Greater Vernon Water (GVW)

Technical Memorandum No. 7
Water Treatment

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2	Brett deWynter	September 14, 2012	Revised draft submission for client review.
3	Brett deWynter	December 14, 2012	Final draft submission for client review.
4	Brett deWynter	February 6, 2013	Final draft submission for client review.
5	Brett deWynter	March 12, 2013	Final submission including revised raw water turbidity graphs.
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AECOM Signatures

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Table of Contents

Distribution List

List of Figures

List of Tables

1. Introduction

1.1 Introduction

A critical component of any Master Water Plan is identifying and confirming the long term water treatment needs necessary to consistently supply sufficient quantity and quality of potable water to the distribution network in the most cost effective manner. In addition to identifying the treatment processes necessary, the size of the facilities and the cost, are key items that need to be established as part of a Master Water Plan.

In the case of Greater Vernon Water Service (GVW), this is a challenging exercise given the complex range of possible water treatment alternatives due to the multiple water sources and the need to provide two distinct water products to meet the needs of domestic and agricultural customers. The optimal solution must ensure that high quality water is always available for domestic needs, while agricultural customers have access to adequate volumes of water that is not priced to include the expensive and unnecessary addition of water treatment. The technical option analysis must consider not only different treatment options, but also alternative water distribution and storage options that explore possible system separation strategies. Finally, the cost evaluation must use a life cycle approach to costing, since the magnitude of capital and annual O&M costs will factor into the final recommendation.

This technical memorandum firstly confirms the long term water treatment requirements for all domestic water given the characteristics of the individual raw water sources. This sets the base water quality objectives for water treatment. With the water treatment quality objectives well understood, the location of the individual water treatment facilities can be identified. The rationale for the location of the treatment facilities will be explained within this document based on information from previous completed technical memoranda. The final variable that will affect capital and O&M costs is the required sizing and capacity of the water treatment and water distribution infrastructure necessary to meet the long term potable water needs of GVW. This portion of the Master Water Plan must take into account both the domestic and agricultural users.

The size of the treatment plants will vary depending on the ultimate configuration of the domestic, agricultural and the combined water distribution networks. Examined in other technical memoranda is the physical separation of the existing water distribution system into two discrete distribution systems, one dedicated to the supply of potable water and one specifically for irrigation water. With the significant amount of land under irrigation in the GVW service area, the vast majority of water supplied by utility the summer months is allocated purely to irrigation. This has forced the GVW to consider system separation, whereby some or all of the existing distribution system would be sub-divided into separate domestic and irrigation systems, as an alternative to constructing larger water treatment facilities. Provided within this document is a range of operating and capital costs for various different water treatment plant sizes. This cost information will be used in future technical memoranda for the development of different servicing schemes with various water treatment plant sizes and levels of system separation. Subsequent technical memoranda with the Master Water Plan will consider the entire cost of the water system where the optimum size of the water treatment plants will be determined.

This technical memorandum documents the conceptual treatment requirements on the two long term potable water sources, Duteau Creek and Kalamalka Lake. The remainder of this technical memorandum is sub-divided into the following sub-sections:

- **Section 2.0 – Source Raw Water Quality Characteristics** reviews and summarizes the key raw water parameters related to the long term treatment requirements to ensure the water is potable;
- **Section 3.0 – Treated Water Quality Criteria** establishes long term treated water quality objectives based on the current and projected long term treatment requirements;
- **Section 4.0 – Evaluation of the Treatment Requirements** determines the approach and processes necessary to ensure the potable supply of water;
- **Section 5.0 – Long Term Treatment Approach** establishes the recommended treatment processes necessary

to achieve the treated water quality criteria given characteristics of the raw water;

- **Section 6.0 – Evaluation of Cost** presents conceptual level estimates of construction and operating and maintenance costs for a range of different sized water treatment plants based on the preferred treatment approach for the long term potable sources;
- **Section 7.0 – References** lists the documents used as information sources for this technical memorandum.

1.2 Report Objectives

This technical memorandum reviews the raw water quality associated with the long term raw water sources for the services area for the duration of the planning study. This report addresses several items within the Terms of Reference issued by the Regional District. Summarized below are the specific tasks addressed within this document and a brief description of the concern. The task numbering matches the original Terms of Reference.

1. **Task 8 – Establishment of Water Quality Goals:** British Columbia drinking water quality guidelines have changed dramatically in the past couple of years in an attempt to bring the standards to a level comparable to the remainder of North America. The provincial legislation is still far behind typical standards within North America, but BC Health has issued their potable treatment objectives of “4-3-2-1-0 Dual Treatment guidelines”. These guidelines and the other trends from around North America will be examined to establish a set of recommended long term goals for GVW.
2. **Task 9 – Water Treatment Requirements and Goals:** The establishment of long term water treated water quality goals will be established and compared to current treatment levels provided. Treatment deficiencies for the existing potable sources will be identified and described.
3. **Task 10 – Water Treatment Alternatives:** Historically there has been no treatment of the non-potable supply with the exception being the addition of chlorine. Since this is expected to continue to be sufficient for the foreseeable future, this memorandum limits itself to a review of the relevant treatment alternatives necessary to achieve the potable water objectives given the raw water quality of the candidate long term sources.
4. **Task 21 – BC Health Order:** BC Health issued an order that generally stated that water utilities needed to establish a plan to ensure the supply of potable water to the customers. This technical memorandum will describe the treatment required to ensure this directive is met.
5. **Task 23 – Preparation of Phasing Plan:** Within this technical memorandum the conceptual level framework will be established for the logical phasing of the treatment works. However, the detailed phasing plans for the work will be established in other technical memoranda, as well as the summary report.
6. **Task 26 – Filtration Deferral Assessment:** There are specific raw water quality criteria, sampling requirements, watershed management plans and other requirements as stipulated by the regulator for the deferral of filtration. The raw water sources available for the supply of potable water will be reviewed against the established criteria for filtration deferral and an assessment made to determine if the source qualifies. This assessment is critical given the financial benefit of deferring filtration. Also, completed within this task will be an assessment of risk and prioritization filtration given the raw water sources available to the Regional District.
7. **Task 29 – Treatment Infrastructure Requirements:** Given the raw water quality associated with each of the sources necessary to meet the water demand of the service area for the next 50 years and the infrastructure already constructed, an assessment of the additional treatment works required will be provided. The assessment will be based on meeting the treated water demand with treated water quality that meets the long term goals.

1.3 Background

The 2002 Master Water Plan completed a comprehensive review of all the practical water sources available to the GVW Utility. At the time that the previous Master Water Plan was written, there were three separate and somewhat independently operated water purveyors in the Greater Vernon area, the City of Vernon, the District of Coldstream and the Regional District of North Okanagan. Given the somewhat historical independence of the three main water systems, several different raw water sources were used in the past. Since the completion of the previous Master Plan, water licenses have been consolidated (refer to Technical Memorandum 2 for more information) and water supply infrastructure has been abandoned to improve the operational efficiency and water quality supplied to the customers.

A review of the previous Master Water Plan was completed as part of the preparation of this technical memorandum and there is no new information now available that would suggest the previous findings and conclusions need to be re-visited. Provided below is a brief summary of the water source currently being utilized by GVW. Also, provided is an assessment of the long term use of the water sources related to the supply of potable water:

- The **Mission Hill Treatment Facility and the Kalamalka Lake Pump Station** has been upgraded to maximize the licence available resulting in the capacity of the Kalamalka Lake Pump Station being increased to 58 ML/d. The upgraded facility includes mechanical and electrical equipment redundancy typical for a municipal facility. The existing facility provides 2-stages of disinfection consisting of ultraviolet irradiation and chlorine disinfection. The current intake, pump station and treatment facility are all configured for the long term supply of 58 ML/d. The construction of the Mission Hill Treatment Facility beyond the current plan of 58 ML/d will require significantly more modifications than providing filtration to match the capacity of the existing facility.

  The other key issue associated with an increased reliance upon the Mission Hill treatment facility is the existing maximum annual total water license of 8,842 ML/yr. Given the current demand pattern, the existing annual license is heavily relied upon, meaning it is expected that conveying more water from the Mission Hill facility would trigger the need to obtain more license or pursue trying to transfer an existing license. This issue is discussed in more detail with Technical Memoranda 2 and 3.

- **Duteau Creek** currently supplies the largest volume of water to the distribution network, with a significant portion of the water eventually being used for irrigation of agricultural land. The Duteau Creek water is disbursed primarily by gravity and distribution infrastructure is in place to convey a significant volume of water to meet the needs of the GVW customers.

  Duteau Creek, with an intake on Harvey Lake, receives water from three upland storage lakes, Haddo, Aberdeen and Grizzly, located on the Aberdeen Plateau south of the Coldstream Valley, to feed the Duteau Creek system. These reservoirs rely on snow pack and seasonal rains to fill. A control gate on Haddo, the lowest elevation lake, releases water to Duteau Creek. During high snow pack years, overflow structures allow water to flow past the dam and spill un-regulated into Duteau Creek until reservoir levels decrease below the overflow spillway. Duteau Creek flows approximately 12 km before entering a small reservoir (Lake Harvey) to settle out sediment. This is the location of the raw water intake (Headgates). There is a requirement to release flows downstream of the Headgates to satisfy Fisheries requirements and prior licenses. If the demands increase in the future on this source, eventually raw water storage projects will be required to ensure the sustainable supply of water and to utilize the available licence.

  This source currently has a clarification and disinfection water treatment plant located on Whitevale Road. This facility consists of coagulation, dissolved air flotation for clarification, chlorination, treated water storage and residuals management. The existing clarification facility is configured to supply 162 ML/d of water through 6 basins each sized to convey 27.0 ML/d. Allowing for losses through the future filtration process the total treated water flow is expected to be 150 ML/d. Similar to the Mission Hill facility, if the Duteau Creek facility is expanded beyond the pre-planned total treated water capacity of 150 ML/d, significant modifications to the existing infrastructure will be required. In addition to capacity limitation of the recently constructed treatment infrastructure, the gravity hydraulic gradeline at the treatment plant site is also limited to a total flow of roughly

180 ML/d. Once the total flow between Harvey Lake and the Duteau Creek water treatment plant site exceeds roughly 180 ML/d, a booster pump station or twinning the transmission main is required.

- **Antwerp Springs Well Pump Station** in Lavington consists of 3 groundwater wells. The deep well (Well #2) provides water that meets the health related Guidelines for Canadian Drinking Water Quality. The key water quality with the deep well is elevated levels of manganese, which is an aesthetic concern. The shallow well (Well #1) has elevated nitrate levels and on January 13, 2010 was contaminated with bacteria (E.Coli). This event compromised the water distribution system in the Lavington area for approximately 2 weeks. Since this issue both wells have been isolated from the potable water distribution network. The third well (Well #3) is capped and was decommissioned several years ago.

  Recently, BC Health again provided approval to divert water from the deep well at the Antwerp well site to the distribution system. This well can provide safe water, but has been a source of customer complaints due to the elevated level of manganese. To provide fully compliant water from the Antwerp Springs, treatment of the deep well water to lower the manganese levels is required. The volume of water available from the deep well on the Antwerp Springs site is low compared to the total demand of the service area. Furthermore, preliminary analysis shows that cost per volume of water available is measurably higher for the deep Antwerp well than Duteau Creek or Kalamalka Lake.

  For the purpose of this study, it is assumed that the deep Antwerp well will continue to be used as a supplemental source of water until the longer term plan is able to be implemented resulting in this source not being required to meet the potable water demand. At that time, the Antwerp Springs wells can be retained as irrigation water sources. The Antwerp Springs Well is not part of the long term potable water supply for GVW, meaning that further review of this source is not considered within this memorandum.

- **King Edward Lake** is an open reservoir created with a dam that discharges to Deer Creek. Water then flows down Deer Creek (approximately 6.5 km) to a water diversion structure located on Deer Creek. A chlorination station is located approximately 900 m downstream of the diversion structure for disinfection prior to the water being conveyed by gravity into the irrigation distribution network. This source has water quality comparable to Duteau Creek, but with significantly less water available for consumption. Due to the raw water quality, this source would eventually need treatment prior to using the water for domestic purposes to keep in line with the treatment on other sources. However, due to the limited available capacity, it is considered that this source does not justify the expense of a water treatment facility.

  Given above concerns, the King Edward Lake source was not deemed to be a suitable long term domestic source in the previous Master Water Plan and there is no new information to suggest that the previous findings are still not valid. This means there are two viable uses for the King Edward Lake source. The first potential option is to decommission the existing infrastructure and pursue the transfer of the license to the Kalamalka Lake diversion, allowing the licensed diversion of water from Kalamalka Lake to the Mission Hill facility to be potentially increased. The other option is to continue to implement the construction work that was completed during the past couple of years resulting in the isolation of King Edward Lake from the domestic network. For this option, the King Edward Lake source is connected to the irrigation system in the vicinity of the intersection of Highway 6 and Kalamalka Lake Road. For the purposes of this technical memorandum, it is assumed that King Edward Lake will not be a long term potable water supply. The King Edward Lake source will either be a dedicated irrigation water source or abandoned, allowing the license to be potentially transferred to the Kalamalka Lake diversion license. This issue will be explored further in other Technical Memoranda.

- **Ranch Well #1 and #2** are situated on the Coldstream Ranch in the vicinity of the intersection of Highway 6 and Kalamalka Road. These wells currently provide supplementary water to meet the peak summer water demands. The use of these wells is limited to peak summer use due to high levels of iron and manganese, which lead to customer complaints. Currently Well #1 is connected to the potable distribution network. For the purposes of this report, it is assumed that both Well #1 & #2 are removed from the domestic water network but are available for irrigation supply.

- **Goose Lake** provides peaking storage for the western portion of the historical NOWA water system. Goose Lake is a large open storage reservoir that like all surface water bodies is susceptible to contamination. The reservoir provides peak flow throughout the summer since the existing transmission pipelines from Duteau Creek are not adequately sized to deliver the high summer demands. The storage reservoir is filled with treated Duteau Creek water during winter or non-peak irrigation seasons or as surplus flow from Duteau becomes available.

  Since the completion of the 2002 Master Water Plan several options have been considered for the long term use of Goose Lake. Related to this technical memorandum, the option to construct a local treatment plant at Goose Lake to service the surrounding potable customers was examined in 2007. Refer to *Earth Tech Conceptual Level Assessment of Treatment for Goose Lake Source, Earth Tech Canada, May 23, 2007*. This document concluded that given the number of the potable customers that could be supplied within the Goose Lake service area, there was not an economic benefit to using Goose Lake as a potable source of water as it is less expensive to separate the distribution system within the Goose Lake area and provide potable water through the distribution network from another treatment facility such as Mission Hill or Duteau Creek. Given the previous assessments completed, the GVW will have completed the system separation projects in the vicinity of Goose Lake by the end of the 2013 construction season. Once this work is complete, Goose Lake will be a dedicated irrigation water source.

  Goose Lake will not be part of the domestic system in the near future but this storage reservoir will continue to be a key component of the GVW system. Currently, Goose Lake is filled with clarified Duteau Creek water at an approximate cost of $130/ML (2011 actual cost data). This means the cost of filling Goose Lake is roughly twice the revenue generated from selling irrigation water to agricultural customers. Within other technical memoranda, options will be considered to determine if there is a lower cost source of raw water that can be used to fill Goose Lake. Some of the options that will be considered for the supply of raw water to Goose Lake are untreated Duteau Creek water, BX Creek, Greenhow Creek, Swan Lake, Okanagan Lake and wastewater treatment plant effluent.

Based on the above summary, this technical memorandum focuses on the raw water characteristics of Kalamalka Lake and Duteau Creek and the associated treated requirements to ensure the long term supply of potable water. Once the capacity of these sources is reached, the plan is to then explore Okanagan Lake as the next source of potable water. At this time, it is recommended that a water licence reserve be established on Okanagan Lake. Refer to Technical Memorandum 3 for more information. Given that the production of potable water from Okanagan Lake is not necessary to meet demands in the immediate future, the detailed treatment requirements for this source are not considered at this time.

2. Source Water Quality Characteristics

GVW relies primarily on two sources of water, Duteau Creek and Kalamalka Lake, to meet the potable water demands of the community. The orientation of the Duteau Creek and Kalamalka Lake raw water supply and treatment infrastructure in relation to the GVW System is presented in **Figure 2-1**. Both of these sources are surface water bodies of reasonably high water quality, albeit each having different watershed characteristics and therefore unique water quality challenges. The following sections review the water quality characteristics and define the anticipated water quality challenges for each source.

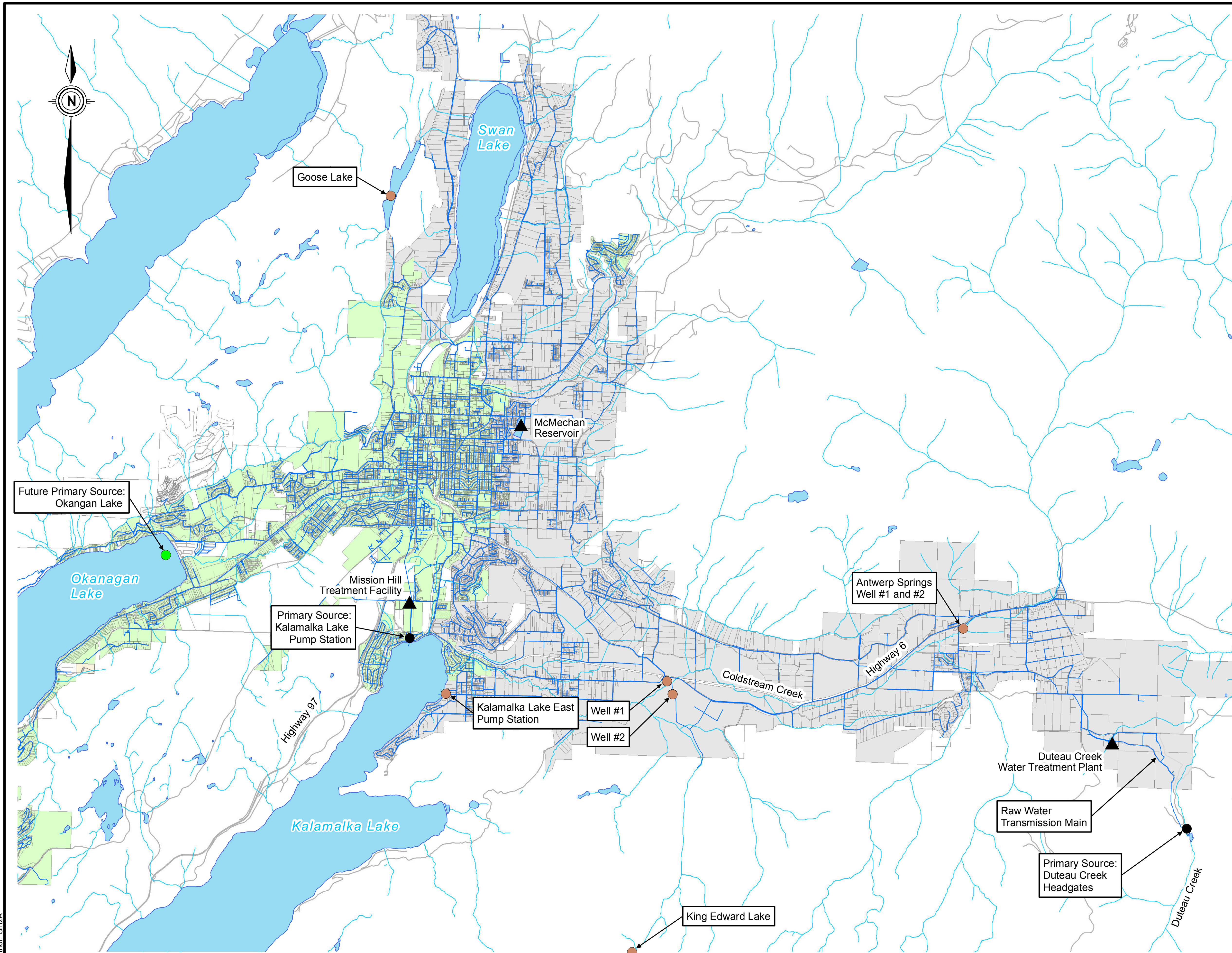
2.1 Kalamalka Lake Source Water Quality

Kalamalka Lake is the second largest surface water source in the Okanagan Valley. Prior to the construction of the Duteau Creek Water Treatment Plant, Kalamalka Lake was the primary source of drinking water for the Greater Vernon urban area for many decades. The GVW abstracts raw water at the Kalamalka Lake Pump Station where it is then pumped to the Mission Hill Water Treatment Plant. Prior to entering the distribution system, the Mission Hill facility provides two stage disinfection of the Kalamalka Lake source water.

Historically, Kalamalka Lake has been an excellent quality water source. However, in recent years the lake has seen a decrease in water quality. The Kalamalka Lake watershed is subject to activities, such as forestry, agriculture, recreation, and urban development, all of which negatively impact lake water quality. The annual inflows to Kalamalka Lake include the Coldstream Creek, Wood Lake connected via the Oyama Canal and groundwater.

The Coldstream Creek and groundwater contributes approximately 80% of the total water inflow to Kalamalka while the remaining 20% originates from Wood Lake. These inflows are roughly 2% of the total lake volume and therefore have a marginal impact to the overall quality of the Kalamalka Lake water. While their influence to the overall Lake water quality is limited, each tributary causes significant variation to the quality of the lake water in the vicinity of the discharge plumes. Specifically, it is expected that the proximity of the Coldstream Creek discharge to the Kalamalka Lake raw water intake negatively impacts the quality of raw water entering the Mission Hill Treatment facility. Water quality sampling conducted by the Ministry of Environment and Larratt Aquatic Consulting demonstrates a direct correlation between changes in the Coldstream Creek water quality and the quality of water entering the Mission Hill Water Treatment Plant. The degradation of water quality at the intake is primarily observed during the freshet and is seen as an increase in the turbidity, nutrient loading and bacteria concentrations at the intake.

During the preparation of this report, the data that has been collected by the GVW at different depths and locations throughout Kalamalka Lake was reviewed. This data indicates some variation in the raw water quality, but there is not a significant enough variation to impact the treatment requirements or the expected operating costs associated with the long term treatment facility. This means the raw water data review and analysis included within this technical memoranda focuses on the characteristics of the water collected from the existing intake pipe as it is assumed that changing the existing intake does not offer GVW any water quality benefits. **Table 2-1** presents a summary of the Kalamalka Lake raw water quality data collected from water entering the North Kalamalka Pump Station between the 2003 and 2012.



RDNO
2012 Water Master Plan Update

Legend

- Watermain
- Water Body
- Water Course
- Kalamalka Lake Service Area
- Duteau Creek Service Area
- Existing Primary Source
- Existing Primary Facility
- Seconday/Irrigation Source
- Future Primary Source

Associated Engineering AECOM

KERR WOOD LEIDAL consulting engineers

0 625 1,250 2,500 3,750 5,000 Meters

Project No.	Date
60224916	August 2012

Water Source Location Plan

Figure 2-1

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Author: GirtzA

Table 2-1 North Kalamalka Lake Intake – Raw Water Quality Summary

Parameter	Units	Minimum	Maximum	Average	95th Percentile	# of Samples	Peak Month
Alkalinity	mg/L as $CaCO_3$	63	167	139	159	49	June
Chlorophyll “a”	µg/L	0.7	5.3	2.3	4.2	54	May
Colour	TCU	0	10	3.7	7.7	46	October
Conductivity	us/cm	205	506	400	441	484	January
Cryptosporidium	counts/ 100L	<0.4	408	51	250	9	August
E. coli	MPN/ 100mL	< 1	> 200.5	5.8	46	298	April
Fecal Coli	counts/ 100mL	0	72	2.9	32	56	September
Giardia	counts/ 100 L	< 0.4	8.1	4.7	7.3	6	September
Hardness	mg/L as $CaCO_3$	138	183	168	180	47	July
Iron	mg/l	0	0.28	0.02	0.03	79	July
Manganese	mg/l	< 0.002	0.007	0.0044	0.007	9	June/July
Phosphorous	mg/l	< 0.01	< 0.20	0.019	0.031	20	July
Sulphate	mg/l	39	69	57	66	112	March
Temperature	Celsius	3	20.4	7.63	11.5	489	September
TOC	mg/l	2.6	14.8	5.43	9.92	155	May
TKN	mg/l	0.12	0.58	0.28	0.43	100	September
Turbidity*	NTU	0.29	8.27	1.40	3.04	697	October
pH		6.73	8.71	7.96	8.4	483	October
%UV transmittance		83%	96%	91%	93%	507	April

Based upon a review of the available water quality data, the following water quality parameters pose a concern to the provision of drinking water in compliance with GVW’s present and future drinking water quality objectives:

- **Turbidity:** While this in itself poses no known direct health concern, there is the potential for the physical masking of pathogens by turbidity particles, thereby reducing the effectiveness of disinfection;
- **Total Coliform and Escherichia Coli (E. Coli):** Coliform are a form of bacteria always present in surface water sources. While not all coliform bacteria are harmful, the presence of coliform serves as an indicator of harmful pathogens. The presence of E. Coli in a water source is an indication of recent fecal contamination from animal activity;
- **Protozoa (*Giardia* & *Cryptosporidium*):** Both of these chlorine tolerant organisms have been positively identified in the Kalamalka Lake source water;
- **Algae:** In most cases, algae do not pose a direct health effect, although there is increasing concern over toxins formed as metabolites by certain types of algae, notably the family of blue-green algae. Algae also are notorious for imparting unpalatable tastes and odour to drinking water, and can also pose operational problems in a water treatment due to filter clogging.

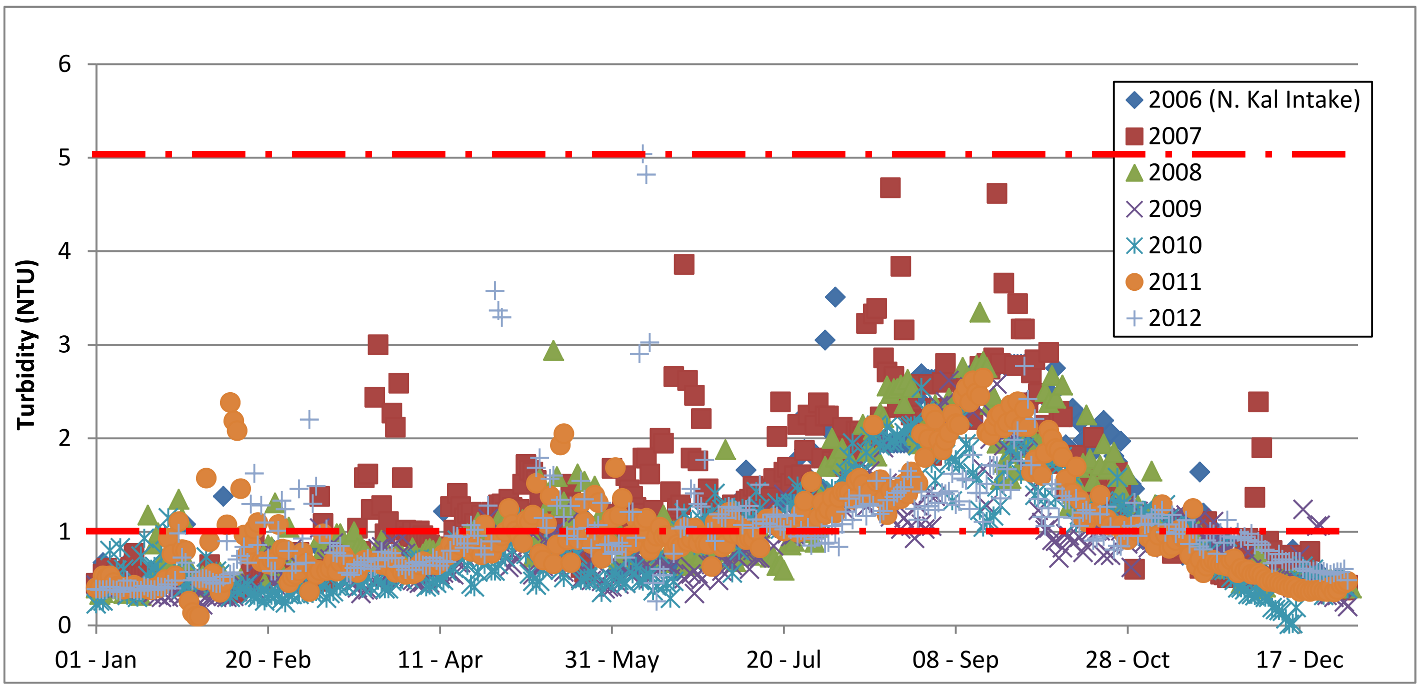
- **Hardness and Alkalinity:** These parameters are indicators of the water chemistry relative to the potential for corrosion posed by the water. The hardness of the Kalamalka Lake water is a current source of customer complaints.

2.1.1 Turbidity

The turbidity of the water entering the North Kalamalka Lake intake averaged 1.4 NTU between 2003 and 2011. The level of turbidity was often greater than 1 NTU and occasionally exceeded 5 NTU. Compared to Okanagan Lake, which typically experiences turbidity levels between 0.1 – 1 NTU, the turbidity of Kalamalka Lake is considered to be relatively high. This is due in a large part to the marl precipitation that forms from the naturally elevated concentrations of calcium and sulphate. The observed seasonal turbidity spikes are caused by a combination of factors including seiches, discharge of Coldstream Creek, and seasonal lake turn-over events.

Figure 2-2 illustrates the seasonal average daily variation in turbidity observed at the Kalamalka Lake Pump Station prior to chlorination between 2006 – 2011.

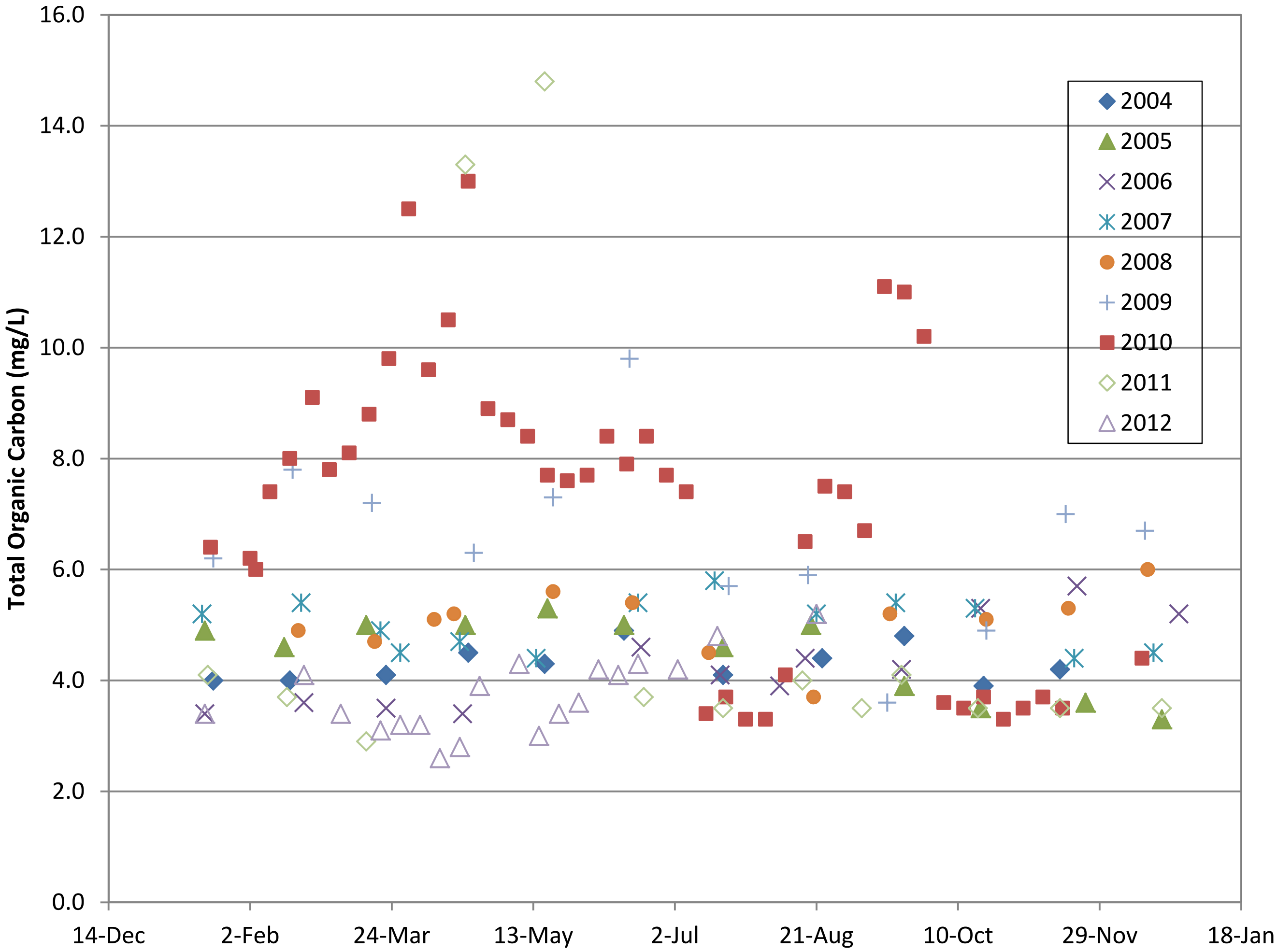
Figure 2-2 Kalamalka Lake Intake Raw Water Turbidity



2.1.2 True Colour and Natural Organic Matter

The colour in the Kalamalka Lake water is considered to be low, having an average value of 3.4 true colour units (TCU) and a peak value of 10 TCU. The level of organics present in the Kalamalka Lake water can be attributed to the Microflora and dissolved organic matter. The total organic carbon (TOC) levels in the raw water vary seasonally due to the limnology of the lake and algae growth occurs. TOC levels range from 2.6 – 14.6 mg/L, with an average measured value of 5.6 mg/L. The average TOC are moderate and correlate with generally acceptable levels of TTHM and HAA concentrations measured within the Kalamalka Lake supply distribution network. However, there are seasonal variations in TOC levels resulting in disinfection by-products that are on the cusp of being unacceptable within at the extreme limits of the distribution system. The TOC is depicted graphically in **Figure 2-3**.

Figure 2-3 Kalamalka Lake Total Organic Carbon Data



2.1.3 Chlorinated Disinfection By-Products

The RDNO regularly tracks total trihalomethane levels (TTHM's) within the distribution network at several different sites within the Mission Hill water supply area. Generally, the TTHM results meet the GCDWQ MAC, with only one sample at the Kokanee Pump Station exceeding the guideline of 100 µg/L.

Also within the past couple of years the RDNO has broadened their disinfection by-products monitoring program to include sampling for Haloacetic Acids (HAA_5s). The levels of HAA_5s present in the distribution network are generally compliant with the GCDWQ MAC of 80 µg/L.

The disinfection by-products are acceptable within the distribution system that conveys Kalamalka Lake water. It is assumed that once filtration is added to the Kalamalka Lake source, the disinfection by-product production will comply with the current and long term water quality guidelines established in Section 3 of this technical memorandum.

The results of the TTHM and HAA5 sampling for Kalamalka Lake water within the distribution system are presented in **Figure 2-10** and **Figure 2-11**.

Figure 2-4 THM Samples for the Kalamalka Lake Distribution System

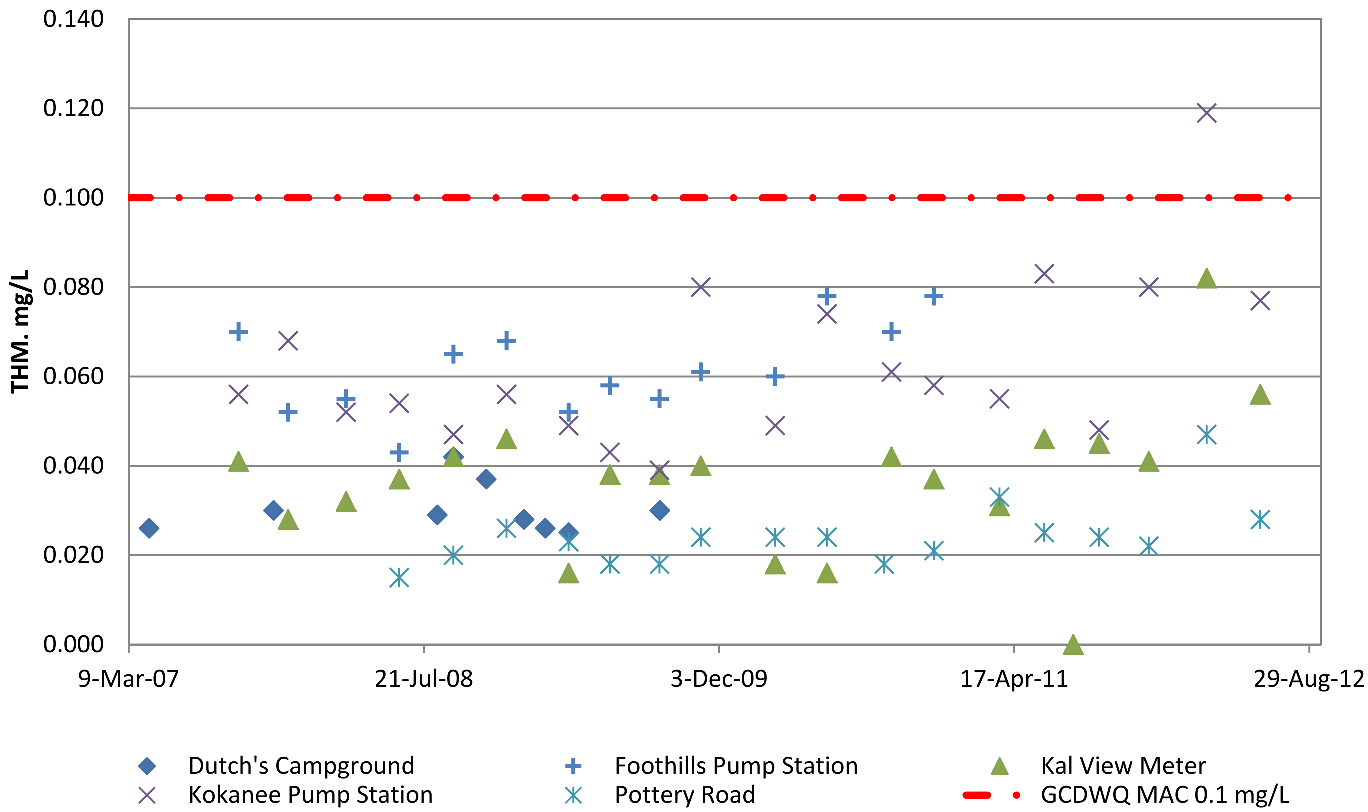
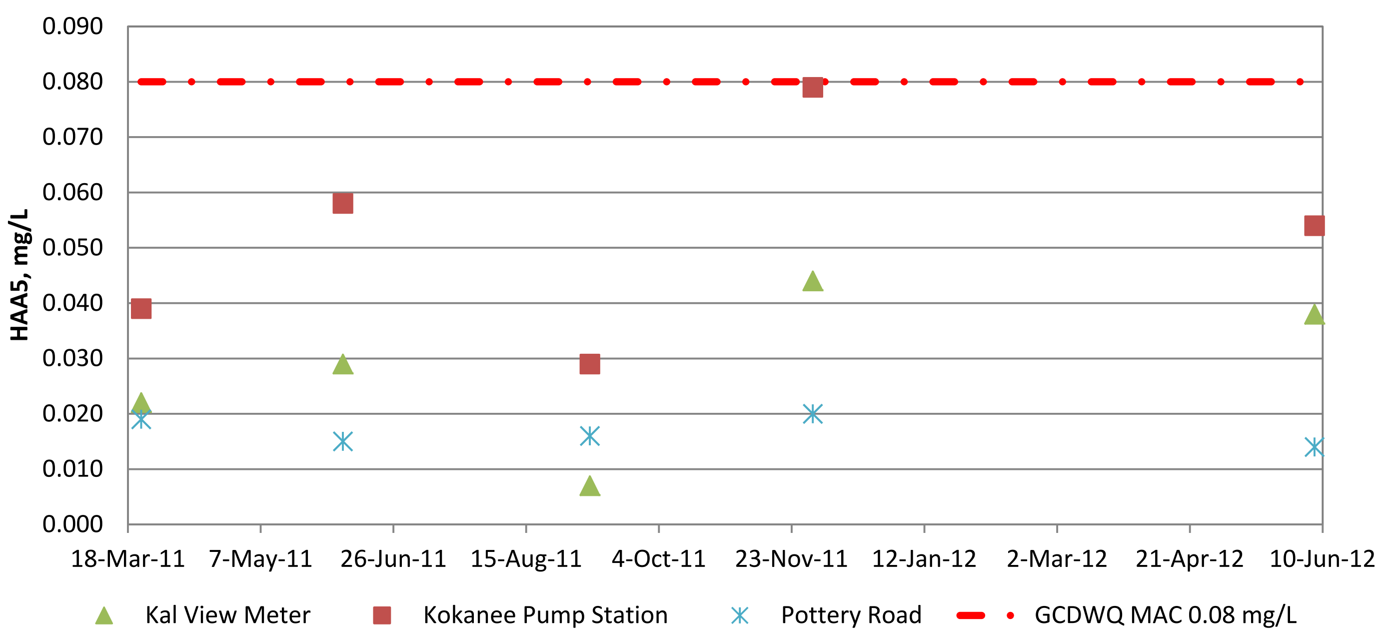


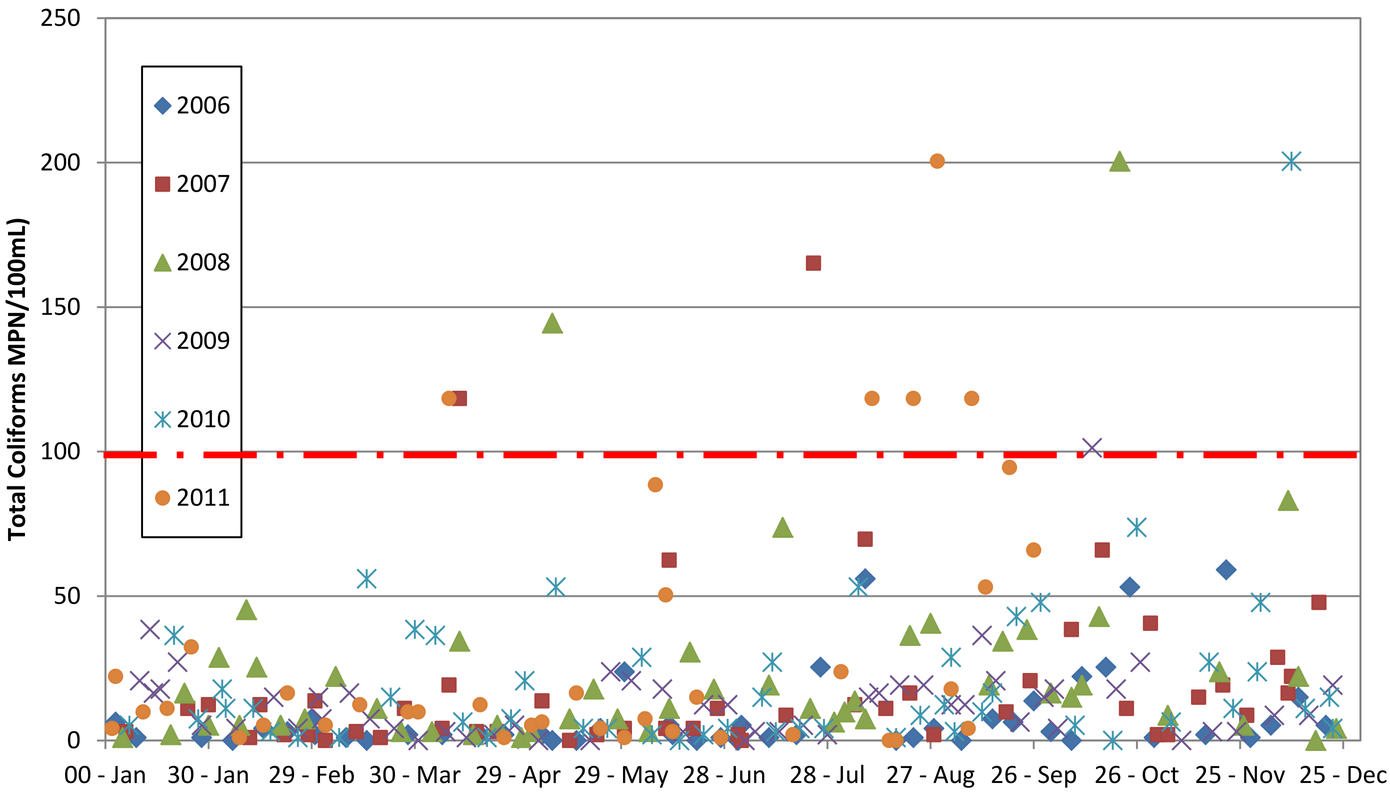
Figure 2-5 HAA5 Samples for the Kalamalka Lake Distribution System



2.1.4 Total Coliform and E. Coli

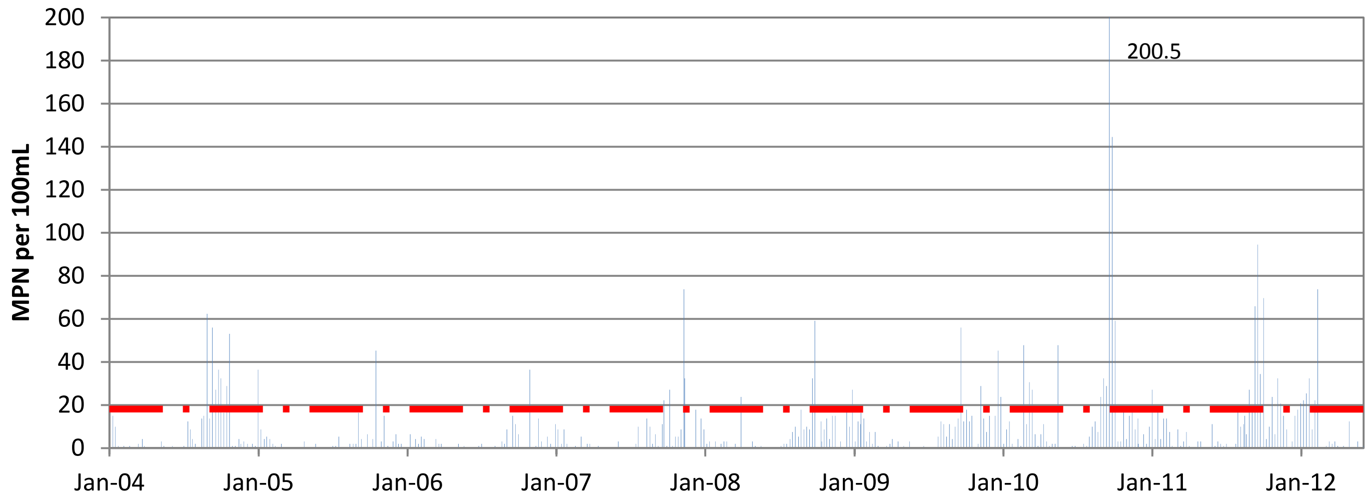
The concentration of total coliform in the North Arm of Kalamalka Lake ranged between <1 and 200 MPN per 100 mL (maximum detection limit) in samples collected between 2006 and 2010. Total coliform count exceeds 100 MPN per 100mL occasionally, typically between July and December. **Figure 2-3** presents the results of the date total coliform data collected between 2006 and 2011. More than 10% of samples for total coliform exceeded 100 MPN per 100 mL in six of the six month periods between 2004 and 2012.

Figure 2-6 Total Coliform at North Kalamalka Lake Intake



Previous sampling for E. Coli at the North Kalamalka Lake intake reveals high concentrations of E. Coli bacteria present in the source water as shown in **Figure 2-7**. The E. Coli counts range between <1 and 200.5 MPN per 100 mL (maximum detection limit) and averaged 9.7 MPN per 100 mL between the 2004 and 2012 sample period. The data shows a consistent trend of E Coli concentrations increasing in the late summer, peaking between the months of September and October, and then declining through to January of each year. Similar to the total coliform data, more than 10% of samples for E. Coli bacteria exceeded 20 MPN per 100 mL in two of the six month periods between 2004 and 2012. E.Coli bacteria levels are significant as the Health Canada guidelines for filtration deferral require sources to have less than 20 MPN per 100 mL. The suitability of the Kalamalka Lake source for filtration deferral is discussed further in subsequent sections of this report.

Figure 2-7 E. Coli at North Kalamalka Lake Intake

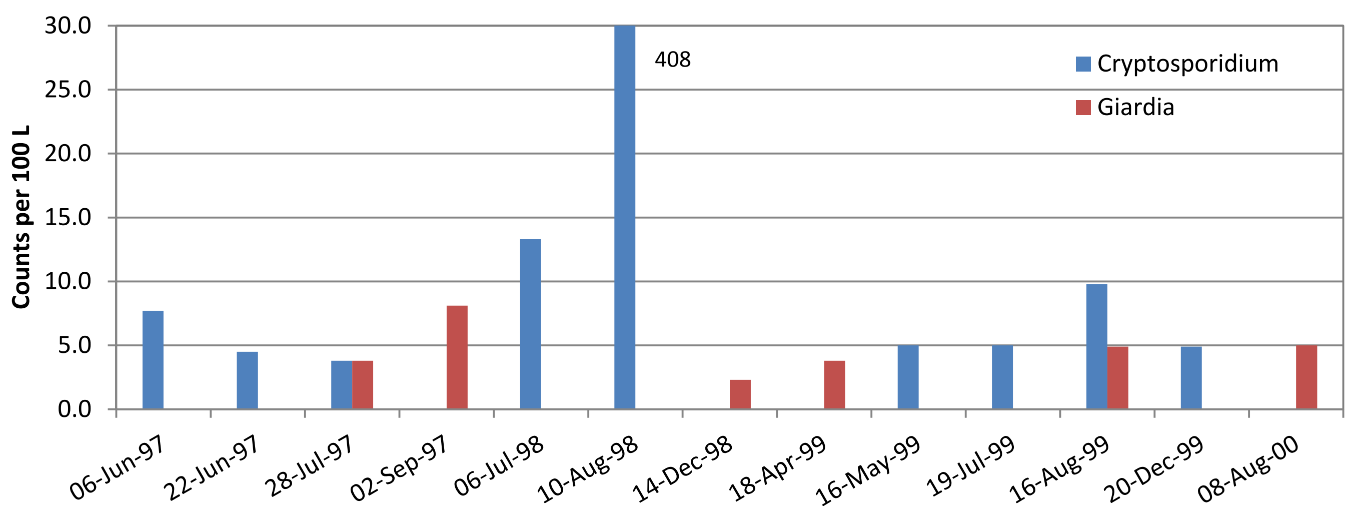


2.1.5 Protozoa (*Cryptosporidium and Giardia*)

Between 1997 and 2003 the City of Vernon monitored for the presence of *Cryptosporidium* and *Giardia* in Kalamalka Lake at the existing intake. During the monitoring 144 samples were collected for *Cryptosporidium* and 144 for *Giardia*. Weekly samples for five years provide an adequate baseline to form a statistical conclusion about the potential risk of pathogens being present in the Kalamalka Lake source. The samples are variable as expected given the seasonal and weather based variability of the raw water quality. Since 2003 *Cryptosporidium* and *Giardia* sampling has not been completed in the Kalamalka Lake source. The data collected was utilized to defend the 2-stage disinfection constructed at the Mission Hill Treatment Facility in 2006 and 2007.

Provided below in **Figure 2-8** is a graphic presentation of the 9 *Cryptosporidium* and 6 *Giardia* samples when protozoa where detected. The general conclusion from the data is that *Cryptosporidium* and *Giardia* were rarely present, but when protozoa were detected the results were significant.

Figure 2-8 *Cryptosporidium* and *Giardia* at North Kalamalka Lake Intake



The current parasite treatment goal based on the provincial standard for surface water is 3-log inactivation or removal. Within the provincial document there is no reference to higher levels of treatment for raw water sources that are considered to be at a higher risk of contamination. The existing ultraviolet disinfection system at the Mission Hill treatment plant meets the 3-log inactivation treatment target for *Cryptosporidium* and *Giardia*, but it is worth highlighting the significance of the parasite samples collected to date relative to the other regulators such as the US EPA.

The results show values ranging from 4 to 408 counts per 100 litres for *Cryptosporidium* and 2 to 8 counts per litre for *Giardia*. Given these results and following the USEPA Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) the treatment requirements for *Cryptosporidium* for filtered and unfiltered sources are as follows:

- The *Cryptosporidium* inactivation goals for filtered systems, the ceiling level for passing from Bin 1 into Bin 2 is 7.5 oocysts per 100 L. This means for a filtered source, given the raw water data currently collected in Kalamalka Lake the *Cryptosporidium* treatment target is Bin 2 or 4-log inactivation/removal.
- The LT2ESWTR also has specific *Cryptosporidium* treatment criteria for unfiltered systems. For an unfiltered source, there are actually only 2 bins for *Cryptosporidium* with the breakpoint between bins being 1 oocysts per 100 L. Given the data collected to date the Kalamalka Lake source would be in the higher bin, and would require the unfiltered system provide a 3-log *Cryptosporidium* treatment target. The requirement goes on to mention that two discrete disinfection techniques must be used, and that each of the two techniques must be able to provide one or more of the disinfection requirements.

Based on the *Cryptosporidium* and *Giardia* data collected from Kalamalka Lake the design of the existing Mission Hill 2-stage disinfection facility it is compliant with the provincial and the more stringent USEPA LT2ESWTR regulations. However, data has not been collected for the past 10 years old, and it is not clear if risk for *Cryptosporidium* has increased or decreased in Kalamalka Lake.

The Bin classification criteria developed by the US EPA for *Cryptosporidium* treatment objectives is used across the United States and a very similar approach is followed by the regulator in Alberta. This means it is probably reasonable to plan for the regulator in BC to adopt a similar approach during the 50 year planning horizon of this plan. Given this we recommend that the GVW continues to collect raw water samples from Kalamalka Lake for *Cryptosporidium* analysis to strengthen the quality of the data set. With a broader raw water data set statistical analysis can be completed in the future to support an analytically based recommendation for the treatment target for *Cryptosporidium* for Kalamalka Lake. This will be important once detailed planning for the Mission Hill filtration plant is completed since the design and in turn the cost of the facility will vary if the treatment target for *Cryptosporidium* is 4-log or 3-log.

2.1.6 Algae

Kalamalka Lake is subject to algae blooms in the spring and fall of each year. The spring algae bloom develops in response to the nutrient loading provided by the Coldstream Creek freshet and increased daylight hours. The spring algae event typically comprises of a combination of diatom and blue-green algae. The algae levels decrease through the summer months as the marl precipitation increases, which consumes the available phosphorus in the water. The fall algae bloom grows as the marl declines and the daylight hours are still relatively long.

The algae concentration in the North Arm of Kalamalka varies with the water depth. Data collected between 2003 and 2010 shows the algae levels between 300 and 1900 cells/mL at a depth of 20 metres (current intake depth) and between 200 and 1300 cells/mL at the 40 metre depth.

The taste and odour complaints received by the GVW have been directly linked to algae events in the North Arm of Kalamalka Lake. Future treatment technologies proposed for the Kalamalka Lake water source should consider the impact algae may have on the process performance and the production of taste and odour compounds.

2.1.7 Hardness and Alkalinity

The hardness of the Kalamalka Lake is greater than the ideal range of between 80 and 100 mg/L as $CaCO_3$ for domestic use. With an average level of 163 mg/L, the Kalamalka Lake water is classified as a hard water source. Because the hardness and alkalinity values are similar, we expect the hardness in Kalamalka Lake to be primarily in the form of “bicarbonate” hardness. This type of hardness is typical for a surface water source. Water with high levels of carbonate hardness can lead to scaling in fixtures and water heaters due to the precipitation of carbonate that occurs when heated.

2.2 Duteau Creek Source Water Quality

The Duteau Creek source is an upland reservoir source that receives water from three lakes located on the Aberdeen Plateau, namely the Aberdeen, Haddo and Grizzly Lakes. The Duteau Creek source is a typical B.C. upland source, of reasonably low turbidity for most of the year, but experiences a marked deterioration of raw water quality during the spring freshet. A deterioration of lesser magnitude also sometimes occurs in late summer due to the reduced influence of surface runoff during the drier months. The Duteau Creek source water is treated at the Duteau Creek Water Treatment Plant using dissolved air flotation clarification followed by chlorination.

Table 2-2 presents a summary of raw and clarified water quality as measured from Duteau Creek. The raw water quality data from Duteau Creek was obtained from historical data provided by GVW staff between 1997 and 2011. The data presented in this report is a combination of historical data from the AECOM files associated with the development of the Duteau Creek treatment facility and recent data obtained from Water Trax during the completion of this technical memorandum.

Table 2-2 Duteau Creek Raw Water Quality Measured at Headgates Chlorine Building

Parameter	Units	Minimum	Maximum	Average	95th Percentile	# of Samples	Peak Month
Alkalinity	mg/L as $CaCO_3$	10	35	18	23	55	September
Chlorophyll “a”	µg/L	0.5	1.5	1.08	1.5	6	May
Colour	TCU	32	81	57	80	12	April
Conductivity	Mmho/cm	31	110	69	107	8	April
Cryptosporidium	counts/ 100 L	<0.1	0.2	0.2	-	27	September
E. coli	MPN/ 100mL	< 1	> 200.5	16	86	109	June
Fecal Coli	counts/ 100mL	6	70	21.792	58	13	July
Giardia	counts/ 100 L	<0.1	1.0	0.45	0.9	27	September
Hardness	mg/L as $CaCO_3$	18	39	26	36	5	November
Iron	mg/l	0.13	0.43	0.22	0.38	12	August
Sulphate	mg/l	<7	24	13.9	22.8	11	April
Temperature	Celsius	0.5	18.9	7.7	13.7	60	May
TKN	mg/l	0.19	0.4	0.27	0.4	11	April
TOC	mg/l	8.2	70.6[1]	17.4	35.1	29	May
TSS	mg/l	<1	9	6.3	8.8	3	June
Turbidity	NTU	0.48	10.1	1.5	7.4	57	June
pH		6.4	7.8	7.2	7.5	61	May

Based upon a review of the available water quality data, the following water quality parameters pose a concern to the provision of drinking water in compliance with the GVW’s present and future drinking water quality objectives:

- **Turbidity:** While this in itself poses no known direct health concern, there is the potential for the physical masking of pathogens by turbidity particles, thereby reducing the effectiveness of disinfection.
- **True Colour and Natural Organic Matter:** This is first and foremost an aesthetic concern, as it significantly impacts the visual appeal of the water. However, if the colour has been impacted by the presence of naturally occurring organic acids, including the families of humic and fulvic acids, there is also an increased potential for the formation of chlorinated disinfection by-products, such as trihalomethanes or haloacetic acids, upon chlorination of the water before distribution;
- **Disinfection By-Products (DBP’s):** RDNO have historically tracked only trihalomethanes (THM’s) as these are as yet the only regulated chlorination DBP’s in Canada. The THM’s within the Duteau Creek supply distribution network consistently exceed the Canadian guidelines;
- **Protozoa (*Giardia* & *Cryptosporidium*):** Both of these chlorine tolerant organisms have shown themselves to be present in the Duteau Creek watershed. It is noted that given the significantly lower levels of urbanization and human activity within the upland water sources, the data indicates lower levels of protozoa in the Duteau Creek raw water;

[1] *It is suspected that this data point is a result of a sampling or analytical error.*

- **Algae:** In most cases, algae does not pose a direct health effect, although there is increasing concern over toxins formed as metabolites by certain types of algae, notably the family of blue-green algae. Algae are also notorious for imparting unpalatable tastes and odour to drinking water and can also pose operational problems in a water treatment due to filter clogging.
- **Iron:** Iron does not pose a health concern, but if left unchecked through treatment can result in aesthetic concerns due to post precipitation of iron due to chlorination and the possibility of laundry stains and fixtures.
- **Hardness and Alkalinity:** These parameters are indicators of the water chemistry relative to the potential for corrosion posed by the water. The potential corrosion of the Duteau Creek source water is a known concern that needs to be addressed during the long term water system planning.

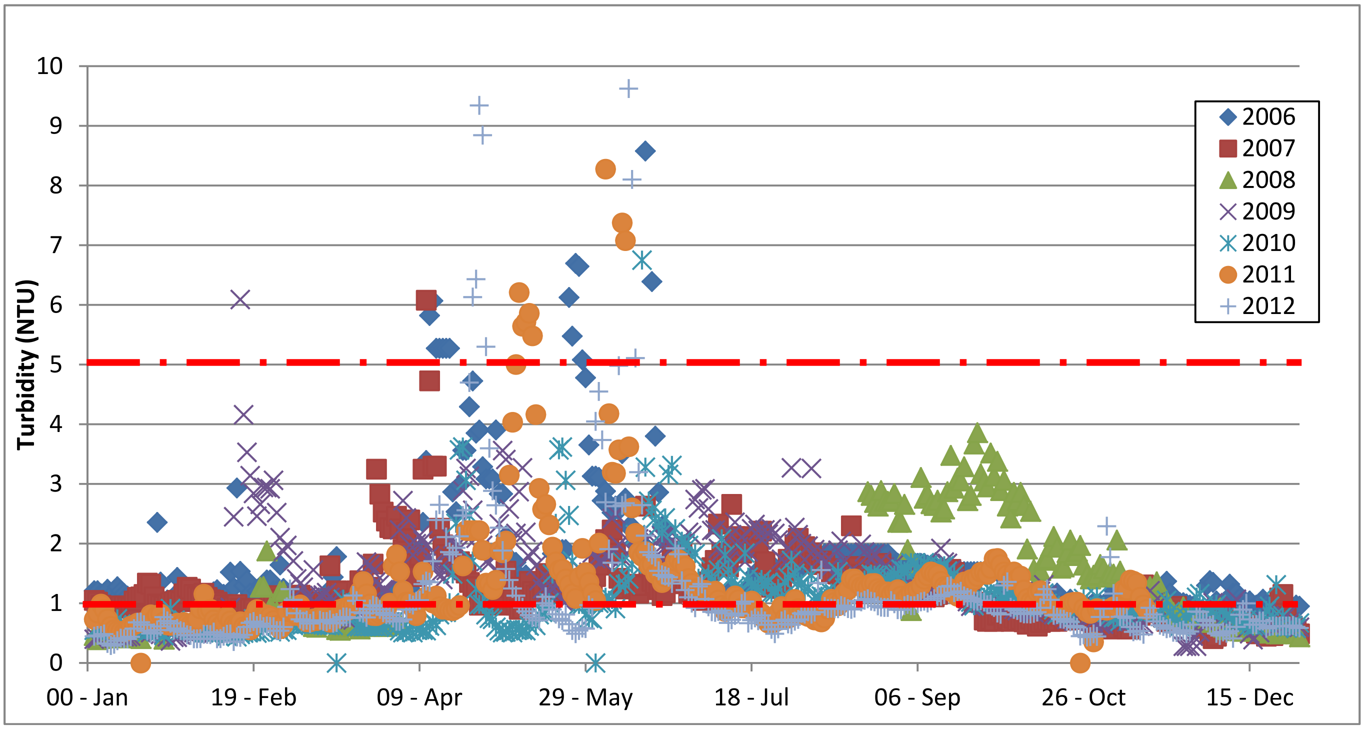
2.2.1 Turbidity

It is evident that raw water drawn from Harvey Lake is of low turbidity for most of the year, averaging less than 5 NTU over 97% of the time, but experiences seasonal spikes during the spring freshet. Water entering the distribution system exceeded the GCDWQ MAC for turbidity of 1 NTU over 61% of the time over the period 1997-2012. Observation of the Lake during the spring freshet clearly indicates that this phenomenon is aggravated by hydraulic flow patterns within Lake Harvey. Placement of the dam spillway at the northwest abutment of the dam clearly fosters a strong and readily visible current along the western shore of the Lake and tends to generate a circulatory pattern within the Lake when creek discharge is elevated. This results in re-suspension of sediment that contributes to the historical peak turbidity levels observed in the late spring when the dam begins to spill. The re-suspension of turbidity combined with elevated levels of turbidity entering Lake Harvey during the freshet flow results in higher turbidity levels during the spring. In addition to the re-suspension of turbidity during high spring flows, there is turbidity being transported into Harvey Lake. The re-suspension of accumulated material and the sediment transport results in elevated turbidity levels during the spring freshet.

The issue of turbidity accumulating in Lake Harvey has been discussed many times in the past. To mitigate this concern, the lake was drained and dredged in the past; however, it is not expected that approval could be obtained from the regulators to complete a comparable dredging exercise today. A detailed review of the cost to benefit of cleaning Lake Harvey was completed in 2006 and it was concluded that benefit provided is not worth the cost as the Duteau Creek treatment plant can easily remove the slightly elevated turbidity levels associated with particulate material accumulation in Lake Harvey. For more information refer to the March 8, 2006 report titled *Harvey Lake By-Pass Feasibility Final Report* completed by Earth Tech Canada.

Figure 2-9 illustrates the seasonal variation in average daily turbidity levels as measured at the Lake Harvey Headgates.

Figure 2-9 Duteau Creek Source Water Turbidity 2006 - 2011



2.2.2 True Colour & Natural Organic Matter

Duteau Creek is a typical upland British Columbia water source and routinely exhibits moderate to elevated colour levels primarily due to the presence of humic and fulvic acids derived from decay of natural organic matter in the watershed. True colour averages 57 TCU, but experiences a seasonal spike during the months of April through June, primarily due to the spring thaw. Total organic carbon follows a very similar trend, with typical TOC levels in the 7 - 15 mg/L range for most of the year, but peaking to the 30 – 80 range in the spring months.

2.2.3 Chlorinated Disinfection By-Products

The RDNO regularly tracks the total *Trihalomethanes* (TTHM's) levels within the distribution network through sampling at three different sites downstream of the Duteau Creek WTP. Historically, the TTHM levels have consistently exceeded the GCDWQ Maximum Acceptable Concentration (MAC) of 100 µg/L. Since the commissioning of the Duteau Creek Water Treatment Plant, there has been a marked reduction in the levels of TTHM measured in the network. However, the TTHM results continue to be in excess of the GCDWQ MAC, ranging between 99 and 236 µg/L. The species of TTHM measured in the Duteau Creek source water is almost exclusively composed of chloroform.

After the commissioning of the Duteau Creek WTP, the GVW broadened their disinfection by-products monitoring program to include sampling for Haloacetic Acids (HAA5s). The levels of HAA5s present in the distribution network are in excess of the GCDWQ MAC of 80 µg/L. The highest record level of HAA5s exceeded the GCDWQ MAC by 60%.

The recently constructed Duteau Creek water treatment plant provides a noticeable improvement in the TTHM levels of the treated water within the distribution network as the operation of the existing coagulation and clarification processes remove typically 50 – 60% of the disinfection by-product precursor material from the raw water. Even with the significant reduction in TTHM levels, the GCDWQ are still being exceeded meaning that future improvements to the Stage 1 Duteau Creek water treatment plant needs to consider further treatment to reduce the TTHM's within the distribution network.

It is not expected that organic material accumulation on the interior surface of the distribution system pipes will significantly contribute to the TTHM's or HAA5 levels. However, if organic matter does become an issue this item could be addressed with flushing.

The results of the TTHM and HAA sampling for the Duteau Creek source water are presented in **Figure 2-10** and **Figure 2-11**.

Figure 2-10 Total Trihalomethanes Duteau Creek Supply

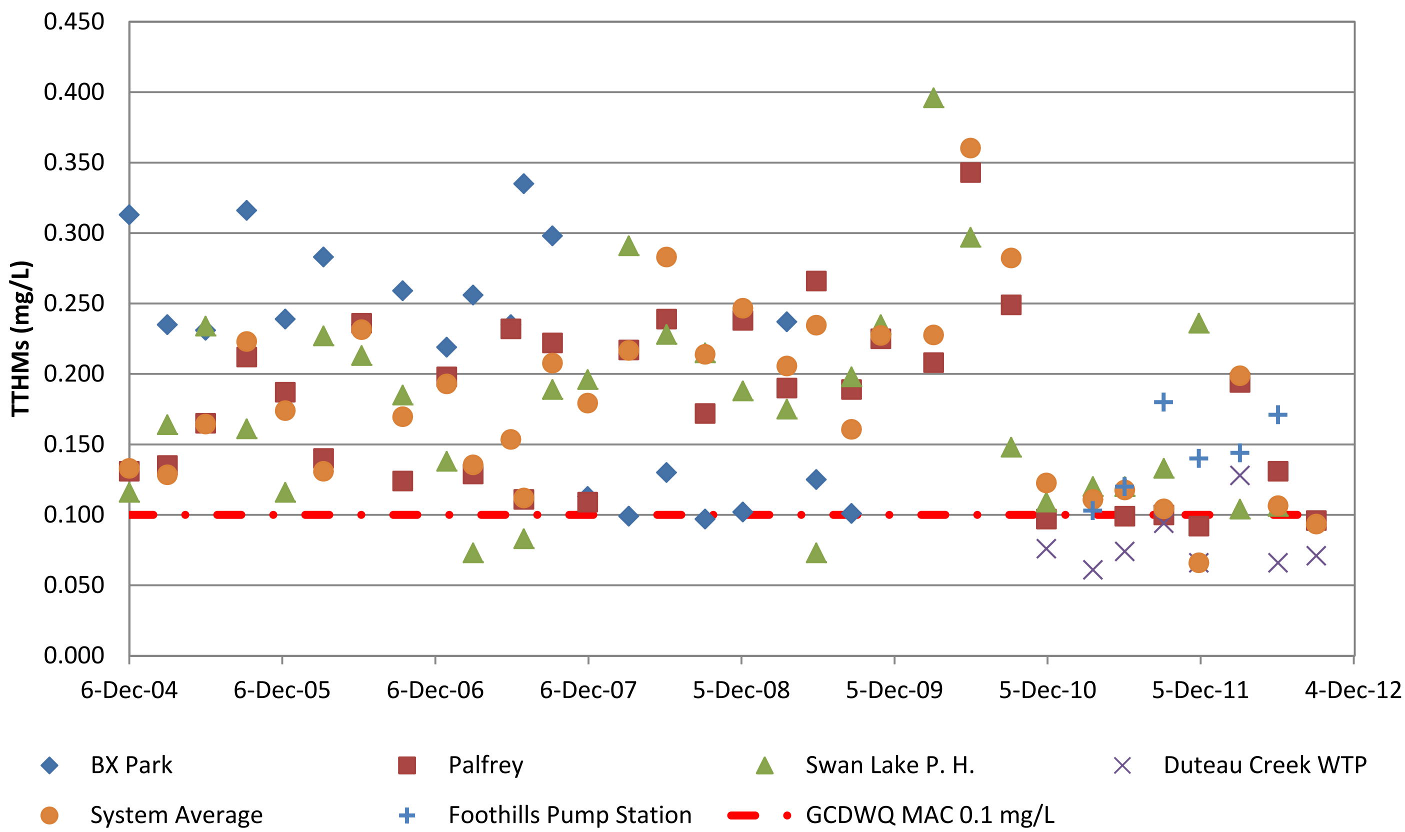
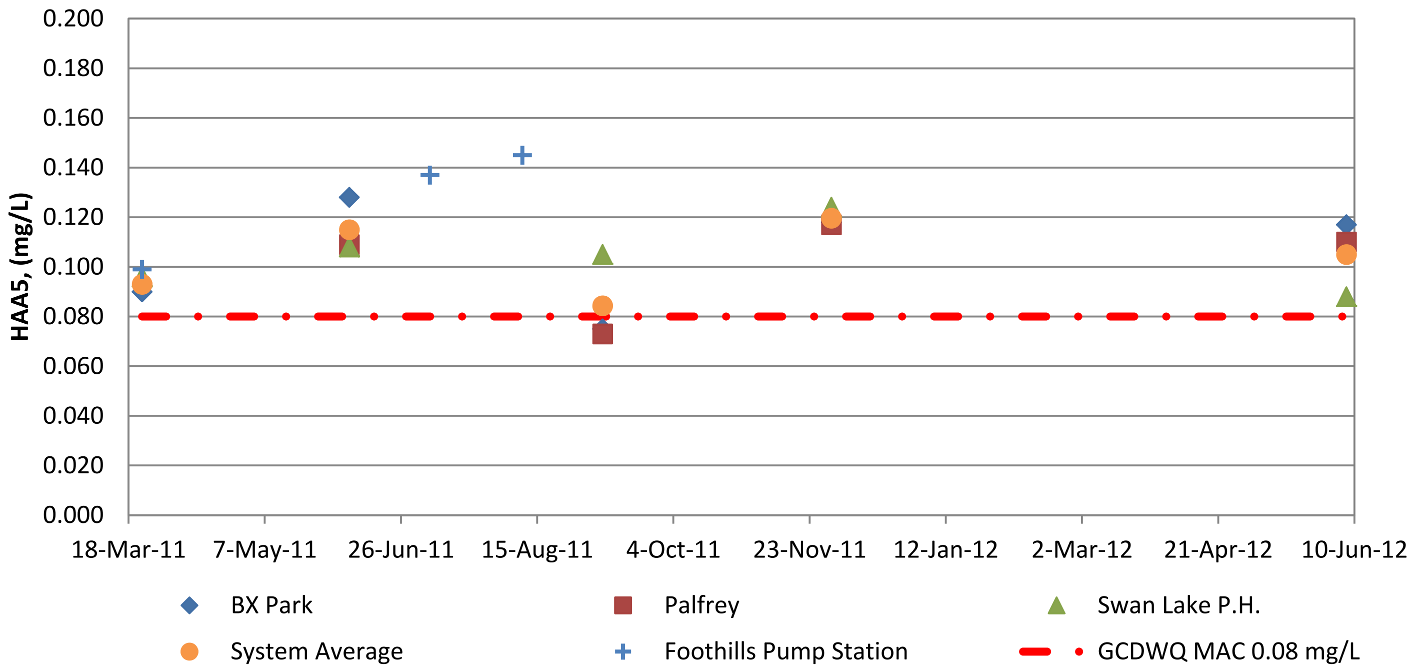


Figure 2-11 Haloacetic Acids Duteau Creek Supply



2.2.4 Total Coliform and E. Coli

The Duteau Creek Community watershed is crown land and subject to grazing tenures and forest harvest licensing. Cattle, wildlife and avian are the main contributors of the E. Coli bacteria observed in the Duteau Creek source water. The total coliform MPN per 100mL, as measured at the Duteau Creek Headgates, typically ranged between 0 and 50 but experienced seasonal spikes between 50 and 200 (maximum detection limit) during the late spring to early fall months. The average total coliform measured at Duteau Creek Headgates during the 2006 to 2010 sample period was 50 MPN per 100 mL. The Duteau Creek sees peak levels of E. Coli bacteria between June and July, followed by a less pronounced spike between September and October of each year. Between 2006 and 2010 the concentrations of total coliform and E. Coli exceeded 100 and 20 MPN per 100mL, respectively, in more than 10% of samples during the majority of the six month sampling periods.

The results of the total coliform and E. Coli sampling from the Duteau Creek Headgates are presented in **Figure 2-12** and **Figure 2-13**.

Figure 2-12 Coliform Samples at Duteau Creek Headgates

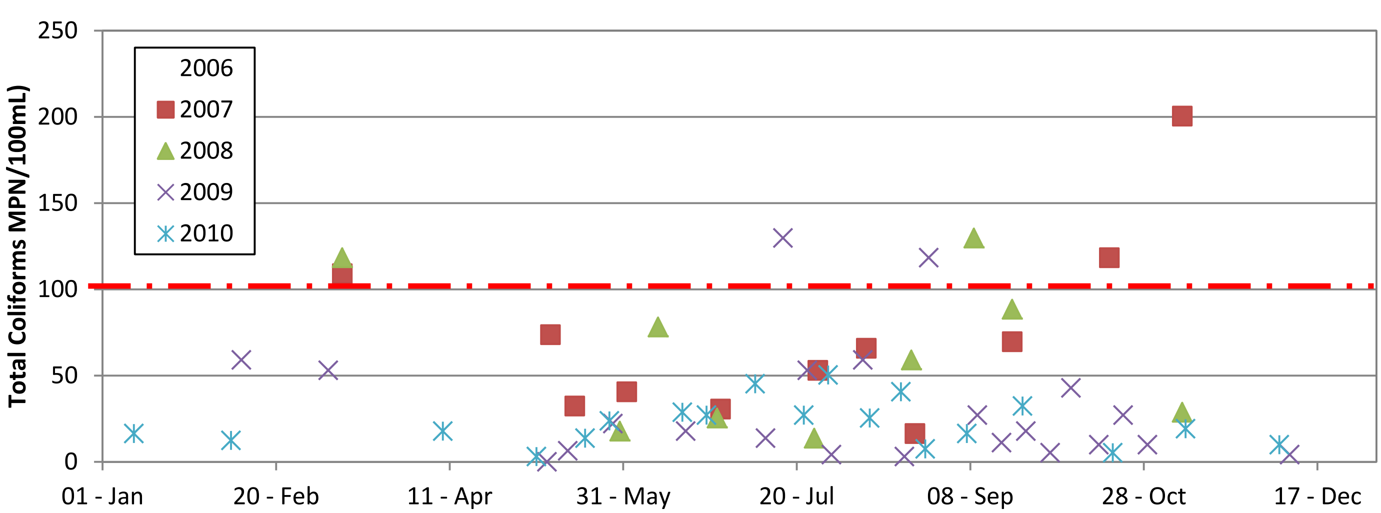
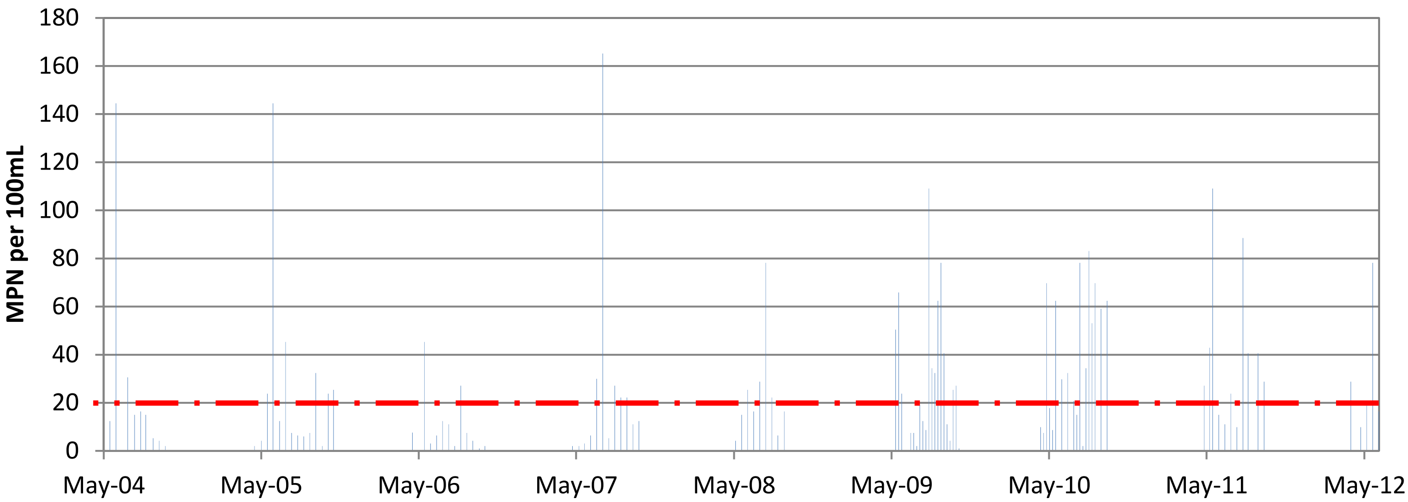


Figure 2-13 E. Coli at Duteau Creek Headgates



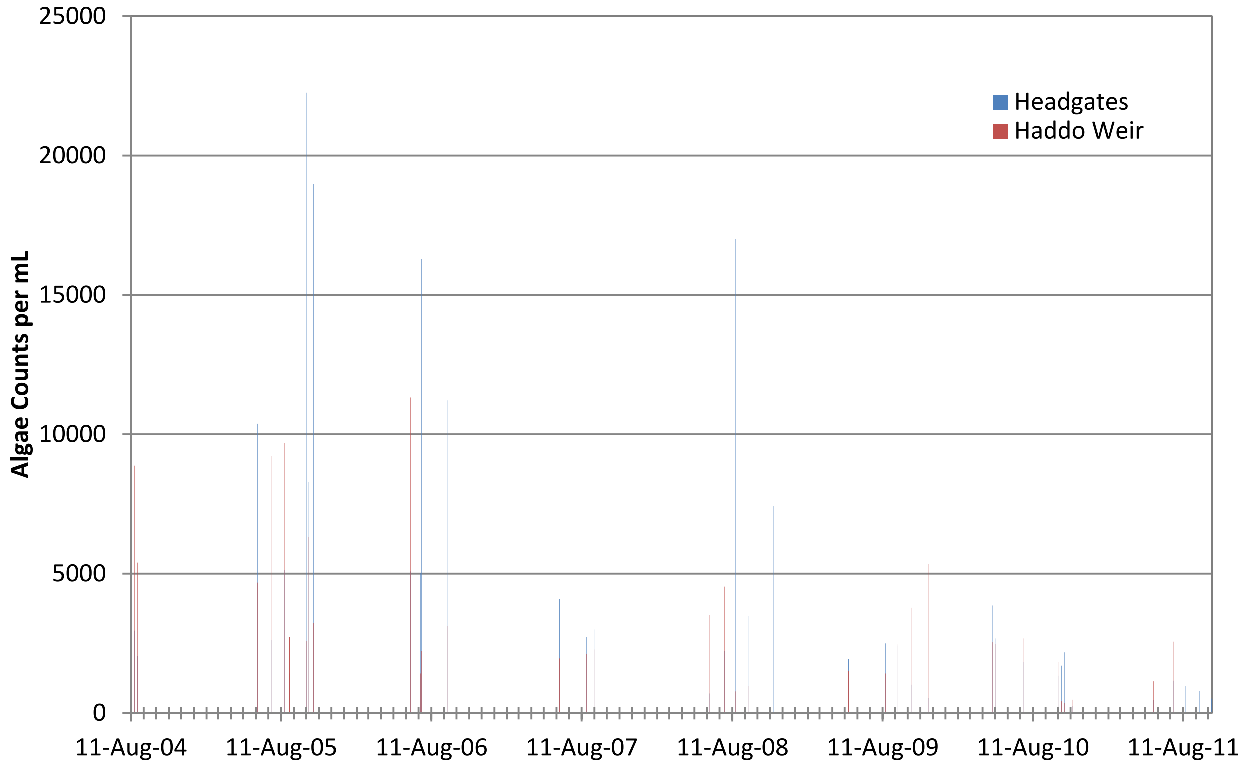
2.2.5 Protozoa

Previous sampling of Duteau Creek has resulted in the occasional positive assay for both *Giardia* and *Cryptosporidium*, although the levels detected have been quite low. During the period August 1999 through December 2001, there was one positive assay for *Cryptosporidium*, of 0.2 oocysts per 100 Litre, and 6 positive assays for *Giardia*, with an average of 0.45 cysts per 100 Litres. Since the original testing was completed in 2001, additional samples have not been collected.

2.2.6 Algae

Background levels of algae are known to be present in Harvey Lake, and the Regional District annually undertakes analytical work to track levels of algae in the raw water. The 2004 Water Quality Report found that levels were low, with anacystis and diatoms being the predominant species. Chlorophyll “a” was also analyzed, and also found to be relatively low for an upland water source with the peak values only being as high as 1.5 µg/L.

Figure 2-14 Algae Count Data at Duteau Creek Headgates and Haddo Weir



2.2.7 Iron

The RDNO monitors iron monthly in Duteau Creek and have generally found raw water iron levels to be comfortably below the Canadian Aesthetic Objective of 0.3 mg/L. Occasional excursions in raw water iron levels have been seen in the months of August and September in recent years. These excursions are likely a result of drawdown of the lakes in the Duteau Creek watershed, resulting in the use of waters from the deeper, lower dissolved oxygen sections of the lake, which carry dissolved iron.

2.2.8 Hardness & Alkalinity

Raw water drawn from Duteau Creek is low in both hardness and alkalinity, with typical levels of 26 mg/L as calcium carbonate ($CaCO_3$) and 20 mg/L as $CaCO_3$ respectively. Based upon available raw water quality data, the water has a typical Langelier Saturation Index (LSI) in the order of -2, which would typically result in the water being characterized as inherently corrosive to many types of piping materials. In reality, this is an over-simplification, as corrosion is a highly complex phenomenon, and LSI is often a very poor indicator of corrosion in many cases.

3. Water Quality Criteria

3.1 Treated Water Quality Criteria

British Columbia drinking water quality guidelines and the Health Canada guidelines have evolved in a significant fashion during the past 10 years with some minor adjustments in the past 5 years in an attempt to bring the standards to a level comparable to United States.

The provincial legislation in British Columbia is still somewhat limited compared to other provinces as the law focuses on bacteriological contamination but also includes references to ensuring the conveyance of safe potable water. To support this goal, the local Health Regions within British Columbia have been provided the authority to implement more stringent drinking water quality guidelines. Recently, BC Health issued a document titled *Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia, November 2012*. This document provides the expectations for water treatment within British Columbia and can be summarized as the "**4-3-2-1-0 Dual Treatment Guidelines**". These guidelines indicate the following objectives:

1. 4-log (99.99%) inactivation for enteric viruses;
2. 3-log (99.9%) inactivation or removal for Giardia;
3. 3-log (99.9%) inactivation or removal for Cryptosporidium;
4. Dual stage treatment; two (dual) barriers to pathogens;
5. Less than 1.0 NTU turbidity in the treated water at all times; and
6. Zero total and faecal coliforms.

Further to the above guidelines from BC Health, it is recommended to consider not only present regulations but to attempt to anticipate water quality regulations which might come into force during the life of the upgrades to ensure that the facility is able to satisfy these more stringent future requirements where practical. Through completion of several similar studies of this nature in the Okanagan, including work for Westbank, Kelowna, and Summerland, we recommend that the RDNO consider the following additional water quality goals in their long term plan:

- **Chemical Constituents:** Consistent compliance with all water quality parameters listed in the Guidelines for Canadian Drinking Water Quality (GCDWQ);
- **Turbidity:** Production of a finished water consistently less than 0.3 NTU turbidity for at least 95% of the time for granular media filtration plants and less than 0.1 NTU turbidity for at least 95% of the time for membrane filtration facilities;

  Disinfection By-Products (DBP's): The present day Health Canada guidelines are 100 µg/L total trihalomethanes and 80 µg/L haloacetic acids (HAA5's) all measured on a locational running annual average. While these changes in Health Canada's guidelines are relatively recent, it is worth noting that the USEPA regulations are still more stringent, at 80 µg/L and 60 µg/L for THM's and HAA5's respectively. We believe this is of significance, as the Health Canada guidelines have historically shown a trend of mimicking almost exactly the USEPA regulations over time, albeit typically with a time lag of several years. As such, we expect that the Health Canada guidelines will change again in due course to match the present USEPA regulation for DBP's.

  Locational Running Annual Average, or LRAA, is an alternative means of measuring disinfection by-product concentrations in the distribution system. The LRAA approach requires that the utility show an ability to meet the water quality target at all points in the system individually. The LRAA approach is significantly more stringent than an annual average of all the samples from across the distribution network;
- **Algal Toxins**: Health Canada's existing guidelines include an objective of 1.5 µg/L for cyanobacterial toxins, toxic compounds released by some types of algae (blue-green algae). Both the Kalamalka Lake and Duteau

Creek sources are susceptible to algae blooms and we recommend that this objective be adopted by the RDNO. As such, we recommend that toxins such as microcystin-L should be tracked and mitigative measures addressed in the long term treatment approach. This testing is quite specialized meaning once an algae bloom is detected within a raw water source during regular monitoring, a sample should be collected and sent to a qualified laboratory for toxin analysis such as microcystin-L.

- **N-Nitrosodimethylamine (NDMA)**: NDMA can be formed during water treatment by the chlorination or chloramination of waters containing organic nitrogen, as a by-product of degradation of water treatment polymers, or in processes where anion exchange resins are used. It is presently unregulated by Health Canada, but is regulated in Ontario at a level of 9 ng/L. Currently, disinfection by-products are an issue within the distribution network and one of the suggested historical solutions has been to use chloramines as the residual oxidant within the distribution network. Establishing a contaminate goal for NDMA is a critical first step to ensure the long term water treatment approaches meet the long term needs of GVW.
- **Bromates**: Bromates are presently regulated by Health Canada and the USEPA at 10 µg/L but are normally not a concern in water treatment unless ozone is used in the process, as bromates are the usual by-product of the oxidation of naturally occurring bromides. Bromate formation potential should therefore be verified if ozonation becomes a strong candidate for inclusion in one of the treatment process trains.

A summary of the recommended treated water quality goals for the RDNO are presented in **Table 3-1**.

Table 3-1 Regional District Water System Long Term Treated Water Quality Goals

Parameter	Units	Quantity
Total alkalinity	mg/L as $CaCO_3$	> 25
Aluminium, total	mg/L	< 0.1
Coliform bacteria	organisms/ 100 mL	< 1
Cryptosporidium parvum	log reduction	> 3-log (99.9 %) removal or inactivation[2]
Giardia Lamblia	log reduction	> 3-log (99.9 %) removal or inactivation
Enteric viruses	log reduction	> 4-log (99.99 %) removal or inactivation
Iron	mg/L	< 0.3
Sulphates	mg/L	< 200
pH		Stable, non-aggressive
Temperature	^{o}C	< 15
Trihalomethanes	ug/L	< 80, on a Locational Running Annual Average
Haloacetic Acids	ug/L	< 60, on a Locational Running Annual Average
N-Nitrosodimethylamine	ug/L	< 9, on a Location Running Annual Average
Total Organic Carbon	mg/L	Reduce raw water levels by a minimum of 60% with automated, optimized coagulation
True Colour	TCU	< 15
Turbidity	NTU	Granular Media Filtration < 0.3 NTU 95% of the time, never to exceed 1 NTU Membrane Filtration < 0.1 NTU

[2] *Based on future Cryptosporidium sampling the Kalamalka Lake treatment target could be increased to 4-log removal or inactivation.*

3.2 Filtration Deferral Criteria

Many communities across Canada and British Columbia have access to high quality water sources that are not required to filter the water prior to distribution. The basis for a water purveyor avoiding or delaying filtration needs to be established on safety and reliability of the water source, both in the water quality characteristics and the nature and activities within the watershed. The local regulatory, BC Health, stipulate compliance with the GCDWQ Filtration Exclusion Criteria and their own guidance documents for utilities that seek deferral of filtration. The following is an excerpt from the BC Health I*ssue Paper: Planning for Drinking Water Filtration Recommendation*:

"Systems may qualify for deferral of filtration if they demonstrate the following:

- 4-log removal or inactivation of viruses and 3 log inactivation of protozoa is achieved using a minimum of 2 disinfection processes.
- Background baseline levels of *Cryptosporidium* and *Giardia*, adequate to establish trends, have been established.
- A watershed control program designed with the express purpose of minimizing faecal contamination in the source water is being implemented. Watershed control programs expressly intended to minimize faecal contamination can be accomplished by completing appropriate modules of the comprehensive source to tap assessment guide developed by MOE and MOH. Modules appropriate to the water supply system will be identified by the DWO and may be included in conditions of the operating permit.
- No more than 10% of source/raw water *E.coli* samples exceed 20/100 mL in any 6-month period.
- No more than 10% of source/raw water total coliform samples exceed 100/100 mL in any 6-month period.
- Turbidity in source immediately before disinfection does not exceed 1NTU 95% of the time in any 30-day period.
- Peak turbidity readings do not exceed 5 NTU for more than 2 days in a 1-year period.
- Expected average annual total Trihalomethanes at locations farthest from treatment will not exceed 0.100 mg/L or 100 µg/L."

Given the raw water characteristics, it is accepted that filtration is required in addition to the existing clarification and disinfection infrastructure at the Duteau Creek treatment site. Due to the acknowledged need for filtration for the Duteau Creek source the remainder of the discussion in this section will focus on the Kalamalka Lake source.

Significant raw water quality data has been collected in the recent past by GVW for the Kalamalka Lake source. It has been determined that there are variations in the raw water quality at different depths and locations within the Kalamalka Lake. There are also consistent seasonal variations in the Kalamalka Lake raw water quality. The general conclusions from the previous studies are:

1. Seasonally the raw water quality is consistently high enough to support the use of a 2-stage disinfection facility to provide acceptable treated water quality. If the Mission Hill treatment facility operation was able to be limited to the periods of high raw water quality, there is a potential opportunity to defer filtration.
2. Moving the existing intake to a deeper location and creating the ability to divert water from different depths to maximize the raw water quality being conveyed to the customers is a potential solution given the data available. If an intake tower was constructed in Kalamalka Lake with multiple diversion points, it is possible that filtration could be deferred longer than if the existing intake is maintained in the current location. The challenge associated with extending the intake and providing an intake tower with multiple diversion points is the benefit compared to the cost.

> Based on the variability in the raw water data, it is reasonable to expect that filtration will eventually be required. This means the cost of filtration will be deferred, but not avoided. Also, extending the existing intake and providing a tower with multiple diversion points is easily a $ 25 M project, if environmental permitting is achieved. An extension of the existing intake is a possible consideration to defer filtration, however, the actual filtration delay is unknown. Given that the duration of the filtration, delay cannot be accurately predicted and the capital investment associated with extending the existing intake pipe cannot be justified. The lowest cost with the highest quality water being supplied to the GVW customers is to provide filtration instead of considering expensive intake relocation projects.

In addition to the above comments it has been documented in other technical memorandum that it is reasonable to expect regulatory pressure to reduce the Kalamalka Lake water license as part of an application for an extension to the existing intake. The exact magnitude of the potential pressure from the regulators to reduce the existing water license is unknown, but it is a document and known risk associated with a project that involves modifications to the existing Kalamalka Lake intake.

Another consideration for the Kalamalka Lake source is the potential for further deterioration of the raw water in the future. Kalamalka Lake is subjected to numerous potential sources of pollution given the urbanization within the watershed and surrounding the lake, meaning immerging contaminates such as endocrine disruptors could be a concern in the future that could drive the need for more treatment of this source.

Long term water supply options that utilize the Kalamalka Lake source during times of high raw water quality to maximize the potential to defer filtration with be explored within Technical Memorandum 9. However, given the annual raw water characteristics and the document presence of *Cryptosporidium* and *Giardia,* filtration will be required in the future for the Kalamalka Lake source.

4. Evaluation of Treatment Requirements

4.1 Overview of the Treatment Needs

Within the preceding sections the raw water quality associated with Kalamalka Lake and Duteau Creek was presented. Also provided was the long term recommended treated water quality goals. Given the treatment infrastructure already available at each source, the source water quality and the treated water quality objectives the following work is required:

1. Mission Hill: This report assumes that the existing intake is retained and that filtration needs to be added to the existing disinfection facility on Mission Hill. The raw water organic levels and turbidity are low enough that clarification is not required upstream of the filtration process. The exact timing of the filtration plant for the Kalamalka Lake water source will be examined further in Technical Memorandum 9, but given the characteristics of Kalamalka Lake, it is assumed for the establishment of a master water plan that a filtration plant will be needed.
2. Duteau Creek: This source exhibits high levels of dissolved organic matter and colour that generates a tremendous volume of floc once the water is coagulated. To address this issue the water is currently clarified and disinfected, but there is no filtration provided. Also, given the high levels of organic matter in the raw water, even with coagulation and clarification, the levels of the disinfection by-product precursors are too high resulting in elevated levels that exceed the treated water objectives. To address this concern, filtration combined with a strategy to address the generation of disinfection by-products needs to be provided.

Provided below is a summary of the candidate treatment processes that can resolve the outstanding treatment issues at the existing Mission Hill and Duteau Creek treatment facilities. It should be noted that a detailed pilot testing and process selection process is currently being completed at the time that this memorandum is being written. This document is not intended to provide a complete and comprehensive review of all the potential treatment process that could be used at the Duteau Creek facility. Instead the key conclusions evolving from the pilot testing related to the development of a sustainable long term treatment option is presented within this memorandum and used for the basis of developing a long term water supply solution.

4.2 Review of Candidate Processes

4.2.1 Filtration Processes

A wide variety of variant filtration processes are used in water treatment, but these generally are sub-divided into two general families: Granular media filtration and low pressure membrane filtration. Depending on the specific type of granular media used and the pre-treatment, granular media filtration can also operate in a sorptive mode, and also as a biological filter. The following sections present an overview of these various filtration processes and discusses their viability for consideration for this project.

4.2.1.1 Granular Media Filtration

Conventional granular media filtration is the most common type of filtration used in water treatment. It involves placement of one or more layers of inert granular media placed within a concrete filter structure, with flocculated and clarified water being allowed to permeate downwards through the media. As the water passes through the media, solids are removed using a variety of mechanisms and are retained within the filter bed.

In modern granular media filter designs, media is placed in layers, with larger media at the top, and finer media placed nearer the bottom of the bed. This gradation allows solids to penetrate into the depths of the bed, rather than be captured primarily at the surface, and allows for excellent filtered water quality maintained over a reasonable filter run time.

Over time however, and as solids accumulate in the bed, the total head loss through the filter gradually rises, until it reaches a terminal head loss. At this point, the filter must be washed to remove these accumulated solids and restore the filter to its clean state.

Backwashing involves passing clean water upwards in the reverse direction at sufficient velocity to fluidize the bed. Air is typically used before or during the early stages of washing to facilitate in the separation of solids from the filter media during washing.

4.2.1.2 Granular Activated Carbon (GAC) Filtration-Sorption

When used as a filter medium, GAC is most often used as a passive sorptive agent. Since it is relatively non-selective, it is commonly used in water treatment as a sorbent for contaminants including taste and odour, pesticides, endocrine disruptors, or other synthetic organic compounds.

While the GAC has residual sorptive capacity, it will tend to remove many contaminants in the feed water, including dissolved organic carbon, reducing them to very low levels. However, after a period of time, usually 3 to 9 months in most water treatment plants, the sorptive sites become exhausted. Once this point has been reached, the selectivity of the GAC media comes in play, and compounds in the feed water more strongly bound to the GAC are sorbed, and less selective compounds are de-sorbed (stripped from the GAC into the filtered water).

Depending on the specific objective of GAC filtration, it may or may not be cost effective. It tends to reach capacity quickly for dissolved organic carbon (DOC), and it is rarely cost effective to utilize GAC purely for DOC reduction, as regeneration or GAC replacement costs will be excessive. However, for compounds in very low concentrations, such as taste and odour causing compounds such as 2-methylisoborneol (MIB) or geosmin, GAC can provide effective protection even long after the GAC has exhausted with respect to DOC. For the Regional District, taste and odour compounds are not the driving issue resulting in GAC being considered. The primary applicable concern is DOC removal for the Duteau Creek facility, however as previously stated, GAC is effective but known to be a higher cost option to achieve the treatment target.

4.2.1.3 Biological Filtration

Filters are also increasingly being used as a support medium for the deliberate growth of micro-organisms for the removal of dissolved substances such as natural organic matter, ammonia, and manganese, as so-called biological filtration.

As with any biological treatment process, the particular organisms able to target specific contaminants often naturally proliferate if that contaminant is present in elevated concentrations, as long as the nutrients required to support biological activity (carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus) are present in sufficient quantities. If this is not the case, even for one nutrient, growth (and therefore removal) will tend to be hindered. As such, a variety of pre-treatments may be necessary to support biological filtration including:

- Ozonation upstream of the biological filters, which by virtue of its strength as an oxidant, is able to cleave long chain naturally occurring organic molecules into short chain organics more easily assimilable as a food source by the biomass;

- Oxygenation is sometimes necessary, particularly for biological ammonia removal, as the process of ammonia removal is the biologically mediated oxidation of ammonia into nitrites using oxygen. These nitrites are then subsequently oxidized further to nitrates;
- The addition of one or specific nutrient supplements to boost nutrients such as nitrogen or phosphorus which are often deficient in raw waters to support growth;

A specific feature of biological filters that differs from conventional granular media filter design is that a porous media is usually used as the support medium to maximize available surface area for attached growth. Pre-exhausted GAC is often used in this capacity as are engineered ceramic porous medias.

As with conventional filters, biological filters also need periodic backwashing to flush out particulate matter trapped in the bed, and also to remove accumulated biomass.

The reduction of TTHMs in the treated water from the Duteau Creek treatment plant is important and biological filtration will be closely considered to achieve this for the Duteau Creek source. In fact biological filtration pilot testing is ongoing at the Duteau Creek facility.

4.2.1.4 Low Pressure Membrane Filtration

Low pressure membrane filtration (or LPMF) processes used for particulate removal in the drinking water industry almost exclusively are based upon the use of hollow fibre membranes, with pore sizes in the 0.01 – 0.1 micron range. Two specific types of membranes are used -- microfiltration (MF) and ultrafiltration (UF) --- characterized by the pore size of the membranes. The small size of the pores provides excellent removal of particulate matter under all conditions and can provide essentially complete removal of pathogens such as *Giardia* and *Cryptosporidium* through physical size exclusion.

The hollow fiber membranes are housed within individual modules, several of which are mounted in parallel to form a membrane train. Two distinct configurations are used:

- Pressure Fed Membranes where membranes are housed within fabricated pressure vessels, and water is pumped through the membranes under a positive pressure. In pressure fed membranes, water can be fed to the outside of the fibres, and forced through to the inside under pressure (outside-in) or fed to the inside of the fibre, and forced to the outside under pressure (inside-out) depending upon the particular manufacturer; and
- Immersed (or Submerged) Membranes are by definition outside-in membranes, as they involve the placement of bundles of membrane fibers into an open tank of water to be treated. The inside of the fibres are placed under vacuum, drawing water through the membrane fiber wall and into the inside of the fiber.

The scale of membrane filtration plants has been growing rapidly in recent years, driven by the water quality benefits provided by membranes compared to granular media filters, but also by a continual reduction in the unit price of membranes driven by an increasingly competitive market and ongoing research.

For this project, the water treatment plants will be in the order of 60 and 150 ML/d meaning there are several previous low pressure membrane facilities of comparable size. Considering the typical raw water quality variations between the two sites, two discrete approaches of design would be considered:

- Direct membrane filtration (Mission Hill): This would use membrane filtration as the main treatment barrier in the plant for solids removal, without pre-clarification. For this option the membranes would potentially be exposed to higher loading of solids and other foulants, meaning the packing density and configuration of the membranes would need to be carefully considered. Such a facility would be provided with the option for coagulation and flocculation, although it would not necessarily always be used; and

- Membrane filtration with pre-clarification (Duteau Creek): This would use the existing coagulation-flocculation and clarification as a pre-treatment process to remove solids and other foulants upstream of the membranes. Downstream of the clarification process either a pressure or immersed low pressure membrane system could be provided.

In a similar fashion to granular media filters, membrane filters gradually clog with solids during normal operation, requiring shorter duration but more frequent backwashing. Over the course of several operational cycles, the membranes also become fouled with organic matter and other foulants. The membranes require periodic chemical cleanings to remove these foulants to restore the membrane to their clean state.

4.2.1.5 Chloramination

Chloramination is the practice of adding ammonia to chlorinated water to generate the production of chloramine compounds. Chloramination is used by water purveyors throughout North America as a secondary disinfectant to provide a residual oxidant within the distribution system. Even though chloramination is used across North America there are few utilities that use chloramines within British Columbia. The only sizable water purveyor in British Columbia that uses chloramines is the Capital Regional District. They have been using chloramines in their distribution network since the 1940s.

The production of chloramines typical results in lower chlorine based disinfection by-products such as THM's. The other potential benefit of chloramination is the production of a more stable oxidant within the distribution system meaning the need for re-chlorinating is reduced. The challenge associated with the use of chloramines is:

1. Recent and ongoing research is indicating that N-Nitrosodimethylamine (NDMA) disinfection by-products are more harmful to human health at lower concentrations than THM's. The practice of chloramination results in the generation of NDMA if the precursors are not removed from the water prior to disinfection; and
2. Water management during regular maintenance and emergency watermain breaks is far more important as chloramine compounds are far more persistent in the natural environment. There are documented cases of watermain breaks resulting in chloramined water entering natural water bodies causing aquatic damage and death.

The additional of ammonia dosing systems to create chloramines within the distribution system is a potential solution to reduce the THM levels associated with the water currently provided to the GVW customers. In fact the pre-design report for the current Duteau Creek treatment facility recommends that the secondary disinfectant be converted from free chlorine to chloramination to reduce the TTHM levels within the distribution network. Prior to embarking on construction the infrastructure associated with providing ammonia dosing facilities it is recommended that bench top testing be completed to confirm that the chloramine disinfection by-products (NDMA) do not also exceed the Canadian drinking water quality guidelines. Regardless of the short term solutions that could be explored as part of a detailed implementation program for a preferred water supply solution, for the establishment of a long term plan for the utility it is recommended that the disinfection precursors be removed with the necessary treatment processes at the water treatment plant(s). Based on separate planning studies, the selection of chlorination or chloramination as the secondary disinfectant can be made in the future.

4.3 Evaluation of the Candidate Processes

The advantages and disadvantages of the candidate filtration processes are summarized in **Table 4-1**.

Table 4-1 Advantages & Disadvantages of the Candidate Filtration Processes

Filtration Process	Advantages	Disadvantages	Short-Listed for Further Consideration ?
Granular Media Filtration	• Low maintenance • Low O&M cost • Commonly used at other Okanagan facilities of a comparable size.	• Larger footprint	Yes
Granular Activated Carbon Media Filtration - Sorption	• Low maintenance • Limited specialized operator training	• Larger footprint • High cost of carbon regeneration or replacement	No
Biological Filtration	• Low maintenance • Low O&M cost • Very effective for organics and ammonia removal	• Larger footprint • Need to own and operate an ozone generation system • Potential operator health concerns	Yes
Low Pressure Membrane Filtration	• Potentially smaller footprint	• High O&M Cost • Proprietary system	Yes

Generally, the raw water quality from Kalamalka Lake related to the filterability is good as there are low to moderate levels of organic matter and turbidity meaning direct filtration is acceptable. The key concern with the Kalamalka Lake source is the slightly elevated turbidity levels and the measured coliform and parasite concentrations. Further testing should be completed and a detailed cost analysis completed during subsequent engineering studies, but the basis of design for the Master Water Plan for filtration at Mission Hill is low pressure membrane. The key benefits of a membrane filtration are:

1. A fixed barrier against the passage of impurities for a direct filtration plant would be beneficial given the potential for high concentration of parasites as document in samples collected in 2008; and
2. No need to regularly coagulate resulting in less residual production and lower operating cost.

It is acknowledged that a direct filtration plant using granular media filtration combined with the existing disinfection process at the Mission Hill site would be an acceptable treatment approach for Kalamalka Lake water. It is expected that the capital cost of this treatment approach should be less expensive than a membrane filtration plant, but not significantly given that coagulation will only be required seasonally. For the purpose of developing a long term plan, the higher cost treatment approach of membrane filtration is assumed; but further studies should be completed to finalize the treatment process selection prior to constructing the filtration facility.

As previously noted, pilot testing is currently on-going at the Duteau Creek treatment facility to determine the optimum solution to provide filtration, while also reducing the disinfection by-product precursors in the process flow. The results of this ongoing project will be summarized in a separate report that is still being completed, but preliminary analysis is showing that biofiltration will provide an effective barrier for the final polishing of the clarifier water and will suitably reduce the DOC levels resulting in acceptable levels of disinfection by-products in the treated water within the distribution network. For the basis of establishing a long term plan for the Duteau Creek facility the assumption is biofiltration consisting of ozonation of the clarified water followed by ozone quenching, filter aid-polymer and deep bed filtration using exhausted GAC.

5. Long Term Treatment Approach

Based on the information presented in the previous sections this portion of the report offers candidate long term treatment process trains for the Kalamalka Lake and Duteau Creek raw water sources. The candidate long term treatment process trains are intended to be a reasonable basis for the establishment of capital and operating costs for different sized treatment plants for each raw water source. The cost information is intended to be a reasonable representation of the actual expected long term treatment costs and be acceptable for the purpose of comparing different long term water supply options. It is expected that the actual selection of the final treatment process for each raw water source will be based on a detailed engineering assessment.

5.1 Mission Hill Water Treatment Plant

The existing Mission Hill water treatment plant is currently sized to produce 58 ML/d of disinfected water with the provision for the future addition of a direct filtration plant. The existing site is pre-planned to support the additional of filtration complete with the associated chemical and residual handling facilities that are all rated to produce 58 ML/d. A facility larger than 58 ML/d will result in the need to acquire additional land. In addition to acquiring land the raw water supply infrastructure will need more upgrades than currently planned if the ultimate treated flow is more than 58 ML/d of treated Kalamalka Lake water.

A schematic diagram of the process is included as **Figure 5-1** showing the existing and proposed treatment processes necessary to achieve treated water that is compliant with the long term treated water goals given the raw water quality characteristics of the Kalamalka Lake source. In summary, the existing and recommended treatment processes used for the basis of the capital and operation cost estimates are:

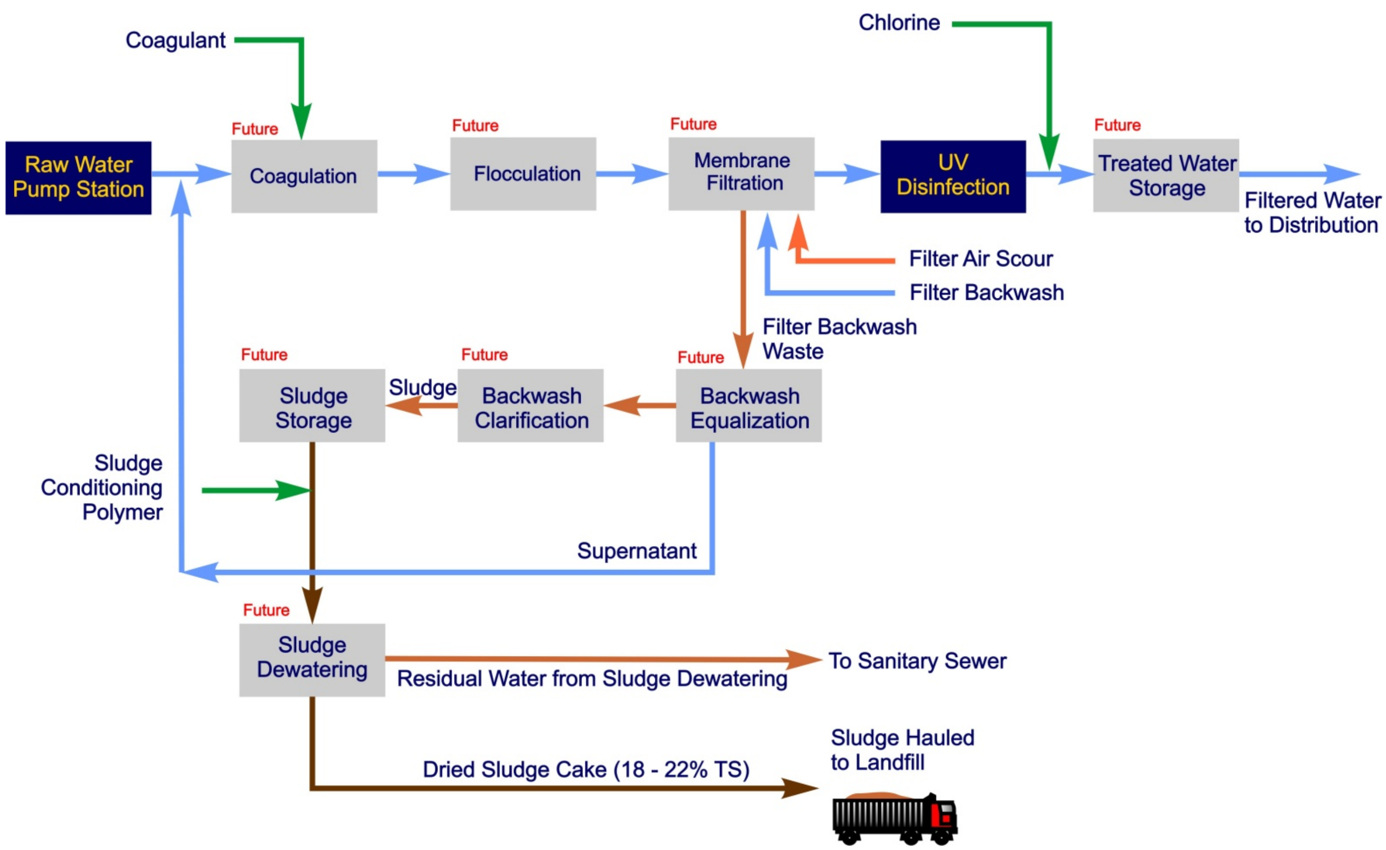
1. Existing treatment processes
    a. Raw water connections to the supply mains and associated flow control;
    b. On-site hypochlorite generation system for chlorination;
    c. Medium pressure ultraviolet disinfection;
    d. A large diameter pipe for chlorine contact time (a chlorine analyzer was added by the Operations staff in 2012); and
    e. Treated water pumping.
2. Proposed treatment processes
    a. Coagulation, using poly-aluminium chloride, to destabilize colloidal material, and entrap natural colour in the water within a chemical floc;
    b. Jet flash mixing facilities, to rapidly mix the coagulant into the raw water;
    c. Mechanical flocculation, to gently stir the newly coagulated water and encourage the small floc particles formed during coagulation to adhere together and grow larger flocs;
    d. Chemical feed facilities for poly-aluminium chloride, caustic soda (sodium hydroxide), and polymers for the sludge treatment process;
    e. Filtration consisting of low pressure membranes. The water backwash will be processed on-site as explained below and the chemical enhanced backwashes and CIP wastes will be discharged to the sanitary sewer;
    f. Filter backwash equalization and clarification. The thickened sludge produced by this process

will be pumped to a sludge storage tank for de-watering. The de-watered sludge will be hauled off-site and it is assumed that the centrate will be discharged to the sanitary sewer. During the completion of the detailed design other centrate disposal options should be examined such as re-use at the adjacent research forest.

g. Balancing storage at the Mission Hill site to support the treatment process.

It is assumed that the new filtration infrastructure will be located in a new building on the west side of the existing disinfection facility. Given the information available at this time it is also assumed that the membrane filtration facilities will need coagulation and 20 minute flocculation time. During further testing associated with the future development of this project, it may be possible to reduce (or even eliminate) the flocculation time resulting in reduced building footprint and cost. It is assumed that the electrical and control of the new filtration plant will be constructed to the same standard used at the existing treatment facilities (i.e. standby electrical power is assumed at the Mission Hill facility).

Figure 5-1 Mission Hill Water Treatment Facility Recommended Process Train



5.2 Duteau Creek Water Treatment Plant

The existing Duteau Creek water treatment plant is sized to produce 162 ML/d of clarifier water with the current plan being for the eventual construction of a granular media filtration plant. The existing site is pre-planned to support a filtration plant rated to produce 150 ML/d. However, the existing clarification facility can suitability function with a filtration plant ranging in size from 20 ML/d to 150 ML/d. The exact size of the filtration plant will vary in size based on preferred long term system separation solution.

A schematic diagram of the process is included as **Figure 5-2** showing the existing and proposed treatment processes necessary to achieve treated water that is compliant with the long term treated water goals given the raw water quality characteristics of the Duteau Creek source. In summary, the existing and recommended treatment processes used for the basis of the capital and operation cost estimates are:

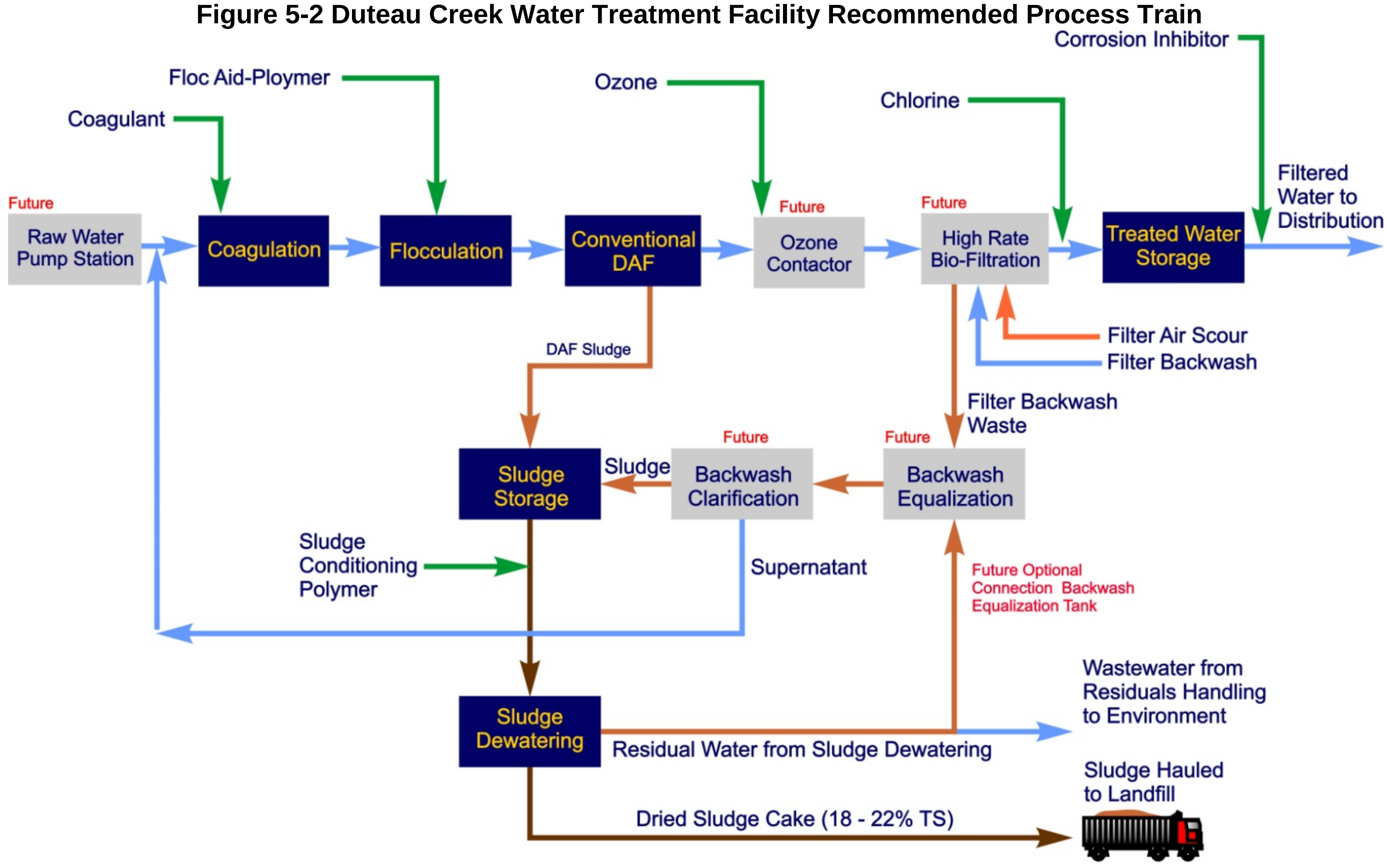
1. Existing treatment processes
    a. Connections to the existing 1200 mm low pressure concrete raw water main, to draw raw water from the existing Duteau Creek transmission main into the treatment plant. Currently, the clarified water is returned to the same main by gravity;
    b. Coagulation, using poly-aluminium chloride, to destabilize colloidal material, and entrap natural colour in the water within a chemical floc;
    c. Jet flash mixing facilities, to rapidly mix the coagulant into the raw water;
    d. Mechanical flocculation, to gently stir the newly coagulated water and encourage the small floc particles formed during coagulation to adhere together and grow larger flocs;
    e. Conventional dissolved air flotation (DAF), using micro-bubbles to float the flocs to the surface of the tank, forming a sludge layer which can be scraped from the surface, and separated from the water;
    f. Facilities to capture sludge formed by the DAF process, and pump the sludge at a steady rate to the sludge treatment facilities;
    g. A sludge treatment facility based on the use of centrifugation for mechanical dewatering of the sludge, allowing for most of the water contained in the raw sludge to be removed, rendering the sludge amenable for hauling and disposal off-site;
    h. A clarification process and wetland for treating and disposal of the centrate generated during the de-watering of the DAF float;
    i. Chemical feed facilities for poly-aluminium chloride, caustic soda (sodium hydroxide), polymers for the sludge treatment process, and an on-site hypochlorite generation system for chlorination;
    j. An administration building and operation & maintenance facilities. The administrative and operations & maintenance building will be constructed as part of a consolidated facility with the water treatment plant proper;
    k. A 10,000 m^3 treated water reservoir to provide chlorine contact time and balancing storage.
2. Proposed treatment processes
    a. Low lift pump station to supply the raw water to the treatment facility. During high flow in the existing transmission main, the residual pressure in the transmission main is too low to allow the water to be conveyed by gravity. A low lift raw water pump station will be constructed in the future once the total flow between Harvey Lake and the Duteau Creek WTP site exceeds a maximum of roughly 2083 L/s;
    b. Ozone generation system based on a liquid oxygen supply and an ozone contactor;
    c. Filtration consisting of deep bed gravity granular media. With the upstream ozone process the goal is to achieve bio-filtration to enhance the removal of dissolved organic material;
    d. Treated water low lift pump station to replace the headloss provided by the filtration process;
    e. Filter-to-waste and filter backwash equalization and clarification. The thickened sludge produced

by this process will be pumped to the existing sludge equalization tank for de-watering and the clarified water re-cycled to the head of the treatment process. It is typical for in the order of 90% of the solids in the raw water to be captured in the clarification process, meaning the volume of sludge produced from the treatment of the filter backwash will be proportional small compared to the total sludge volume. The existing sludge de-watering equipment is expected to have sufficient capacity to effectively manage the sludge produced by the filtration process.

With the exception of the raw water low lift pumps that will be located in the lower level of the existing inlet piping gallery, all the other new infrastructure will be provided in a new building between the existing clarifiers and treated water reservoirs.

A key long term concern with the Duteau Creek source is low hardness and alkalinity of the water, resulting in the treated water being categorized as corrosive. To address this concern, the Stage 1 facility at Duteau Creek includes the addition of caustic soda. To ensure that the caustic soda dose is optimized, GVW should monitor the corrosivity of the Duteau Creek water supply by conducting coupon tests and sampling for dissolved metal concentrations within the network. For the basis of the Master Plan, it is assumed that the caustic soda will continue to be dosed at levels comparable to the past couple years of operation.

Figure 5-2 Duteau Creek Water Treatment Facility Recommended Process Train



6. Evaluation of Costs

6.1 Existing Kalamalka Lake and Duteau Creek Water Treatment Operating Costs

The long term operating cost of the treatment plants is a significant component of the life cost of a municipal water supply system. Ensuring the estimate operating costs are representative of the actual expected costs that will be incurred by GVW is important for any cost based decisions made in the Master Water Plan.

At both the Mission Hill and the Duteau Creek site there are partial treatment plants that have been functional for a couple years. To ensure our operating cost projections are reasonable the first task we completed was to compile the existing operating costs. During the review of the existing facilities the existing actual costs were separated into the following categories:

- Energy;
- Equipment, maintenance and training;
- Chemicals; and
- Wages.

Based on data obtained from the Regional District for the past couple of years the actual annual operating cost for the Mission Hill facility is roughly $ 700 k/year. The total annual volume of water processed is in the order of 8,200 ML resulting in an existing cost of $ 85/ML. For the Duteau Creek facility the annual cost was $ 1.45 M in 2012 while treating a total annual water volume of 12,360 ML. The unit cost of water at the Duteau Creek facility is $ 117.50 ML. These values represent all the costs associated with the operation of the existing treatment plants such as labour, chemicals, electrical power, repairs and all other cost items allocated to the operating cost of the treatment plants.

Using the actual costs for the above categories estimates of the future operating cost once filtration is added at both sites can be generated for various different plant sizes. Once the estimated operating costs were produced based on detailed calculations the values were compared to industry standard operating cost curves for other similar facilities across Canada.

6.2 Kalamalka Lake Water Treatment Costs

The following assumptions were used to develop the capital and operation cost projections for the long term treatment requirements for the Mission Hill Water Treatment Facility:

- Treatment train to include flash mixing, flocculation, membrane filtration, UV disinfection and chlorination using on-site hypochlorite.
- Construction of a new building required to accommodate the membrane filtration infrastructure. New building includes provision for immersed membrane filtration, backwash waste equalization, and on-site residuals management.
- The existing facility is capable of providing UV and chlorine disinfection up to 58 ML/d.
- Treatment capacities beyond 100 ML/d include provision to expand the existing building to accommodate the increased disinfection requirements.
- The existing Mission Hill water treatment plant property can accommodate the filtration building requirements up to 100 ML/d. Beyond 100 ML/d the GVW will need to purchase additional land. Cost of land purchase based on $100,000 per acre.

- Provision to upgrade the electrical service included in the 200 ML/d.
- The annual operational and maintenance costs are based on the current facilities operating data as provided by the RDNO and the City of Vernon. Energy and chemical consumption cost projections increase proportional to the increase in total annual treated water volume of the facility.
- The ratio of maximum day demand to average day demand of 2.52 was applied to determine the average treated water demand projections based the probable worst case flow condition.
- One additional operator will be required on staff with the addition of the filtration building for the 58 ML/d and 100 ML/d operating scenarios. For a scenario where raw water is diverted to the existing Mission Hill site and the plant is significantly expanded to a maximum rated capacity of 200 ML/d, two additional operators will be required.
- The cost of membrane replacement is included in the Equipment, Maintenance, and Training cost category. Replacement cost based on amortization of the full membrane cost at 3% over the 10 year life expectancy of the membranes.

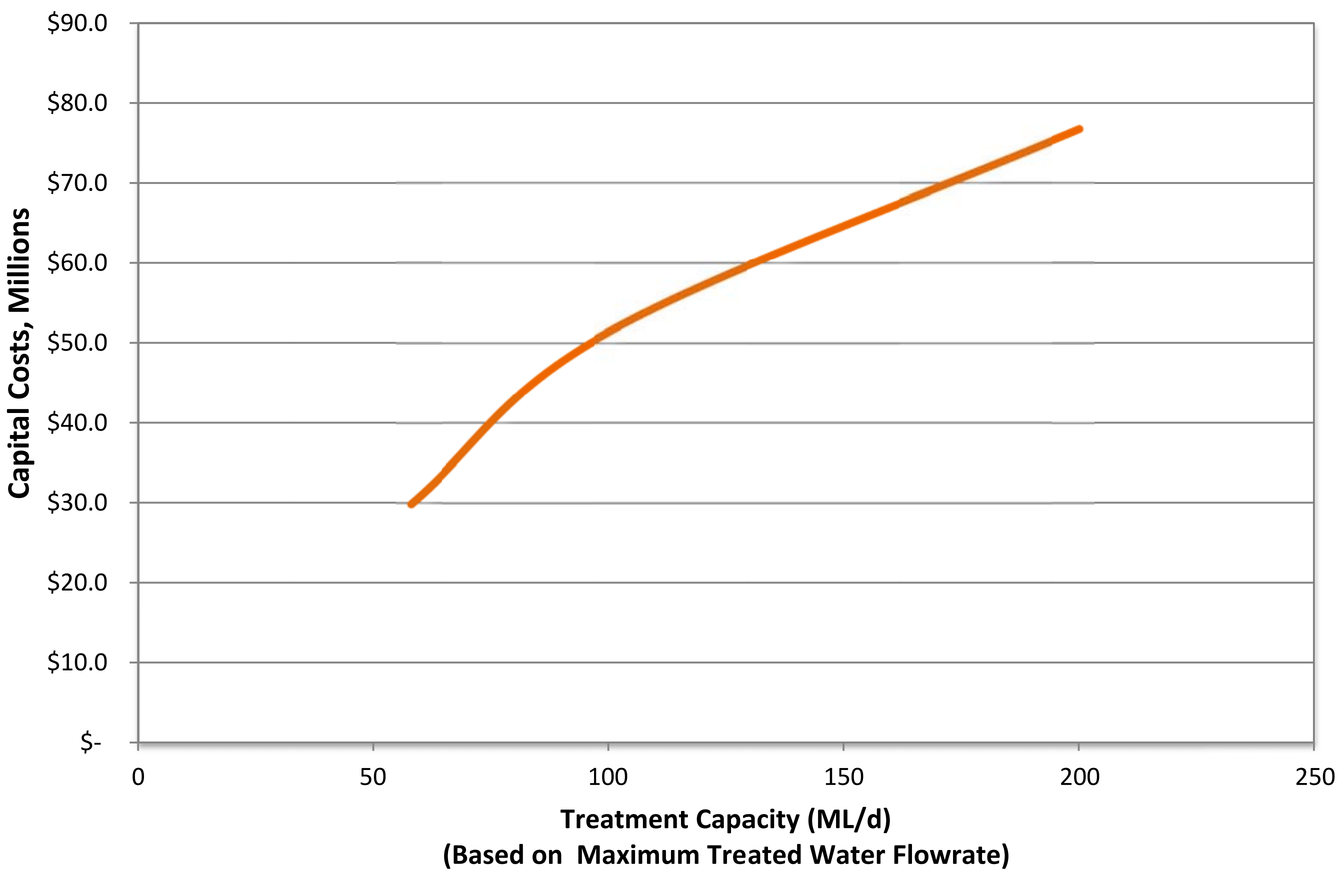
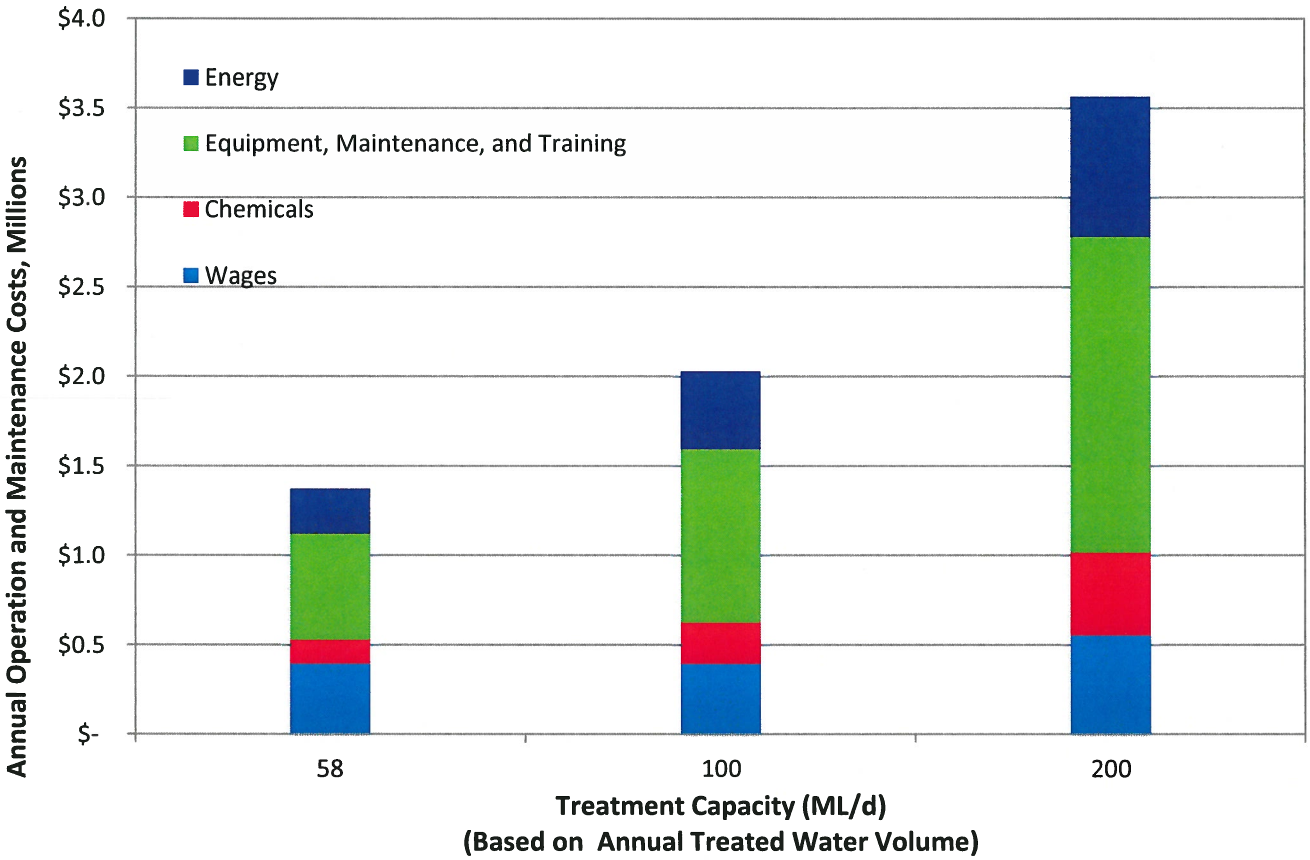


Figure 6-2 Mission Hill Water Treatment Facility Operational Cost Projections (with Filtration)



6.3 Duteau Creek Water Treatment Costs

The following assumptions were used to develop the capital and operation cost projections for the long term treatment requirements for the Duteau Creek Water Treatment Facility:

- Treatment train to include Low lift pumping (200 ML/d ONLY), flash mixing, flocculation, DAF clarification, intermediate ozonation, biological media filtration, and chlorination using on-site hypochlorite;
- Construction of a new building required to accommodate the new filtration infrastructure. New building includes provision for ozone contact, ozone generation, biological filtration, backwash waste equalization, treated water equalization, and on-site residuals management;
- The existing facility is capable of providing DAF clarification up to 150 ML/d;
- Treatment capacities beyond 150 ML/d include provision to expand the existing building. The estimated cost for the 200 ML/d capacity includes two additional DAF clarification basins to provide the additional 50 ML/d of treated water capacity;
- The existing Duteau Creek Water Treatment Plant property can accommodate the filtration building requirements up to 200 ML/d;
- The annual operational and maintenance costs are based on the current facilities operating data as provided by the RDNO and the City of Vernon. Energy and chemical consumption cost projections increase proportional to the increase in total annual treated water volume of the facility;

- The existing clarification facility to operate at a reduced capacity for the 25, 50 and 100 ML/d scenarios;
- The ratio of maximum day demand to average day demand of 4.05 was applied to determine the average treated water demand projections based on the probable worst case flow condition;
- One additional labourer will be required on staff with the addition of the filtration building for the 100 and 150 ML/d operating scenarios. Two additional labourers required to operate the 200 ML/d filtration facility. One less labourer will be required on staff for the 25 ML/d scenario;
- The annual consumption is expected in increase in relation to the peak water demand at the 50 and 100 ML/d due to the increasing proportion of domestic water consumption (i.e. increase in system separation to reduce the seasonal irrigation demand from the treated water supply). To account for the modified cost projections the consumables costs were adjusted by reducing the average day demand to peak day demand ratio by 30% for the 100 ML/d and by 150% for the 25 and 50 ML/d respectively.

Figure 6-3 Duteau Creek Water Treatment Plant Capital Cost Projections (with Filtration)

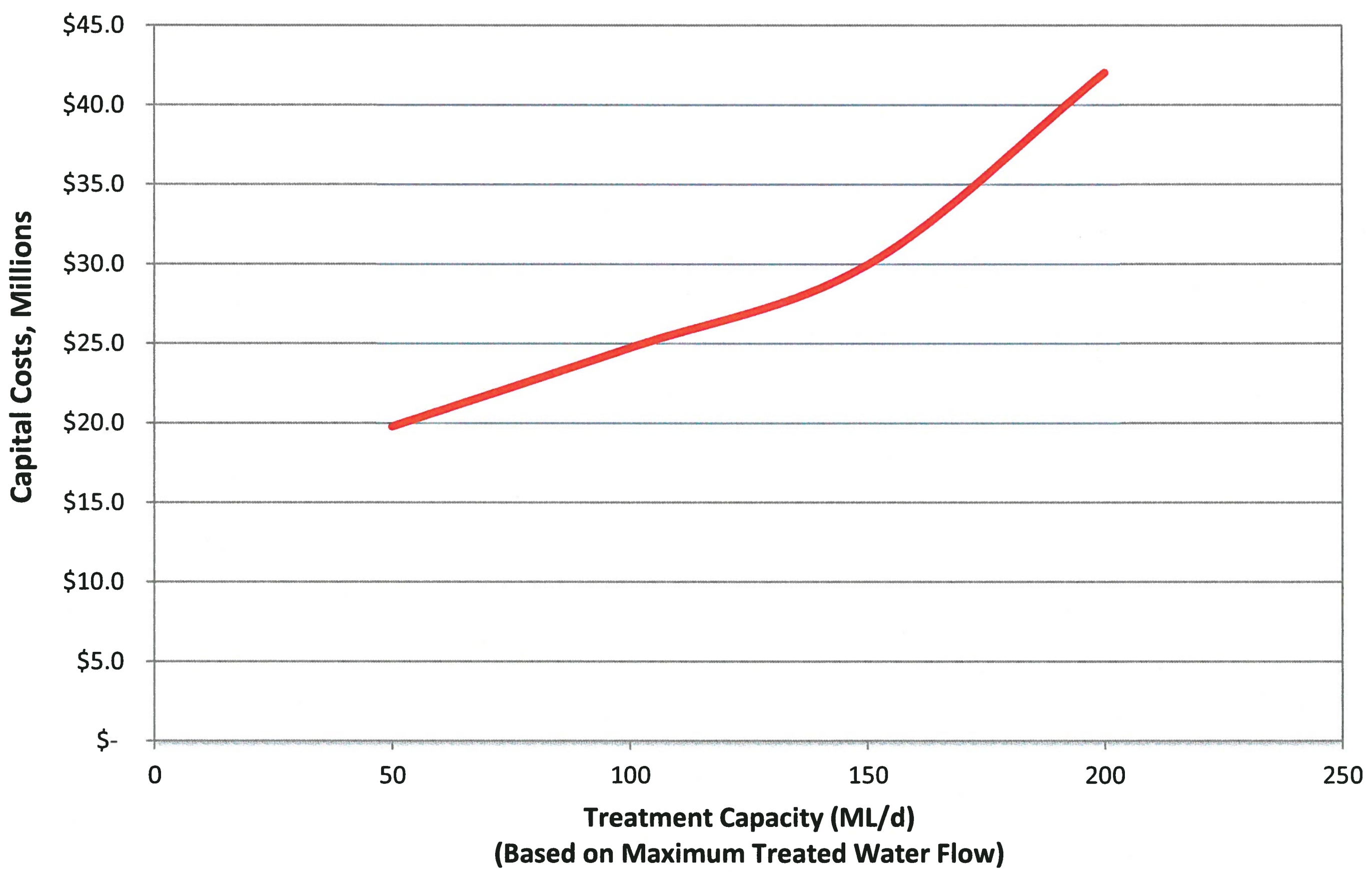
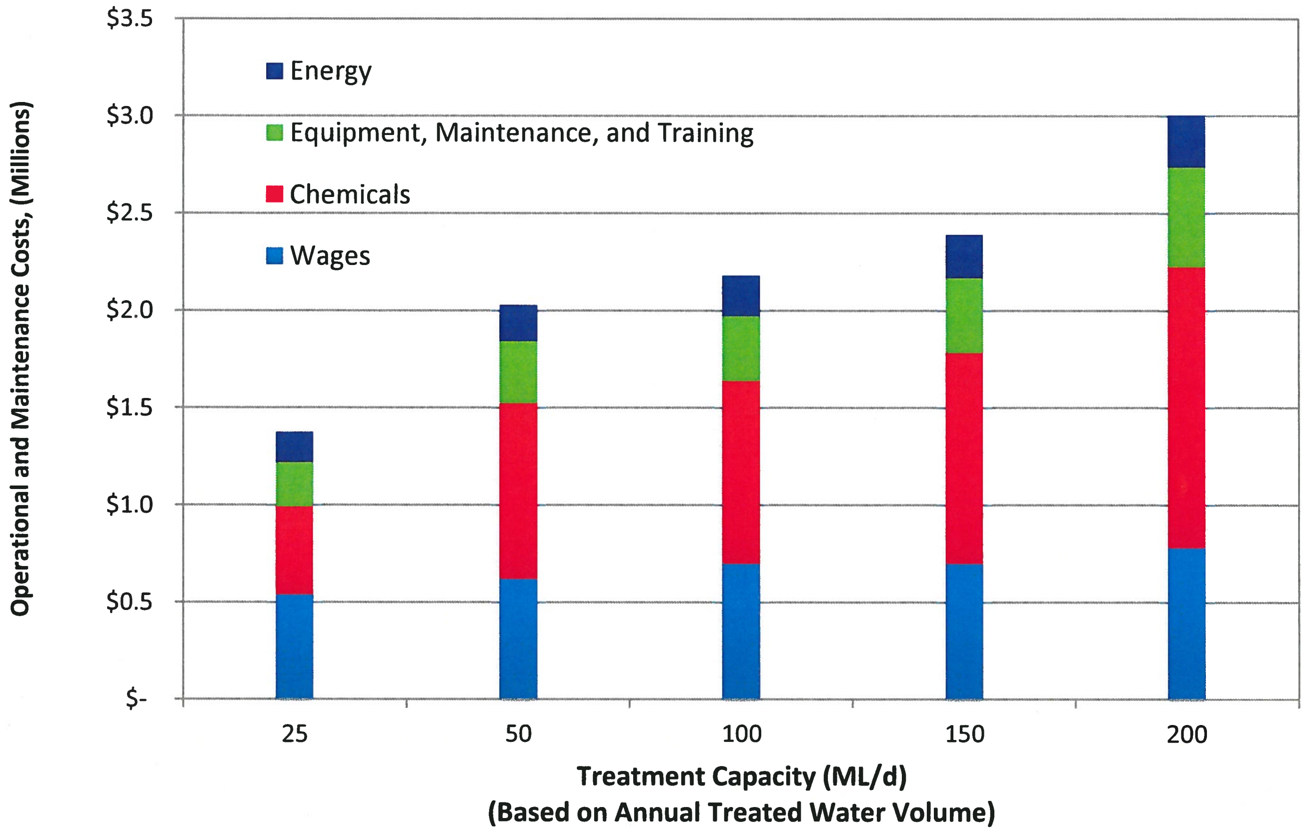


Figure 6-4 Duteau Creek Water Treatment Plant Operational Cost Projections (with Filtration)



6.4 Capital and Operating Cost Discussion

The capital costs provided are based on the water treatment process trains described in Section 5 of the report. The operating costs were developed for each of the proposed facilities by examining the existing operating cost and then adding the additional operating cost associated with the new treatment processes. This approach was taken to ensure the projected operating costs are a reasonable reflection of the actual operating cost experienced in the future as the operating costs have a measurable impact on the life cycle cost of a treatment plant.

Generally, the operating cost on a volume of water treated basis is expected to be lower for the Duteau Creek facility once filtration is provided at both sites. Some of the key variations and reasons for the lower operating costs are summarized below:

1. The chemical cost for the Duteau Creek facility will be measurably higher than the Mission Hill facility. This is a result of the characteristics of the raw water. The chemical costs are based on actual operational data and bench top testing meaning the variation in chemical cost is expected to be reasonable.

2. The labour costs associated with the Mission Hill facility are assumed to be lower than Duteau Creek. This is based on a reasonable estimate of the staff necessary to operate a fully automated membrane filtration plant versus the existing staff already employed at the Duteau Creek plant. The labour component of the operating cost estimate are reasonable given the size and complexity of the treatment facilities being planned, but will be subject to staffing decision made by the Utility.
3. The Duteau Creek facility is planned to use conventional treatment processes whereas the Mission Hill facility is planned to be a membrane filtration plant. This resulting in the equipment replacement cost being higher for the Mission Hill facility. The majority of the cost increase is associated with membrane replacement.
4. In the future there will be some minor pumping at the Duteau Creek plant to replace the headloss through the granular media filters; however, the majority of the flow from the Duteau Creek facility will be by gravity. This means there is less cost associated with energy consumption at the Duteau Creek facility versus the Mission Hill facility where all the water is pumped from Kalamalka Lake.

The cost to provide filtration at the Duteau Creek site is expected to be a lower cost than the Mission Hill site. The primary reason for this is the assumption that filtration at the Mission Hill site will be accomplished using membranes. For the capital costs the key comments are:

1. Duteau Creek Water Treatment Plant
    a. The cost per volume of water treated increases for facilities larger than 150 ML/d as the existing site has been developed for a 150 ML/d water treatment plant.
    b. A complete water treatment plant that includes filtration could be accommodated on the existing site to a maximum size of roughly 200 ML/d. Any option that requires a treatment facility larger than 200 ML/d would require the acquisition of more land and it deemed to not be practical.
    c. All the Duteau Creek filtration plant options assume that treated filter backwash can be re-cycled to the head of the inlet of the plant. This is a common practise around the world, but will be subject to BC Health approval.
2. Mission Hill Water Treatment Plant
    a. The minimum filtration plant size assumed for this site is 58 ML/d. This is the facility size pre-planned for the current site.
    b. Additional land will be required for larger than 58 ML/d facilities, but it is assumed that this can be acquired from the adjacent tree farm.
    c. Associated with a filtration plant at the Mission Hill site larger than 58 ML/d will be raw water supply upgrades. These upgrades could include an intake and Kalamalka Lake pump station improvements or raw water pipelines from Duteau Creek. The source of the raw water supply will vary depending on the option being considered and the cost impact the raw water infrastructure needs to be examined separately from the cost of the water treatment plant.

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7. References

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