrawn from the clear well by one of two pumps and then dosed with a polymer and passed through a pressurized sand filter for turbidity and colour reduction before being chlorinated and discharged into the 160 m^3 (35,000 igal) concrete storage reservoir. The infiltration gallery and water treatment building are located at 3475 Hebert Way, while the water storage reservoir is located at 979 Poplar Way. A booster pump station at the reservoir site, pumps water out of the reservoir and into the distribution system.

Since 2012, the RDN has undertaken a number of system upgrades including installing alarms at the treatment building and the reservoir site, and carrying out upgrades to the diversion berm and weirs for the infiltration gallery impoundment area. The existing media filtration system and associated piping are nearing the end of their useful life and are not considered salvageable.

2.6 KEY CHALLENGES

Similar to other small water systems, the Whiskey Creek Water Service Area has a number of challenges to overcome in order to meet Island Health's 4-3-2-1 Surface Water Treatment Objectives. The challenges identified during the preparation of this study are identified below:

- Whiskey Creek relies solely on a surface water source for its drinking water. The quality of surface water in Crocker Creek typically fluctuates up and down depending on the severity of rainfall events in the watershed. Elevated turbidity, colour and organic carbon levels tend to spike on many Vancouver Island surface water sources and removal of these parameters usually requires complex treatment processes.

- There is no existing sewage collection system at the location of the proposed water treatment facility. Complex treatment processes that reduce colour and organics in drinking water produce a waste sludge that needs to be discharged or treated on site.

- Similar to other small communities on Vancouver Island, Whiskey Creek has a limited tax base and finds it very difficult to take on capital projects without funding assistance from higher levels of government.

3.0 WATER QUALITY ASSESSMENT

3.1 CROCKER CREEK WATER QUALITY

The Regional District of Nanaimo has carried out water quality testing on the Crocker Creek water source. The analysis results have indicated elevated colour and turbidity at certain times, likely after rainfall events.

3.1.1 Turbidity

Insoluble particles of soil, organics, microorganisms, and other materials impede the passage of light through water by scattering and absorbing rays. This interference of light passage is referred to as turbidity. Turbidity is measured in Nephelometric Turbidity Units (NTU), where low NTU is associated with low levels of scattering and absorption of light, and therefore low amounts of particles in the water. Elevated turbidity can decrease the effectiveness of disinfection, allowing pathogens to enter the distribution system.

Turbidity is important to control in water supplies for both health and aesthetic reasons. Suspended matter can harbour microorganisms, such as cryptosporidium and giardia, protecting them from disinfection processes. These microorganisms can cause outbreaks of illness. Turbidity levels in daily raw water samples taken between January, 2012 and April, 2014 regularly exceed 1 NTU. It is likely that these daily grab samples did not capture the most extreme turbidity event. An online turbidity analyzer that is calibrated regularly and capable of storing continuous turbidity data would provide the information necessary to determine the severity of these events and assist with the design of the treatment process.

Turbidity data can be seen on the following page. Figure 1 presents a plot of the turbidity in the raw and treated water from February 2012 to April 2014.

3.1.2 Colour

Hues in water may result from natural minerals and vegetation origins, such as humus material and tannins or coloured wastes from a variety of industries such as logging and mining. Colour in water is reported as true colour and apparent colour. True colour is usually due to colloidal organic compounds only and apparent colour is due to a combination of coloured suspended matter and colloidal organic compounds.

Daily apparent colour testing conducted by the RDN between 2012 and 2014 has indicated elevated levels. Since the completion of the berm upgrades all samples results for apparent colour have exceeded the Aesthetic Objective of 15 CU.

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Figure 1: Whiskey Creek Water Service Area
Crocker Creek
Raw & Treated Water Turbidity, 2012 - 2014

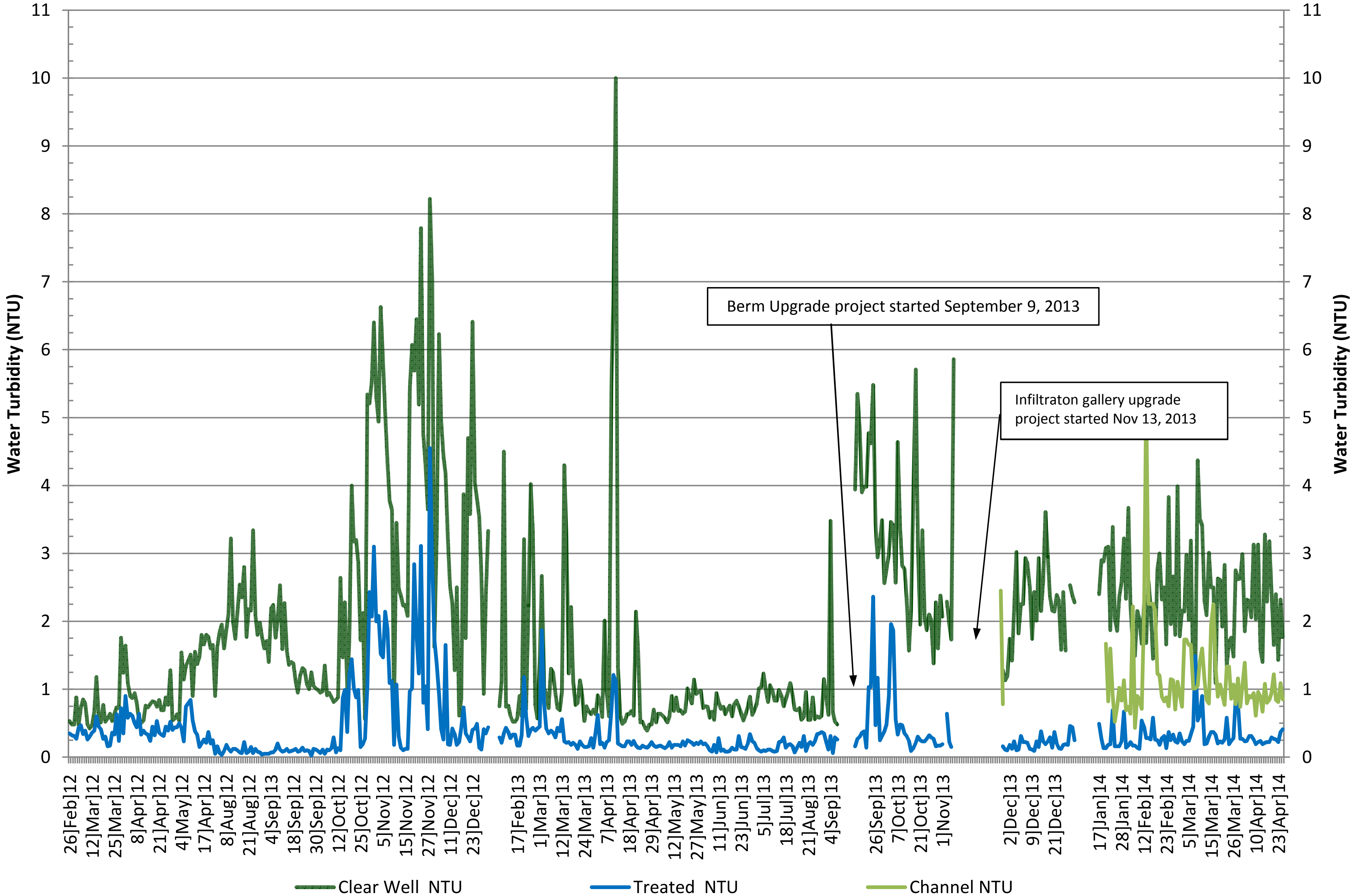

FIGURE 1

Based on the photos provided by the RDN the berm upgrades included the placement of a fine sand layer directly above a layer of pea gravel and clear well intake. Following the placement of this sand, the turbidity temporarily increased due to fine silt and clay particles migrating into the pea gravel layer, through the intake and eventually fouling the media. Following replacement of the media the turbidity has normalized at a higher concentration than previously measured at the creek. This is likely due to the berm upgrades, which included the installation of a geotextile liner below the infiltration gallery intake and repair of the existing clearwell preventing potential ground water infiltration. These improvements may have reduced the groundwater recharge in the impoundment area and clear well, potentially increasing the ratio of surface water to groundwater and resulting in an increased concentration of colour and turbidity.

Apparent colour data can be seen on the following page. Figure 2 presents a plot of the colour in the raw and treated water from March 2013 to April 2014.

3.2 DISINFECTION BY-PRODUCT FORMATION

Elevated colour can be an indication of high organic content which can react with chlorine and create disinfection by-products (DBPs) such as trihalomethanes (THMs), which are suspected carcinogens.

3.2.1 Trihalomethanes (THM)

THMs are a group of compounds that can form when water is treated with chlorine and the chlorine reacts with naturally occurring organic matter that is present in the raw water. The four most common THMs found in drinking water are chloroform, bromodichloromethane, dibromochloromethane, and bromoform, with chloroform being the most common.

THM formation potential is generally higher in surface water, like Crocker Creek, compared to groundwater, because of higher organic content in surface water. The rate of formation of THM is a function of temperature, with higher water temperatures increasing the formation rate. As a result, higher THM concentrations can occur during the summer months as surface water temperatures increase.

3.2.2 Total Organic Carbon (TOC)

TOC is in a wide variety of organic compounds found in runoff containing decaying vegetation. TOC is used as a surrogate measure of the capacity of the drinking water to form disinfection by-products. Dissolved Organic Carbon (DOC) is the dissolved fraction of TOC.

Total and dissolved organic carbon (TOC / DOC) are good indicators of the potential for the formation of THMs and can be tested at a much lower cost than

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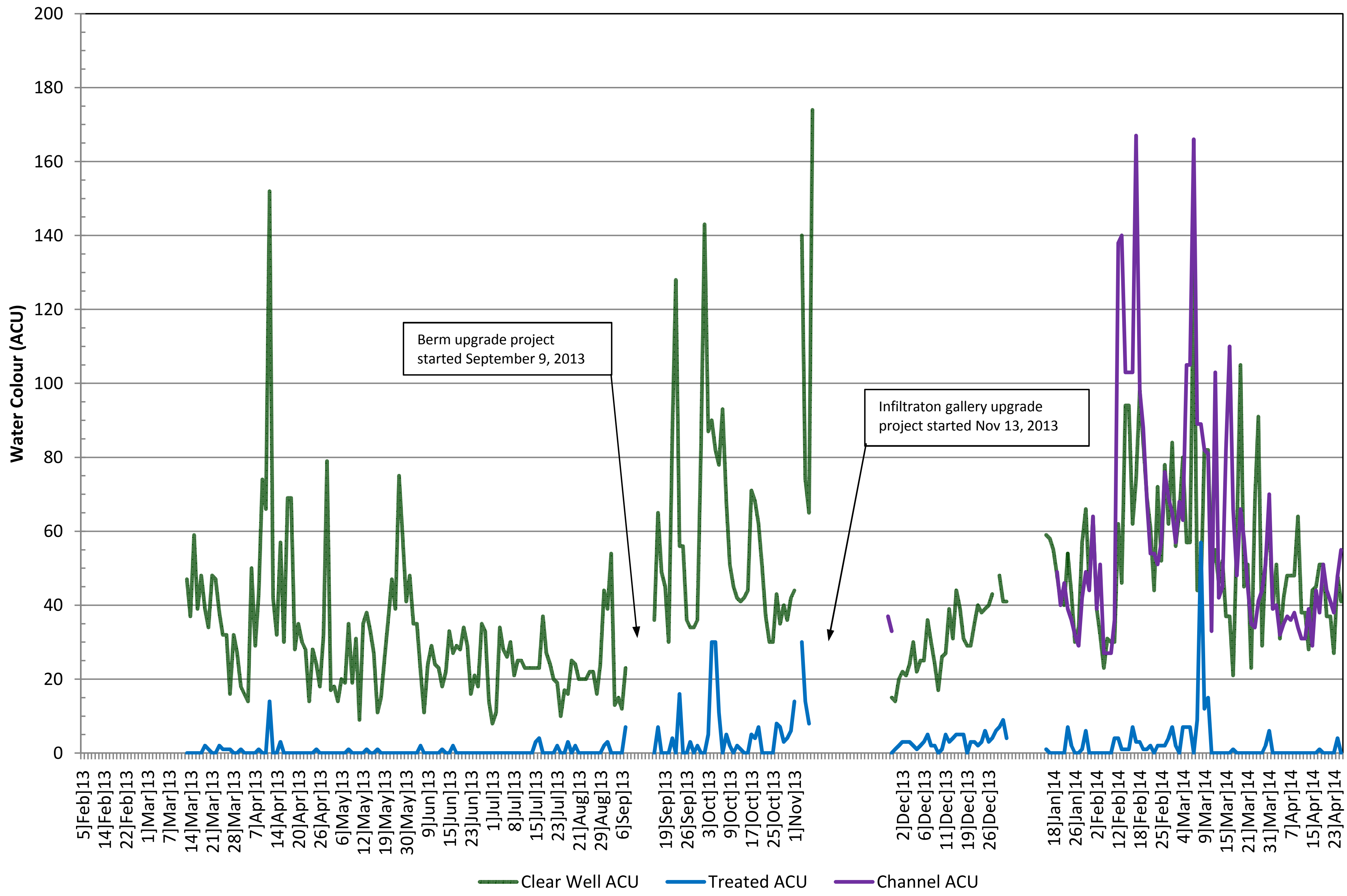
Figure 2 : Whiskey Creek Water Service Area
Crocker Creek
Raw & Treated Water Apparent Colour, 2013 - 2014



THMs. In general, it is desirable to reduce TOC concentrations in the treated water to less than 2 mg/L, in order to reduce the precursors associated with disinfection by-product formation.

3.3 FUTURE WATER QUALITY TESTING

Additional raw water testing data is recommended to assess the range and rate of change in water quality that the treatment process will experience. Samples should be collected after heavy rainfall events. Each analysis should be performed on raw water and at a minimum include; TOC, DOC, turbidity, true and apparent colour, UVT (unfiltered), pH and alkalinity, total and dissolved metals. The test results would be used to assess or confirm potential treatment processes which would be tested by setting up small-scale pilot plants. A pilot testing program would confirm which treatment process will be most effective at treating the raw water supply.

4.0 WATER TREATMENT ASSESSMENT

4.1 TURBIDITY REDUCTION METHODS

Turbidity is reduced by physically removing particles by passing the raw water through a porous medium. The most common types of filtration systems used for reducing turbidity are chemically assisted filtration, gravity granular media filtration, and membrane filtration.

Filtration systems should be designed and operated to reduce turbidity levels as low as reasonably achievable and strive to achieve a treated water turbidity target of less than 0.1 NTU (Guidelines for Canadian Drinking Water Quality).

A surface water source may be permitted to operate without filtration if the source water and treatment processes can meet certain criteria mandated by the local health authority. Island Health's current policy states that, under the following conditions a water supply system may be permitted to operate without filtration:

- Average daily source water turbidity levels measured at equal intervals (at least every 4 hours) – 1 NTU or less (95% of days) and not above 5 NTU on more than 2 days in a 12 month period.
- Escherichia coli 20/100ml or less in 90% of source water samples.
- Two primary disinfectants are provided, which together achieve a 4-log removal/inactivation of viruses and 3-log reduction in Giardia and Cryptosporidium.

Historic turbidity data collected between 2012 and 2014 by the RDN indicated turbidity levels were > 1 NTU on numerous occasions. Therefore, we do not believe Island Health would issue a filtration deferral for Crocker Creek.

4.2 COLOUR REDUCTION METHODS

For municipal systems, there are two general methods for reducing colour, TOC, and DOC. These include removal of the naturally occurring organics from the source water using treatment or switching to an alternate water source.

There is no simple method of reducing naturally occurring organics from a potable water supply. Treatment processes that use an oxidizing agent and/or activated carbon may provide satisfactory removal. However, based on our experience a more complex treatment process is typically required to remove the organics from surface waters on Vancouver Island. These processes typically consist of conventional treatment or nanofiltration. Once a potential process has been identified, pilot testing is needed to determine treatment effectiveness.

Since dissolved organics can pass through granular media filtration systems, we do not anticipate that the upgrades to the river bank filtration system, infiltration gallery, berm or construction of a shallow well using natural filtration will remove the dissolved organics in the raw water. Should the colour and turbidity return to their original (pre-berm) concentration, the outcome of the treatment process selection would remain the same. Therefore, we do not recommend that funds be allocated to these upgrades.

The review of alternate water sources is outside the scope of this study; however the Regional District may want to consider the feasibility of constructing a new well on the existing water treatment building site. For preliminary discussion purposes, the cost to engage a hydrogeologist and install a test well would be approximately $50,000. A high quality groundwater source not under the influence of surface water may delay the need for additional treatment or result in a simplified dual disinfection treatment system and not filtration, resulting in lower treatment costs. The exploration process would begin with the review of available existing well information in the Whiskey Creek area, including existing well capacity and quality, land features, topography, geology, soils, terrain and aquifer mapping.

4.3 WATER SYSTEM DEMANDS

Water treatment equipment is typically sized to service future max day demands based on projected population growth. Based on discussions with the RDN, the Whiskey Creek Service Area is completely built out with the exception of two lots.

The 2013 maximum day demand data presented below in Table 2 was derived from daily meter records provided by the Regional District of Nanaimo. In general, the highest water usage occurs in the summer.

Table 2 also shows the amount of water that Whiskey Creek can divert from Crocker Creek. Whiskey Creek has two water licences on this source which allow an overall maximum withdrawal of 107,026 m^3/year (3.4 lps).

Table 2 – 2013 Water Demands

Date	Consumer	Maximum Day Demand		Estimated Peak Hour
		m^3/day	lps	lps
Feb 26, 2013	Whiskey Creek	241	2.8	5.6
	Licenced Withdrawal	*293*	*3.4*	

The 2013 daily meter records provided by the Regional District of Nanaimo indicate a maximum day demand of 241 m^3 occurring on February 26, 2013 (including backwash consumption). Backwash consumption has been estimated by multiplying the number backwashes that occurred on that day by the specified backwash volume of 1.42 m^3 (375 USgals). This equates to an estimated backwash volume of 15 m^3. Therefore, the estimated water consumption for Whiskey Creek service area has been approximated by taking the max day consumption and subtracting the estimated backwash water to waste. This equates to an estimated design flow of 2.6 lps (226 m^3/day). This number will be used for the purpose of estimating treatment equipment costs and should be confirmed prior to procurement or detailed design.

The Whiskey Creek service area currently consists of 123 residential lots and the service area is almost completely built-out for the exception of two empty lots. Also, there are no plans to expand the water service area. Assuming a density of 2.4 capita per dwelling unit, the max day water use equates to 765 lpcd. In general, higher per capita demands can be expected with smaller populations. However, Whiskey Creek’s per capita consumption is similar to larger communities on the Island. For example, the max day demand for Nanaimo (2013) and Port Alberni (2013) was 870 lpcd and 1072 lpcd respectively.

The peak hour demand is estimated by multiplying the maximum day demand by 2.0. Storage reservoirs provide peak hour balancing and emergency storage required during power outages and for fighting fires. Water system modelling was not part of this assignment.

4.4 WATER TREATMENT PLANT CAPACITY

Based on the information provided by the RDN the water treatment plant design capacity of 2.6 lps (226 m^3/day) has been used to estimate the cost of the proposed water treatment facility. The plant capacity is based on the most recent metering data that is currently available for Whiskey Creek and should be confirmed prior to equipment procurement or detailed design. If population growth or additional water demands are anticipated, then additional treatment plant capacity would be required. During design, the building and piping could be configured to accommodate future expansion of each treatment process.

5.0 WATER TREATMENT OPTIONS

5.1 WATER TREATMENT PROCESS OPTIONS

Understanding the capabilities of the various treatment processes to effectively deal with water quality issues, it is possible to conceptualize potential treatment processes prior to completing pilot testing. The following processes are considered viable options.

5.1.1 Conventional Treatment

For municipal systems, the conventional treatment process for reducing turbidity and naturally occurring organic matter is coagulation, flocculation and sedimentation (floatation) followed by filtration. A chemical agent (coagulant) is added to the water to encourage suspended solids to bind together to form larger particles (flocculation). These larger particles are then removed after they sink (sedimentation). For low density particles, the process of Dissolved Air Floatation (DAF) can be used in place of sedimentation. DAF introduces a cloud of very fine air bubbles which attach to the floc particles causing them to rise to the surface where they are skimmed off. Following either of these two processes the water is typically filtered to remove the remaining particulate matter. Pilot studies are required to assess the effectiveness of various treatment processes. Jar tests can be performed to determine coagulant types, dosages and optimum pH for floc formation. Alkalies are added to water to adjust the pH for optimum coagulation. If the water does not contain sufficient alkalinity to react with the coagulant, then lime, sodium hydroxide or soda ash is fed to provide the necessary alkalinity.

The treatment processes associated with the removal of organics all generate significant waste streams that need to be discharged into a municipal sewer or an onsite disposal system. The existing municipal sewage collection system does not currently extend anywhere near the proposed water treatment plant site. Therefore a holding tank from which filtered sludge or solids can be pumped and hauled to a landfill will be required.

5.1.2 Ozone Disinfection

Ozone is a strong oxidizing gas that reacts with most organic and many inorganic molecules. It is more reactive than chlorine. The reaction is rapid in inactivating microorganisms and oxidizing metals such as iron and manganese. Unlike chlorine, it does not leave a residual after being added to the water. Since ozone does not produce a disinfecting residual, chlorine is normally added afterwards to provide a protective residual throughout the distribution system.

5.1.3 Ultraviolet Disinfection

Ultraviolet Disinfection works by inactivating microorganisms. The UV light penetrates the DNA of a microorganism altering it such that the microorganism is unable to reproduce. Interest in using UV light to disinfect drinking water is growing among public water systems due to its ability to inactivate pathogenic microorganisms without forming disinfection byproducts (DBPs). UV is capable of providing disinfection without the addition of chemicals, avoiding the potential of generating DBPs such as THMs. UV is most effective against cysts such as Cryptosporidium and Giardia. However, UV does not maintain a residual within the distribution system and some double stranded viruses may be able to withstand doses of 40 mJ/cm^2. Also, UV treatment on its own can be ineffective when turbidity spikes and/or high colour events occur in the raw water supply.

5.1.4 Gravity Filtration (GF)

Water enters a gravity filtration system above the media and passes downward through the granular media and supporting gravel bed. A typical filter bed is placed in a concrete box. Filters are cleaned by backwashing upward through the bed with wash troughs suspended above the filter to collect the backwash water for disposal. Gravity filters can be used effectively for source water with lower turbidity levels. Pilot testing is required to confirm the treatment effectiveness of gravity filters during high turbidity events.

5.1.5 Membrane Filtration (MF)

Membrane filtration involves passing water through microscopic pores causing the suspended and/or dissolved solids to be physically strained out of the water. There are different types of membranes, which are classified by pore size. From largest to smallest, they are; microfiltration (10 to 0.1 um), ultrafiltration (0.1 to 0.01um), nanofiltration (0.01 to 0.001 um), and reverse osmosis with pour sizes as small as 0.001 um. Micro and ultrafiltration membranes have limited ability to remove dissolved organics and the addition of a coagulant may be necessary. Inappropriate use of a coagulant can shorten the life of membranes. Pilot testing is typically required to verify whether or not particle removal can be improved with coagulant addition.

Membrane treatment systems have a smaller footprint compared to gravity filtration systems, but are more technically complex, have higher energy consumption and operation and maintenance costs.

Prior to pilot testing it is important to select a couple of viable treatment processes that are currently available from reputable suppliers.

5.1.6 Reverse Osmosis (RO)

Filtration by the process of RO involves using water pressure to force water through a semi-permeable membrane, leaving dissolved and suspended contaminants behind. A waste stream is created during backwashing when the accumulated contaminants are flushed off the surface of the membrane. RO units are very effective at removing very fine particulate and most dissolved material. However, elevated turbidity and organic loadings can reduce membrane capacity (flux) requiring excessive backwashing and waste generation. RO can also cause low alkalinity water to become deficient in alkalinity, requiring pH adjustment following treatment. Also, these units can have high capital costs, high volume of waste, and can require an elevated level of operator training.

A high pressure pump is typically required to push the water through the membrane, resulting in higher energy consumption. The adequacy of the existing single phase electrical service and RO pumping requirements will need to be reviewed in detail once a membrane has been selected.

5.1.7 Cartridge and Bag Filtration

The most common method of filtration for smaller water systems are cartridge and bag filters. The particle size of the impurity present in the raw water typically dictates the type of filter media. Typically a NSF 53 filter cartridge for cyst reduction is required. Additionally, different types of adsorptive filter media are available, such as activated carbon. Carbon's particles have a large surface area with high adsorptive qualities. Activated carbon can be used to reduce dissolved organic carbon compounds that are generated by decaying vegetation in the watershed, which is the main cause of high colour events. These cartridges are relatively simple to install and maintain and offer a lower initial capital cost. However, disposable cartridge and bag filters may have higher maintenance costs for water high in turbidity and organics. Extreme turbidity events may require filters to be replaced immediately. Pilot testing is recommended to determine replacement frequency.

5.2 PACKAGED WATER TREATMENT PLANT

Packaged water treatment plants typically consist of a modular building enclosure or trailer unit that houses multiple treatment processes (typically filters) which are pre-assembled and then set-up onsite in a cost effective manner as compared to constructing a conventional treatment facility. A packaged treatment plant will still require an adequate power supply, inlet/outlet piping connections to the downstream treated water reservoir to help supply peak demands, and a method of disposing of the waste products that are backwashed from the filters. Therefore, we don't feel that a modular building enclosure will provide significant installation advantages over a traditional wood frame building addition.

These plants can be an attractive option for small water system purveyors in remote locations that find it difficult to construction a conventional treatment facility. As with any water treatment process, a package plant must be designed to meet the Island Health's 4-3-2-1 surface water treatment objectives. Based on the water quality data that is currently available, the most challenging aspect of treating the Whiskey Creek's surface water supply will likely be removal of the organics following rainfall events. It will be the responsibility of the water purveyor to demonstrate to the Island Health that the packaged system can effectively treat the source water to the desired quality.

For Whiskey Creek, the cost difference between a prefabricated modular building enclosure and traditional wood frame building addition is negligible.

5.3 TREATED WATER EFFLUENT DISPOSAL

There is no existing sewage collection system at the location of the proposed water treatment facility. Complex treatment processes that reduce colour and organics in drinking water produce a waste sludge that needs to be treated on site or stored and hauled to a landfill.

Discharges from drinking water treatment plant processes are not listed in the Waste Discharge Regulation; therefore they do not require authorization under the Environmental Management Act (EMA). However, EMA 6(4) does apply, which indicates that waste must not be in introduced into the environment in such a manner or quantity as to cause pollution.

Upgrades to the existing disposal/collection system will be required. The type of waste being generated will determine the complexity and cost of the disposal/collection system. A variety of methods are employed for disposing of drinking water treatment sludge, including lagoons, landfills and sewer systems. For example, the installation of a below grade tank that decants into a rock pit may be acceptable for wastes with low risk of pollution. Higher risk wastes or sludge will need to be disposed offsite to a landfill. Conventional treatment processes can consist of both high and low risk effluent discharges.

5.4 TREATMENT PROCESS OPTIONS

The selection of treatment processes and equipment depend on an evaluation of the nature and quality of the particular water to be treated, seasonal variations and the desired quality of finished water. A number of the treatment processes identified can be too costly and complicated for use at small water systems. For example, ozone disinfection typically requires a biological filtration process which is complex and can be challenging to operate.

Two readily available and proven treatment processes which are considered viable options are conventional treatment (DAF) and reverse osmosis (RO). These treatment process options are recommended based on proven effectiveness, availability and relative operational complexity.

Table 3 below shows treatment process options and their theoretical treatment effectiveness.

Table 3 - Summary of Treatment Effectiveness for Conceptual Process Options

	Conceptual Treatment Effectiveness				
	Giardia Crypto	**Viruses**	**Colour**	**Turbidity**	**Residual**
Option 1:					
Coagulation	✓**	-	✓	-	-
Gravity Filtration	-	-	-	✓*	-
UV (tbd)	✓	-	-	-	-
Chlorination	-	✓	-	-	✓
Option 2:					
Cartridge/Media	-	-	-	✓	-
RO	✓***	-	✓	✓	-
UV (tbd)	✓	-	-	-	-
Chlorination	-	✓	-	-	✓

*limited turbidity reduction on its own
**depending on (oo)cyst level in source water - UV disinfection may be required
***removal efficiency demonstrated through challenge testing and verified by direct integrity testing (GCDWQ)

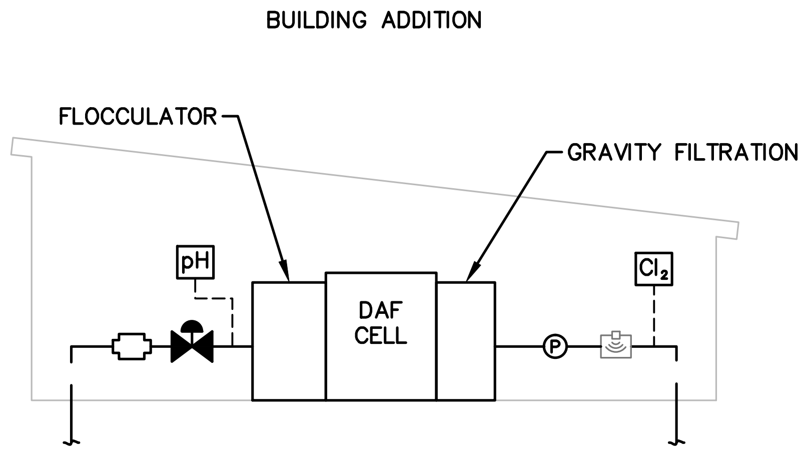
It is important to note that both treatment processes will create a waste sludge that will need to be treated onsite or delivered to a treatment facility. The volume of waste that is generated from each treatment process can be assessed during pilot testing.

The following minimum level of treatment for microbiological contaminants will have to be provided as stated in the Guidelines for Canadian Drinking Water Quality (GCDWQ).

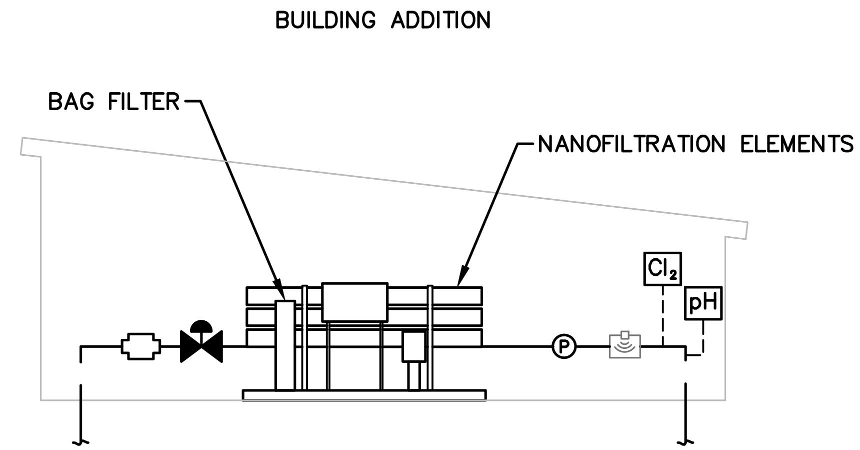
Table 4 – Microbiological Treatment Requirements

Target Pathogens	**Removal/Inactivation**
Cryptosporidium	3 log (99.9%)
Giardia	3 log (99.9%)
Viruses	4 log (99.99%)
Bacteria	100%

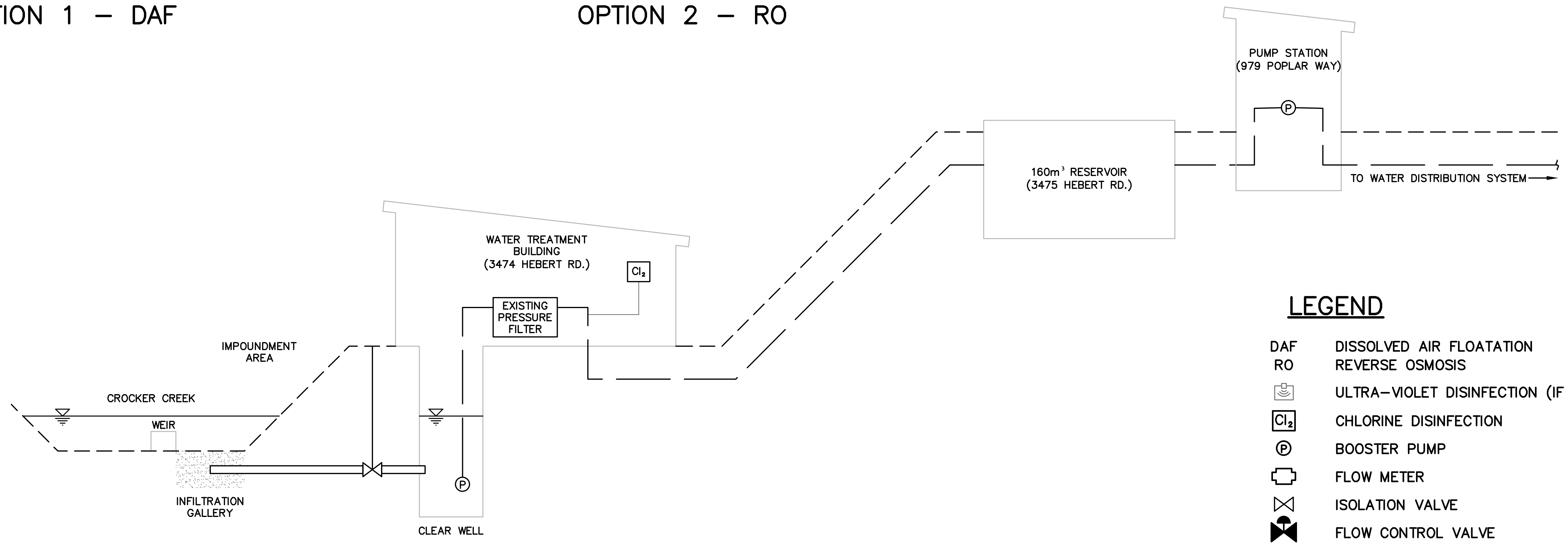
Therefore, depending on the type of equipment installed it may be necessary to include a UV disinfection system to satisfy the Cryptosporidium and Giardia



OPTION 1 – DAF



OPTION 2 – RO



LEGEND

DAF	DISSOLVED AIR FLOATATION
RO	REVERSE OSMOSIS
	ULTRA-VIOLET DISINFECTION (IF REQUIRED)
Cl_2	CHLORINE DISINFECTION
(P)	BOOSTER PUMP
	FLOW METER
	ISOLATION VALVE
	FLOW CONTROL VALVE
pH	pH ADJUSTMENT (IF REQUIRED)

EXISTING WATER SUPPLY AND TREATMENT SYSTEM

KOERS & ASSOCIATES ENGINEERING LTD.
Consulting Engineers
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CLIENT	REGIONAL DISTRICT OF NANAIMO
PROJECT	WHISKEY CREEK WATER TREATMENT OPTIONS

TITLE	CONCEPTUAL WATER TREATMENT OPTIONS OPTION 1 – DAF AND OPTION 2 – RO		
APPROVED		SCALE	NTS
DATE	AUGUST 2014	DWG No.	1435–Fig. 3
PROJECT No.	1435		

inactivation requirements noted above. The local Health Authority should be notified once the treatment process and equipment has been selected to discuss overall Cryptosporidium and Giardia removal credits.

5.5 PILOT TESTING

Pilot testing is a very important first step in the process of selecting a treatment technology. Small scale pilot plants are used to prove out the treatment technology and make sure it can achieve the desired results before proceeding with a costly full scale treatment plant. The information collected during pilot testing is typically used to:

- Compare alternative treatment processes.
- Investigate new treatment processes if selected processes are unsuccessful.
- Demonstrate confidence in recommended treatment processes.
- Establish design criteria for the full scale plant.

Pilot testing should be conducted for an adequate period of time to enable analysis of treatment effectiveness and conducted during a time of year when significant rainfall events normally take place in the watershed and water quality issues (turbidity and colour spikes) are most likely to occur. Pilot plants are typically set-up to treat a small flow. These small scale plants need to be sourced and then rented for the duration of testing. The pilot plant will require its own power supply, raw water feed, and drain to waste, so it can operate while the existing system is online and operating. They are typically set-up in a trailer unit or temporary enclosure that is heated, secure, and has adequate space to house all the testing equipment.

Pilot testing is of limited use without a detailed testing protocol. Water quality parameters to be tested and the frequency of monitoring during pilot testing need to be established. The drinking water officer and local health authority may have some testing requirements that need to be considered during pilot testing. All monitoring data and process adjustments made to the pilot plant have to be recorded during its operation. To minimize piloting costs, a staff member will have to be trained in the operation of the pilot plant for routine inspection, data logging, taking water samples and reporting. The amount (recovery) and type of waste generated from pilot testing should also be documented.

Following pilot testing, all water quality data and information associated with treatment process operation needs to be reviewed and interpreted. The data should be analyzed and used to support conclusions as to why a particular treatment process would be chosen or eliminated. It is possible that additional follow-up pilot testing may be required prior to selecting the final treatment process. Once satisfactory pilot testing results are obtained, detailed design of the ultimate treatment facility can commence.

5.6 OPERATIONS & MAINTENANCE

Following the installation of the treatment plant water quality testing and on-going maintenance will be required. Water quality monitoring frequency will need to be established and should be based on discussions with the drinking water officer and local health authority.

As part of the equipment installation project it is recommended that the clear well be cleaned and checked for leaks. The water quality data has indicated a higher concentration of turbidity in the clear well than in the channel. This may be due to the settlement of suspended particles in the clear well. The colour test results are more consistent and indicate the dissolved elements are similar in each sample. Therefore, the increased turbidity is likely due to the migration of suspended particles in the clear well.

5.7 OPERATOR TRAINING AND CERTIFICATION

Operator training and certification may be required for the new treatment plant. As a condition on the operating permit, the water system owner must ensure the persons operating the water system are certified to operate, maintain or repair the drinking water system at the level of system classification, as classified by the Environmental Operators Certificate Program (EOCP). British Columbia Water and Waste Association (BCWWA) offer courses to water operators. Allowances for training and operator certification have not been included in the cost estimates.

5.8 PRELIMINARY COST ESTIMATES

The summary table below presents the preliminary Class C cost estimates (±40%) for the conceptual water treatment equipment and building addition. Based on the information collected to-date, the following Table summarizes the estimated capital costs for the water treatment options.

Table 5 – Preliminary Class C Estimated Cost Comparison

	Option 1 - DAF	**Option 2 - RO**
Total Estimated Capital Costs (±40%)	$555,000	$450,000
Estimated Annual O&M Costs (±40%)	$22,000	$30,000
Evaluation based on Estimated Capital and 20 year Life Cycle Costs	$995,000	$1,050,000

The Total Estimated Capital Costs include estimated costs for treatment equipment purchase, installation and treatment facility upgrades including waste tanks, but does not include engineering, public education costs, operator training, initial year water quality monitoring, pilot testing, land acquisition costs, inflation or UV disinfection. An estimated allowance of $25,000.00 should be added if UV Disinfection equipment is required. Breakdown of the preliminary construction cost estimates are included in Appendix A.

The Estimated Annual O&M Costs include allowances for sodium hypochlorite, coagulants, acids & alkalies, media & membrane replacement, pump & haul, electricity and miscellaneous part replacements.

6.0 PHASING OF WORK

6.1 CONCEPTUAL PHASING OPPORTUNITIES

The conceptual treatment processes were developed using water quality information available at the time of this report. Two reputable water treatment equipment suppliers were engaged to provide typical equipment installation details.

Due to the size of the difficult water quality there are limited phasing opportunities for the proposed treatment equipment. The conceptual treatment processes work as a single system and have limited effectiveness on their own.

Pilot testing is a very important first step in the process of selecting a treatment technology. Small scale pilot plants are used to prove out the treatment technology and make sure it can achieve the desired results before proceeding with a costly full scale treatment plant.

Following pilot testing, all water quality data and information associated with treatment process operation needs to be reviewed and interpreted. The data should be analyzed and used to support conclusions as to why a particular treatment process would be chosen or eliminated. Once satisfactory pilot testing results are obtained, detailed design, tendering and construction of the ultimate treatment facility can commence.

An expansion to the building footprint would be required for the addition of any future water treatment equipment. To minimise the time the system is offline the new building addition should be constructed large enough to house the treatment equipment, while the existing filtration and chlorination continues to operate. The installation of new treatment equipment would reduce turbidity, colour and the potential for microorganisms, such as cryptosporidium and giardia, to enter the distribution system.

6.1.1 Option 1 – DAF, GF & Chlorination

Option 1 is based on the assumption that pilot testing proves that Dissolved Air Floatation and Media Filtration (followed by chlorination) is an effective treatment process.

The work would include the piping, building addition, foundation preparation, chlorine disinfection equipment, waste disposal system, electrical, instrumentation, controls, commissioning and Dissolved Air Floatation (DAF) equipment consisting of coagulation, flocculation and floatation (sedimentation) basins and gravity media filtration system.

Option 1 doesn't allow for any phasing opportunities.

6.1.2 Option 2 – RO & Chlorination

Option 2 is based on the assumption that pilot testing proves that Reverse Osmosis with adequate pre-treatment (followed by chlorination) is an effective treatment process.

Phase 1 would include the piping, building addition, foundation preparation, chlorine disinfection equipment, provision for future chemical (coagulant) injection, waste disposal system, electrical, instrumentation, controls, commissioning and Reverse Osmosis equipment including pre-filtration equipment necessary to improve membrane run times and increase the life span of the membranes.

Phase 2 would consist of coagulation, flocculation and mixing equipment, if during regular operation it was determined that fouling on the membranes was causing premature failure.

6.1.3 Additional Treatment Processes – UV & Cartridge Filtration

Ultra-violet disinfection may be required for Option 1 and 2 for Giardia and Cryptosporidium inactivation, if the principle treatment process cannot provide the full 3 log reduction/inactivation.

As an interim measure, there may be opportunities to install cartridge filters following the existing pressure filters system prior to constructing a new treatment facility. These filters offer a lower initial capital cost but would require significant space within the existing building to install. A bank of filter cartridges pre-configured and installed inside individual housings units would be required at a cost of approximately $2,500, not including installation. Replacement cartridges wold cost approximately $850. These disposable cartridge filters will have high replacement frequencies during elevated turbidity events. Pilot testing is required to determine actual replacement frequency. Extreme turbidity events may require filters to be replaced immediately by staff. Therefore we do not feel that operational efficiencies will be gained by installing the cartridge filters prior to constructing a new treatment plant.

7.0 SUMMARY

7.1 SUMMARY AND RECOMMENATIONS

The following comments may be drawn from the work presented in this report:

- The existing filtration system and associated piping are nearing the end of their useful life and are not considered salvageable.

- Since dissolved organics can pass through granular media filtration systems, we do not think upgrades to the river bank filtration system, infiltration gallery, berm or construction of a shallow well using natural filtration will remove the dissolved organics in the raw water. Even if the colour and turbidity returned to their original (pre-berm) concentration wouldn't change the outcome of the treatment process selection. Therefore, we do not recommend that funds be allocated to these upgrades.

- The Regional District may want to consider the feasibility of constructing a new well on the existing water treatment building site. A high quality groundwater source not under the influence of surface water may delay the need for additional treatment or result in a simplified dual disinfection treatment system instead of filtration, resulting in lower treatment costs.

- Dissolved Air Floatation followed by filtration is a proven technology and treatment process. There are several local installations treating water with similar challenges as those in the Crocker Creek drinking water source.

- Treatment processes using coagulants for the removal of organics can generate significant effluent waste discharges that will need to be stored and/or treated onsite. Pilot testing can assist in the evaluation of effluent generation.

- Reverse osmosis can be effective in removing some of the smallest target parameters in drinking water without the use of a coagulant. However, excessive turbidity and colour can foul the membranes causing excessive backwashing and potentially premature replacement of the membrane elements.

- The colour and turbidity concentration appear to have increased, following the completion of the berm upgrades. The increased turbidity and colour concentration will likely impact the treatment process. The elevated colour and turbidity may cause significant membrane fouling and increase the backwash frequency, resulting in a lower recovery rate and the potential for early replacement.

- Jar tests can be performed to determine coagulant types, dosages and optimum pH for floc formation. Alkalies are added to water to adjust the pH for optimum coagulation. If the water does not contain sufficient alkalinity to react with the coagulant, then lime, sodium hydroxide or soda ash is fed to provide the necessary alkalinity.

- Pilot testing is an important first step in evaluating any treatment processes. In particular for reverse osmosis to determine if pre-filtration alone is adequate to improve filters runs and minimise back washing frequencies. It may be determined during piloting that a coagulation/flocculation system is necessary to improve recovery and minimise membrane fouling.

- Ultra-violet disinfection may be required for Giardia and Cryptosporidium inactivation, if the principle treatment process cannot provide the full 3 log reduction/inactivation.

- It is recommended that water quality testing continue into the fall to assess the seasonal variations in water quality. Appropriate sampling conditions were not present during the preparation of this report.

- Preassembled package treatment plants require a similar power supply, inlet/outlet piping connections to the downstream treated water reservoir to help supply peak demands, and a method of disposing of the waste products that are backwashed from the filters. Therefore, a modular building enclosure will not provide significant installation advantages over a traditional wood frame building.

Based on the availability of funds we recommend that the RDN proceed with piloting both Option 1 and 2 to verify the more effective treatment process. However, if the RDN chooses to pilot only one process then we would suggest the DAF system. DAF followed by filtration is a proven technology for removing colour and turbidity.

The DAF supplier (Corix) has offered to perform basic jar testing services at no cost. We suggest the RDN take advantage of this offer and send a raw water sample to Corix. Preferably the sample should be taken during a time when colour and turbidity are elevated. These tests can assist with determining the effectiveness of chemical coagulation on the raw water. Since other factors such as temperature, alkalinity, and pH influence coagulation, we recommend that the jar tests be run to evaluate these parameters. Corix will offer the basic service free of charge, however there may be some additional minor laboratory costs depending on the final testing protocol. Following jar testing we recommend a pilot testing program be developed and implemented. Pilot testing is of limited use without a detailed testing protocol. Water quality parameters to be tested and the frequency of monitoring during pilot testing need to be established.

The pilot testing program should be conducted for an adequate period of time to enable analysis of treatment effectiveness and conducted during a time of year when significant rainfall events normally take place in the watershed and water quality issues (turbidity and colour spikes) are most likely to occur.

Once pilot testing confirms the proposed treatment processes (Option 1 and/or Option 2) will successfully treat the water from Crocker Creek during heavy rainfall events, the Regional District of Nanaimo can proceed with detailed design. A construction permit issued by Island Health will have to be obtained following detailed design and prior to commencing with tendering and construction.

This report can be submitted to Island Health for the purpose of obtaining preliminary approval and an extension to the Whiskey Creek's Water System Operating Permit.

APPENDIX A

PRELIMINARY CONSTRUCTION COST ESTIMATES

PRELIMINARY CLASS C (+/- 25-40%) CONSTRUCTION COST ESTIMATE

OPTION 1 - Dissolved Air Floatation (DAF) & Gravity Filtration (GF)

KOERS ENGINEERING LTD.
Consulting Engineers

Project: Whiskey Creek WTP **Date:** 10-Sep-14

Client: Regional District of Nanaimo

DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	EXTENSION
PROPOSED WATER TREATMENT FACILITY (PH 1)				
SILT CONTROL & SITE DEWATERING	ls	1	$2,500	$2,500
SITE GRADING, DRIVEWAY & DRAINAGE	ls	1	$5,000	$5,000
BUILDING STRUCTURE ADDITION	ls	1	$40,000	$40,000
FOUNDATION PREPARATION FOR BUILDING	ls	1	$5,000	$5,000
PROCESS PIPING INSIDE WTP	ls	1	$20,000	$20,000
BOOSTER PUMPS	ls	1	$15,000	$15,000
METER & CONTROL VALVE	ls	1	$10,000	$10,000
MISC. WATER PIPING & VALVES OUTSIDE WTP	lm	25	$500	$12,500
ELECTRICAL	ls	1	$10,000	$10,000
HVAC & PLUMBING	ls	1	$5,000	$5,000
DAF, GF & CHEMICAL INJECTION EQUIPMENT	ls	1	$275,000	$275,000
ULTRAVIOLET DISINFECTION EQUIPMENT (TBD)	ls	1	$0	$0
NEW CHLORINATION EQUIPMENT	ls	1	$25,000	$25,000
INSTRUMENTATION & CONTROLS	ls	1	$35,000	$35,000
SCADA UPGRADES & INTEGRATION	ls	1	$30,000	$30,000
CONTROL PANEL (TBD)	ls	1	$0	$0
COMMISSIONING	ls	1	$15,000	$15,000
SOURCE WATER TIE-INS & PIPING/VALVES	ls	1	$10,000	$10,000
WASTE HOLDING TANK AND DISPOSAL SYSTEM	ls	1	$40,000	$40,000
			SUB-TOTAL	**$555,000**
	ENGINEERING & CONTINGENCY (40%)			**$222,000**
			TOTAL	**$777,000**
PILOT TESTING FOR 2-3 WEEKS				
EQUIPMENT MOBILIZATION & DEMOB	ls	1	$5,000	$5,000
INITIAL SET-UP & TAKE DOWN	ls	1	$5,000	$5,000
EQUIPMENT RENTAL	wks	3	$1,500	$4,500
PLANT OPERATOR & EXPENSES	days	12	$1,000	$12,000
MISCELLANEOUS CHEMICALS & MEDIA	ls	1	$500	$500
OFF-SITE ANALYTICAL LABORATORY CHARGES	ls	1	$1,000	$1,000
ADDITIONAL TREATMENT PROCESS BY SAME SUPPLIER	ls	1	$14,000	$14,000
			SUB-TOTAL	**$42,000**
	ENGINEERING & CONTINGENCY (40%)			**$16,800**
			TOTAL	**$58,800**

PRELIMINARY CLASS C (+/- 25-40%) CONSTRUCTION COST ESTIMATE
OPTION 2 - Reverse Osmosis (RO)

KOERS ENGINEERING LTD.
Consulting Engineers

Project: Whiskey Creek WTP **Date:** 10-Sep-14
Client: Regional District of Nanaimo

DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	EXTENSION
PROPOSED WATER TREATMENT FACILITY (PH 1)				
SILT CONTROL & SITE DEWATERING	ls	1	$2,500	$2,500
SITE GRADING, DRIVEWAY & DRAINAGE	ls	1	$5,000	$5,000
BUILDING STRUCTURE ADDITION	ls	1	$40,000	$40,000
FOUNDATION PREPARATION FOR BUILDING	ls	1	$5,000	$5,000
PROCESS PIPING INSIDE WTP	ls	1	$20,000	$20,000
REPLACEMENT OF EXISTING SUBMERSIBLE PUMPS	ls	1	$15,000	$15,000
METER & CONTROL VALVE	ls	1	$10,000	$10,000
MISC. WATER PIPING & VALVES OUTSIDE WTP	lm	25	$500	$12,500
ELECTRICAL	ls	1	$12,500	$12,500
HVAC & PLUMBING	ls	1	$5,000	$5,000
REVERSE OSMOSIS EQUIPMENT C/W PRE-TREATMENT	ls	1	$125,000	$125,000
ULTRAVIOLET DISINFECTION EQUIPMENT (TBD)	ls	1	$0	$0
NEW CHLORINATION EQUIPMENT	ls	1	$20,000	$20,000
INSTRUMENTATION & CONTROLS	ls	1	$35,000	$35,000
SCADA UPGRADES & INTEGRATION	ls	1	$30,000	$30,000
CONTROL PANEL (TBD)	ls	1	$0	$0
COMMISSIONING	ls	1	$15,000	$15,000
VARIABLE FREQUENCY DRIVE	ls	1	$15,000	$15,000
SOURCE WATER TIE-INS & PIPING/VALVES	ls	1	$10,000	$10,000
WASTE HOLDING TANK AND DISPOSAL SYSTEM	ls	1	$40,000	$40,000
			SUB-TOTAL	**$417,500**
	ENGINEERING & CONTINGENCY (40%)			**$167,000**
			TOTAL	**$584,500**
PROPOSED WATER TREATMENT FACILITY (PH 2)				
COAGULANT / pH INJECTION EQUIPMENT	ls	1	$20,000	$20,000
INSTRUMENTATION & CONTROLS	ls	1	$5,000	$5,000
SCADA UPGRADES & INTEGRATION	ls	1	$5,000	$5,000
COMMISSIONING	ls	1	$2,500	$2,500
			SUB-TOTAL	**$32,500**
	ENGINEERING & CONTINGENCY (40%)			**$13,000**
			TOTAL	**$45,500**
PROPOSED WATER TREATMENT FACILITY				
			SUB-TOTAL	**$450,000**
	ENGINEERING & CONTINGENCY (40%)			**$180,000**
			TOTAL	**$630,000**