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Water

Greater Vancouver Water District
2015 Quality Control Annual Report

Volume 1

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Foreword

This report has been produced to meet the requirement for water suppliers to produce an annual report on water quality as per the BC Drinking Water Protection Regulation and as described in the Water Quality Monitoring and Reporting Plan. Volume I of the annual report uses data summaries and graphics to highlight the water quality issues and Volume II provides Chemical and Physical Monitoring results (the actual data). Both Volume I and Volume II will be available on the Metro Vancouver website.

This report discusses numerous water quality parameters with potential health effects. For detailed information on drinking water health effects, the following web sites are suggested:

Health Canada:
http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/index-eng.php
US EPA:
http://www.epa.gov/safewater/mcl.html
World Health Organization:
http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/index.html

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1 EXECUTIVE SUMMARY

- Source Water Quality

  - In 2015, the turbidity levels of the delivered water easily met the requirements of the Guidelines for Canadian Drinking Water Quality (GCDWQ).

  - The Capilano supply was out of service at the beginning of the year. Capilano source water commenced treatment at the Seymour Capilano Filtration Plant (SCFP). Heavy rainfall events in early November resulted in Capilano source water turbidity peaking at 5 NTU. Even with the higher turbidity, the delivered filtered Capilano water was predominately less than 0.1 Nephelometric Turbidity Unit (NTU) for the entire year.

  - The Seymour supply was in service for the entire year and Seymour water was treated at the SCFP prior to delivery. Water entering the GVWD transmission system from the SCFP was consistently <0.1 NTU for the entire year. For source water entering the SCFP, turbidity was generally less than 1 NTU throughout the year except during the heavy rainfall events which resulted in Seymour source water turbidity peaking at 11 NTU. Even with the higher turbidity, the delivered filtered Seymour water was predominately less than 0.1 NTU.

  - The Coquitlam supply was in service for the entire year. The average daily turbidity of the unfiltered Coquitlam source water was over 1 NTU for eighteen days and at no time in 2015 was the average turbidity over 5 NTU. Water treatment levels were increased during periods of higher turbidity in accordance with operating protocols.

  - The microbiological quality of the three source waters was good in 2015. The levels of bacteria and protozoa detected were low and indicative of high quality source water. All three sources easily met the bacteriological requirements for avoiding filtration outlined in the Turbidity section of the GCDWQ.

  - Results of the analyses of the source water for herbicides, pesticides, and volatile organic compounds and radionuclides were all found to be below the recommended limits for these substances as listed in the GCDWQ.

- Water Treatment

  - The Twin Tunnels Project enabled the Capilano source water to be filtered, treated at the SCFP and subsequently returned to the Capilano distribution system commencing April 15, 2015.

  - The Seymour Capilano Filtration Plant provided full filtration and the plant performance, as measured by the quality of the delivered water, was excellent in 2015. The daily average turbidity of water leaving the clearwells to enter the GVWD transmission system was less than 0.06 NTU in 2015.

  - Turbidity levels for Individual Filter Effuent (IFE) met the turbidity requirements of the GCDWQ except for two minor excursions in January 2015. On January 26, 2015, the IFE of one filter exceeded 1 NTU for 5 seconds. On January 29, 2015, the IFE of two filters exceeded 1 NTU for periods of 2 and 3.5 minutes, respectively.

- Filtration consistently removed iron, colour and organics from the Capilano and Seymour source water.

- Levels of total aluminum in filtered water were consistently below the GCDWQ operational guideline value of 0.2 mg/L for direct filtration plants using aluminum-based coagulants. The maximum value for 2015 was 0.05 mg/L.

- The secondary disinfection stations boosted chlorine as required.

- Distribution System Water Quality

  - Bacteriological water quality was good in the GVWD transmission mains. There was no *E. coli* detected in any of the samples collected.

  - Bacteriological water quality was good in the GVWD in-system storage reservoirs. There was no *E. coli* detected in any of the samples collected.

  - Bacteriological water quality was good in the distribution systems of the member municipalities. Of approximately 21,000 municipal samples collected for testing in 2015 a high percentage (99.8%) were free of total coliforms which was similar to 2014 (99.9%). No *E. coli* positive samples were detected in 2015.

  - The running average levels of the Trihalomethane group of chlorine disinfection by-products detected in the delivered water in the GVWD were well below the Maximum Acceptable Concentration (MAC) in the GCDWQ of 100µg/L (0.1 mg/L). The running average levels for the Haloacetic acid group of chlorine disinfection by-products were below the GCDWQ MAC of 80µg/L (0.08 mg/L).

2 ACRONYMS

AO	Aesthetic Objective (characteristics such as taste, colour, appearance, temperature that are not health related)
BCDWPR	British Columbia Drinking Water Protection Regulation
BTEX	Benzene, Ethylbenzene, Toluene, Xylene
CALA	Canadian Association for Laboratory Accreditation
BHT	Capilano Break Head Tank
CRWPS	Capilano Raw Water Pump Station
CFE	Combined Filter Effluent
CFU	Colony Forming Units
CTD	Conductivity/Temperature/Depth
D.S.	Distribution System
DBP	Disinfection By-product
DOC	Dissolved Organic Carbon
DWTP	Drinking Water Treatment Program
E. coli	*Escherichia coli*
ERF	Energy Recovery Facility
EPA	Environmental Protection Agency (USA)
ESWTR	Enhanced Surface Water Treatment Rule (USA)
GCDWQ	Guidelines for Canadian Drinking Water Quality
GVWD	Greater Vancouver Water District
HAA	Haloacetic Acid
HPC	Heterotrophic Plate Count
IFE	Individual Filter Effluent
IMAC	Interim Maximum Acceptable Concentration
MAC	Maximum Acceptable Concentration
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
MDL	Method Detection Limit
mg/L	Milligram per litre (0.001 g/L)
μg/L	Microgram per litre (0.000001 g/L)
mL	Milliliter
MF	Membrane Filtration
mJ/cm^2	Millijoule per centimeter squared
MPN	Most Probable Number
MV	Metro Vancouver
N/A	Not Available
NTU	Nephelometric Turbidity Unit
PAH	Polynuclear Aromatic Hydrocarbon
pH	Measure of acidity or basicity of water; pH 7 is neutral
ppb	Parts per Billion (Equivalent of microgram per litre)
ppm	Parts per Million (Equivalent of milligram per litre)
RCW	Recycled Clarified Water
RWT	Raw Water Tunnel
SCADA	Supervisory Control and Data Acquisition
SCFP	Seymour-Capilano Filtration Plant
T.S.	Transmission System
$THAA_5$	Total $Haloacetic_5$ Acids
THM	Trihalomethane
TOC	Total Organic Carbon
TTHM	Total Trihalomethane
TWT	Treated Water Tunnel
UV_{254}	Ultraviolet Absorbance at 254 nm
WHO	World Health Organization
WQMRP	Water Quality Monitoring and Reporting Plan

3 WATER SAMPLING AND TESTING PROGRAM

Water Type	Parameter	Frequency
Untreated, source water	Total coliform and *E. coli*	Daily
	Turbidity	Daily
	Giardia and *Cryptosporidium*	Monthly at Capilano and Coquitlam
	Ammonia, colour, iron, organic carbon, pH	Weekly
	Alkalinity, chloride, calcium, hardness, magnesium, manganese, nitrate, nitrite, potassium, phosphate, sulphate	Monthly
	Aluminum, copper, sodium, total and suspended solids	Bi-monthly
	Trihalomethanes, haloacetic acids	Quarterly
	Antimony, arsenic, barium, boron, cadmium, cyanide, chromium, lead, mercury, nickel, phenols, selenium, silver, zinc	Semi-annually
	Pesticides and herbicides	Annually
	PAHs, BTEXs	Annually
	VOC	Annually
	Radioisotopes	Annually
Treated water	Total coliform and *E. coli*	Daily
	Turbidity	Daily
	Temperature	Daily
	Ammonia, colour, iron, organic carbon, pH, aluminum at SCFP	Weekly
	Aluminum, copper, sodium, total and suspended solids	Bi-monthly
	Trihalomethanes, haloacetic acids	Quarterly
	Antimony, arsenic, barium, boron, cadmium, cyanide, chromium, lead, mercury, nickel, phenols, selenium, silver, zinc	Semi-annually
Metro Vancouver Water Mains	Total coliform and *E. coli*	Weekly per site
	Heterotrophic plate count	Weekly per site
	Free chlorine	Weekly per site
	Trihalomethanes, haloacetic acids, pH	Quarterly at selected sites
	PAHs, BTEXs	Semi-annually at selected sites
Metro Vancouver Reservoirs	Total coliform and *E. coli*	Weekly per site
	Heterotrophic plate count	Weekly per site
	Free chlorine	Weekly per site
Municipal Distribution system sites	Total coliform and *E. coli*	Weekly per site
	Heterotrophic plate count	Weekly per site
	Free chlorine	Weekly per site
	Turbidity	Weekly per site
	Trihalomethanes, haloacetic acids, pH	Quarterly at selected sites

4 SOURCE WATER QUALITY

The first barrier in place to protect the quality of the drinking water supply is the protection of the watershed to ensure the best quality source water. Source water monitoring provides ongoing confirmation that the barrier is effective, identifies seasonal changes and provides the monitoring information necessary to adjust the level of water treatment that is in place. Regular monitoring of the water sources is also a requirement of the Water Quality Monitoring and Reporting Plan (WQMRP).

4.1 BACTERIOLOGICAL QUALITY OF THE SOURCE WATER

The bacteriological quality of the source water is an important indicator of the degree of contamination, and the treatment required to ensure a safe water supply. The Canadian Guideline for Turbidity (October 2003) stipulates bacteriological quality of the source water in its criteria for avoiding filtration as follows: Prior to the point where the disinfectant is applied, the number of *Escherichia coli (E. coli)* bacteria in the source water can exceed 20/100 mL (or, if *E. coli* data are not available, the number of total coliform bacteria can exceed 100/100 mL) in not more than 10% of the weekly samples from the previous 6 months.

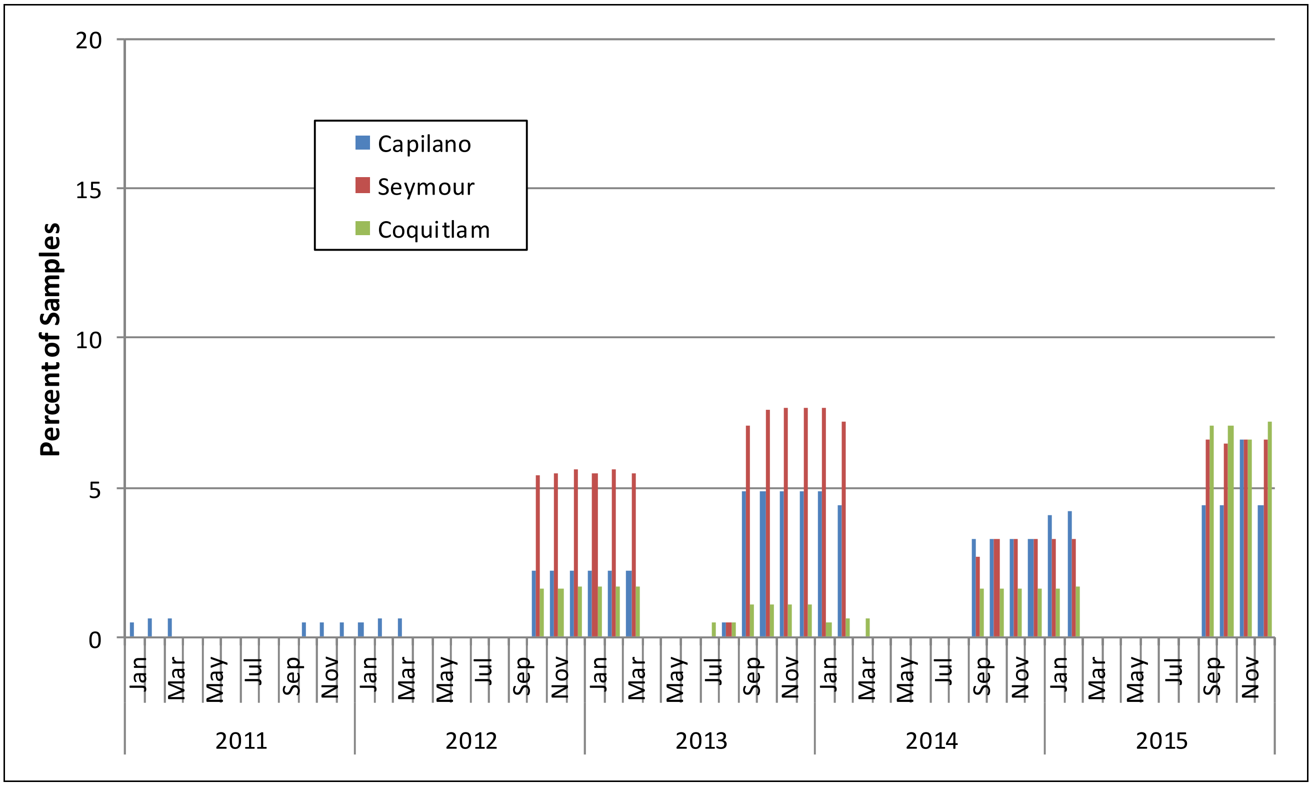
Table 1 below summarizes *E. coli* data for all three Metro Vancouver water sources. The levels of *E. coli* for all three sources were below the 10% limit in the turbidity guideline.

Table 1: Percent of samples in six months (current month plus five previous months) where number of E. coli /100 mL exceeded 20

	Capilano	Seymour	Coquitlam
Jan	4.1	3.3	1.6
Feb	4.2	3.3	1.7
Mar	0	0	0
Apr	0	0	0
May	0	0	0
Jun	0	0	0
Jul	0	0	0
Aug	0	0	0
Sep	4.4	6.6	7.1
Oct	4.4	6.5	7.1
Nov	6.6	6.6	6.6
Dec	4.4	6.6	7.2

Figure 1 shows the results of the analysis of the source water from 2011 to 2015 at all three intakes compared to the limits for source water bacterial levels in the 2003 turbidity guideline. As in the previous years, all three sources easily met the limit of not more than 10% exceeding 20 *E. coli*/100 mL. As was also the case in previous years, samples collected at the intakes in the fall and winter had the highest *E. coli* levels. These *E. coli* can be traced back to high levels at the main tributaries of the supply lakes and a first flush phenomenon after a period of dry weather.

Figure 1: **Percent of samples exceeding 20 *E. coli*/100 mL at all three sources**



Because of the protection of the watersheds from human sources of fecal waste, it is most likely that animals are the source of the *E. coli* detected in the watersheds.

4.2 SOURCE WATER MONITORING FOR *GIARDIA* AND *CRYPTOSPORIDIUM*

Unfiltered surface water supplies have the potential of containing the protozoan pathogens *Giardia* and *Cryptosporidium*. Outbreaks of Giardiasis occurred in a number of locations in B.C. and Washington State in the late 1980s, and the District has been monitoring raw water and animal droppings for *Giardia* since 1987. Since 1992, Metro Vancouver has participated in a project with the Enhanced Water Testing Laboratory, University of British Columbia, to gather more information about the number and nature of the cysts found in the Greater Vancouver water supplies. The project involves collecting samples from the Capilano and Coquitlam supplies upstream of disinfection. Routine monitoring of Seymour source water was discontinued in 2011 because water treatment at the SCFP meets the disinfection requirements for both *Giardia* and *Cryptosporidium* in the GCDWQ. At the SCFP, monitoring for *Giardia* and *Cryptosporidium* has focused on the recycled water returning to the head of the plant and this monitoring has confirmed that the procedures in place effectively control the levels of *Giardia* and *Cryptosporidium* in the recycled wash water from the filters.

The results of the 2015 testing program are contained in the "Report to Metro Vancouver - *Giardia* and *Cryptosporidium* Study January - December, 2015" which was prepared by the BC Public Health Microbiology & Reference Laboratories, Environmental Microbiology, and can be found in Appendix 4. Two of 11 (18%) samples collected at Capilano and none of the 12 (0%) collected at Coquitlam were positive for *Giardia* (Table 2).

As discussed in the previous paragraph Seymour samples for 2015 are all process control samples and not Seymour source water as they were prior to 2011 (shown as N/A in the table).

Table 2: Percentage of Water Samples Positive for Giardia

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Capilano	52	64	52	49	73	50	75	50	18	18
Seymour	26	29	14	24	47	N/A	N/A	N/A	N/A	N/A
Coquitlam	19	27	54	27	53	51	50	23	8	0

One of 11 (9%) samples collected at Capilano were positive for *Cryptosporidium*, 0 of 12 (0%) were positive at Coquitlam. As discussed in the section on Giardia above, Seymour samples for 2015 are all process control samples and not Seymour source water as they were prior to 2011 (shown as N/A in the table).

Table 3: Percentage of Water Samples Positive for Cryptosporidium

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Capilano	20	19	18	10	12	6	16	9	9	9
Seymour	3	0	2	0	0	N/A	N/A	N/A	N/A	N/A
Coquitlam	0	2	0	2	2	3	8	9	0	0

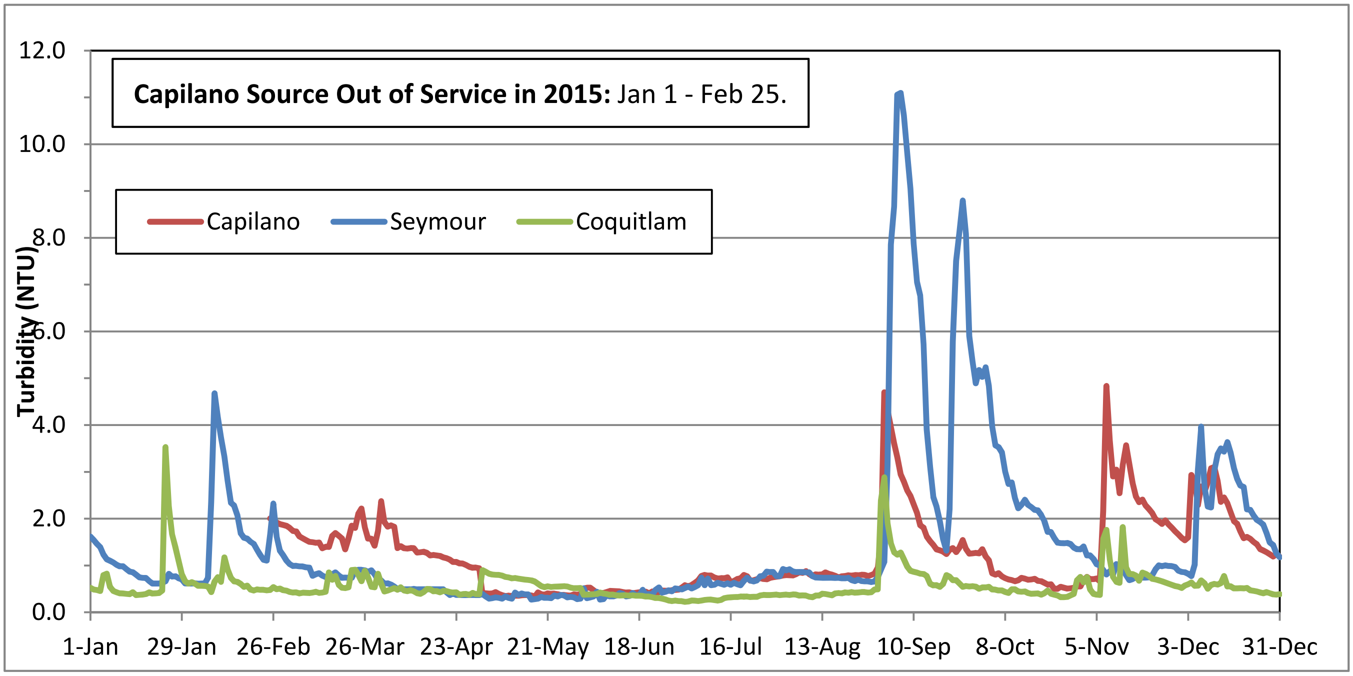
Year to year fluctuations are demonstrated for *Giardia* by Capilano (50% positive in 2013 and 18% positive in 2015) and for *Cryptosporidium* by Coquitlam (9% positive in 2013 and 0% positive in 2015). There has always been considerable variation in the results from year to year.

4.3 TURBIDITY

MV water sources have historically been susceptible to turbidity upsets due to high runoff from storms which can cause slides and stream scouring in the watersheds or from re-suspension of sediment from the edges of the lakes during periods of low water levels. Health Canada published a turbidity guideline in 2003 which recommends filtration for all surface water supplies but the guideline has a provision for exemption from this requirement for filtration if a source meets certain criteria including a turbidity provision. The 2003 guideline allows a utility to avoid filtration if the turbidity does not exceed the requirements (see next paragraph) and provided that a number of other provisions including source water protection and water treatment requirements are in place. Historically the turbidity levels on both the Capilano and Seymour sources would not meet these criteria therefore plans were developed to filter both supplies. Filtration of 100% of the Seymour supply began on January 15, 2010, and filtration and distribution of the Capilano supply through the Seymour transmission system commenced on February 25, 2015. Both the raw and treated water tunnels were fully operational on April 15, 2015.

Section 3.3 of the 2003 Guidelines for Canadian Drinking Water Quality Supporting Documentation titled "Turbidity, Criteria for Exclusion of Filtration in Waterworks Systems" contains the following requirement for the turbidity: "Average daily source water turbidity levels measured at equal intervals (at least every 4 hours), immediately prior to where the disinfectant is applied, are around 1.0 NTU but do not exceed 5.0 NTU for more than 2 days in a 12-month period." In the GVWD, the turbidity of source water is monitored upstream of disinfection using an in-line turbidity meter. The data is captured as 10 minute averages and is stored in the Supervisory Control and Data Acquisition (SCADA) system. These 10-minute average data points (144/day) have been averaged to produce a daily average turbidity which is shown in Figure 2.

Figure 2: 2015 Average Daily Turbidity of Source Water (from In-Line Readings) *



*Commencing on February 25, 2015, Capilano water was pumped through the raw water tunnel and treated at the SCFP and was delivered through the Seymour transmission system. On April 15, 2015 both the raw and treated water tunnels were fully commissioned and operational.

Capilano and Seymour water was filtered so these source water criteria don't apply to the delivered water. Coquitlam (unfiltered) was in service for all of 2015.

4.4 CHEMISTRY

4.4.1 Chemical and Physical Characteristics of the Source Water

The chemical and physical characteristics of the Metro Vancouver source water are summarized in Appendix 1 of this report; detailed analytical results are provided in Volume II. The results from the chemical and physical analyses of the source water in 2015 were similar to those for other years.

4.4.2 Herbicides, Pesticides, Volatile Organic Compounds, Radioactivity, and Uranium

Analyses of the source water for a variety of organic compounds including all the compounds with Maximum Acceptable Concentrations (MACs) in the Guidelines for Canadian Drinking Water Quality is usually carried out on annual basis in accordance with the WQMRP. The results are contained in Appendix 2 of this report and in Volume II of the QC Annual Report. One constituent was detectable in the Capilano, Seymour, and Coquitlam sources and it was below the applicable Canadian Guideline health based limits (MAC); these levels are indicative of erosion of natural deposits, meaning the contribution to total radiation exposure from our drinking water is small, and typical of most areas.

4.5 LIMNOLOGY

The Reservoir Water Quality Monitoring Program started in 2014 as a sampling and analysis structure for the limnology (chemical, physical and biological parameters) of the Capilano, Seymour and Coquitlam Reservoirs. Reservoir monitoring information is important in proactively managing our reservoirs as water quality could be impacted by environmental variability and climate change. This program will assist in ensuring that trends and possible changes are tracked with scientific data.

Water sampling of the source reservoirs is conducted between April and November of each year when biological productivity is highest.

In 2015 Metro Vancouver also employed the services of a limnological consultant to review the program and data collected to date. Results from this review confirm that the three reservoirs remain in the ultra-oligotrophic state because of their low overall primary and secondary productivity. In fact, the rates of zooplankton production were the lowest reported among many lakes and reservoirs in British Columbia and elsewhere. This classification is highly desired for source water systems and indicates that GVWD reservoirs continue to support clean water naturally sustained by watershed and lacustrine processes. The results of the 2015 Reservoir Water Quality Monitoring Program can be found in Appendix 3.

Throughout North America there has been increased interest in blue-green algae in recent years, in particular Merismopedia sp. because of its ability to produce toxins that are collectively known as microcystins. While present in most water systems, the concentration of microcystins in Metro Vancouver reservoirs remain far below levels known to affect human health and far below the required reporting guidelines. Metro Vancouver will continue to monitor for microcystin-producing Merismopedia and will adjust the reservoir monitoring program as sampling technologies improve. This understanding can be used in models to help predict changes over time related to climatic and environmental characteristic changes and aid in making proactive decisions on ongoing reservoir management strategies.

5 QUALITY CONTROL ASSESSMENT OF WATER TREATMENT

Water treatment is the second barrier (after source water protection) relied on to assure the quality of the water supply.

5.1 CAPILANO SOURCE

Completion of the Twin Tunnels Project in 2015 successfully concludes Metro Vancouver's regional long-range water treatment enhancement plans which spanned more than ten years. Each tunnel is 3.8 metres in diameter, 7.1 kilometres long, and 160 to 640 meters below ground level, running beneath Grouse Mountain and Mount Fromme. The water from the Raw Water Tunnel (RWT) is filtered and treated alongside the Seymour source water. Both treated sources enter the Clearwell for further treatment before the blended water is distributed to the region. Blended treated water returns to Capilano through the Treated Water Tunnel (TWT) and provides high quality drinking water to the Capilano area while the remainder is distributed through the Seymour system.

In addition to the Twin Tunnels and the Seymour Capilano Filtration Plant (SCFP), other components of the Seymour-Capilano Filtration Project include the Capilano Raw Water Pump Station (CRWPS), the Energy Recovery Facility (ERF), and the Capilano Break Head Tank (BHT), all adjacent to the Capilano Reservoir. The CRWPS houses 8 pumps used to pump Capilano source water through the RWT to the SCFP, which is at a higher elevation than the Capilano Reservoir. With the treated water returning through the TWT, excess pressure allows the ERF turbine to recover energy that partially offsets the power requirements of the CRWPS.

On February 13, 2015 the CRWPS was commissioned and flushing of the RWT began. Limited flows of Capilano water were directed to the SCFP on February 25, 2015 for filtration, and distributed from SCFP through the Seymour transmission system. Flushing of the TWT began on March 10, 2015, followed by the commissioning of the Capilano Break Head Tank Facility (BHT) and the transmission system. The TWT was commissioned on April 15, 2015 and blended Capilano/Seymour water travelled through the treated water tunnels to the Capilano transmission system. The ceremony to mark the completion of the Seymour-Capilano Filtration Project was held on May 14, 2015.

5.2 SEYMOUR CAPILANO FILTRATION PLANT

The Seymour Capilano Filtration Plant (SCFP) is a chemically assisted direct filtration plant which uses poly aluminum chloride (PACl) as a coagulant with polymers to improve particle removal. These substances help aggregate particles to form a visible floc. The flocculated particles are removed by passing this water through a filter medium of anthracite and sand. The result is the production of filtered water which is then exposed to UV light as the water leaves the filter. Post UV filtered water has sodium hypochlorite (chlorine) and lime added before the water enters the clearwells. The West and East Clearwells are large water storage reservoirs that store and allow controlled passage of water with some mixing or blending of the lime and chlorine that have been added. Clearwells allow sufficient retention or contact time with chlorine to provide any further disinfection required after filtration and UV. Carbon dioxide in solution is added to trim pH. After stabilization of the filtered water in the clearwells, the finished water is ready to enter the transmission system at the Seymour Treated Water Valve Chamber.

SCFP has been operational since December 2009 and the quality of the water produced has been excellent.

5.2.1 Filtration

As a result of treatment now in place on the Capilano and Seymour water sources there have been a number of changes in the characteristics of the delivered water. Some of these changes are visible, some not. The most obvious visible change in the water is the decrease in colour and increase in the clarity. There is a total loss of brown hue that can sometimes characterize Capilano and Seymour waters before filtration. This change in colour is because the natural components that cause the brown hue are removed in the filtration process. Suspended particles in water that cause light to scatter (turbidity) are also removed. The end product is water that is very clear. Due to the purity of the water it may have a slight bluish colour.

Figure 3 is a graph of the apparent colour of SCFP filtered water and Capilano and Seymour source waters for 2015. In late August of 2015, during a storm event the apparent colour of the Seymour source water that was feeding the filtration plant looked brown and exceeded 50 ACU; after the removal of its natural brown colours through filtration, the colour of the filtered water that was delivered to the public was never greater than 6 ACU.

Figure 3: Apparent Colour Levels Before and After Filtration 2015

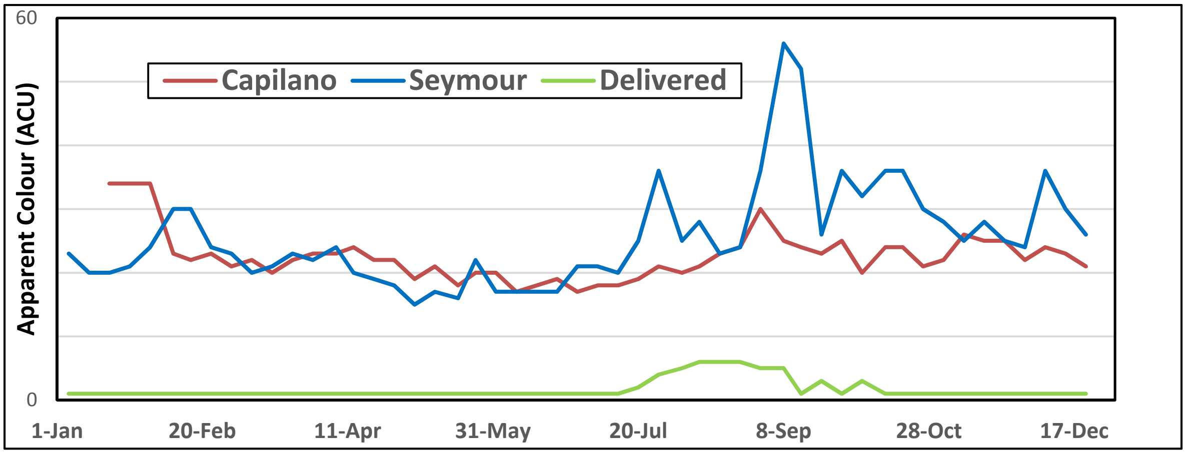
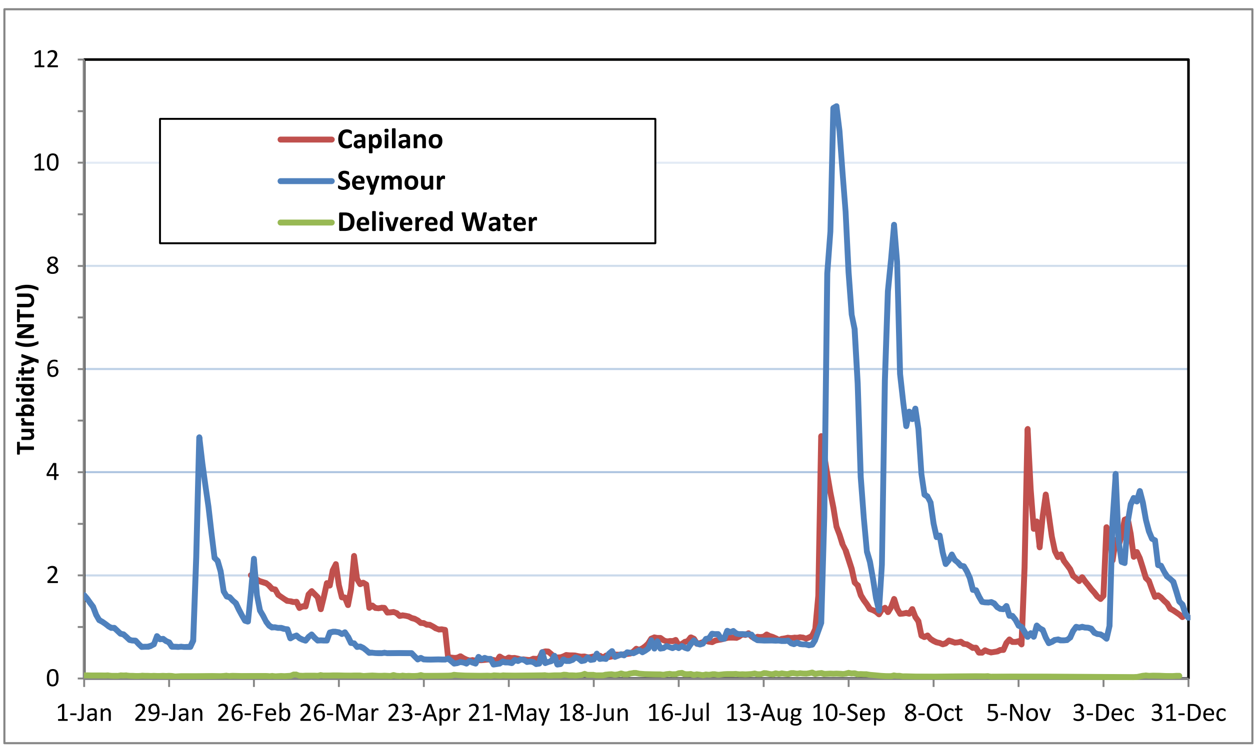


Figure 4 compares turbidity of the two source waters that feed the filtration plant to the turbidity level of the finished filtered water for 2015. Without filtration the Seymour source would have delivered water with an average daily turbidity greater than 1 NTU for 130 days and turbidity >10 NTU (visible as cloudy water) on 3 occasions during the year. If the Capilano source had not been filtered and was delivered, in 2015 it would have exceeded 1 NTU on 150 days. Since both sources were filtered at SCFP, the maximum average daily turbidity of the delivered water was 0.09 NTU and the average was 0.06 NTU.

Figure 4: Average Daily Turbidity Levels Before and After Filtration 2015



Removal of turbidity in the source water improves the appearance of the water but it also has the benefit of removing certain types of pathogenic microorganisms that may be present in source water. At a minimum, properly run direct filtration plants such as SCFP will remove up to 2.5 log (one log is a 90% reduction) of *Cryptosporidium* and *Giardia* plus 1 log of viruses.

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To ensure this removal it is critical that the performance of each filter, determined by the turbidity of its effluent, is monitored on a continuous basis.

The GCDWQ (2012) states, “Where possible, filtration systems should be designed and operated to reduce turbidity levels as low as possible with a treated water turbidity target of less than 0.1 NTU at all times.” If <0.1 NTU is not achievable, the treated water turbidity levels from individual filters (Individual Filter Effluent IFE):

“*for chemically-assisted filtration, shall be less than or equal to 0.3 NTU in at least 95% of the measurements made, or at least 95% of the time for each calendar month, and shall not exceed 1.0 NTU at any time.”*

Ideally the turbidity from each individual filter would never exceed 0.1 NTU; however, there are rare occurrences of turbidity readings that exceed the ideal level. The turbidity performance of all twenty-four filters was measured by examining the percent of time that the turbidity of each individual filter effluent (IFE) met the turbidity guidelines of not greater than 1.0 NTU and at least 95% of time less than 0.3 NTU (Table 4).

Table 4: Monthly Filter Effluent Turbidity Summary

Month	Occurrences of IFE Turbidity Greater than 1.0 NTU None allowed	Percent of Time IFE Turbidity Less than 0.3 NTU Minimum 95% allowed
Jan.	2	99.987%
Feb.	0	99.999%
Mar.	0	100%
Apr.	0	99.999%
May	0	99.999%
Jun.	0	100%
Jul.	0	100%
Aug.	0	99.999%
Sep.	0	99.999%
Oct.	0	100%
Nov.	0	100%
Dec.	0	100%

A water treatment facility such as SCFP should be able to produce a filter effluent that is less than 0.1 NTU. Under normal operating conditions the turbidity of the filtered water at SCFP is less than 0.08 NTU.

In January 2015, two events caused the IFE turbidity readings to exceed 1 NTU. On January 26, 2015, the IFE of one filter exceeded 1 NTU for 5 seconds. This filter’s turbidity rose just as it was being put into service and was removed immediately, but not before the turbidity had exceeded 1 NTU. On January 29, 2015, the IFE of two filters exceeded 1

NTU for periods of 2 and 3.5 minutes, respectively. Flow balancing between filters was identified as being the primary cause of the issue. Operations staff made adjustments to the treatment process and no further problems were experienced.

All water that flows through the filters immediately passes through UV reactors. The intensity of the UV lamps automatically increases when there is an increase in turbidity of the water coming out of the filter. After UV, the water is chlorinated as it enters the clearwell, where more than 1 hour of contact time is provided. It is important to note that 99.987% of the water produced in January at SCFP met the 3 log Giardia and 3 log Cryptosporidium removal/inactivation requirement (99.9% removal).

5.2.2 Ultraviolet Treatment

The effluent from each filter is treated with UV as the water exits the filter. UV treatment is effective in altering the DNA structure of *Cryptosporidium* and *Giardia* thus rendering oocysts and cysts of these parasites non-infectious. Other disinfectants, especially chlorine, are ineffective against Cryptosporidia oocysts. In the unlikely event of a breakthrough of Cryptosporidia oocysts, especially at the end of a filter run, UV light is present to render any potentially present parasites non-infectious. Oocysts are not able to proliferate inside the intestines of human hosts to cause illness after a sufficient dose of UV light. The target dose for UV to achieve 2 Log (99%) of *Cryptosporidium* and *Giardia* inactivation is 21mJ/cm2.

Under normal operating conditions two rows of lamps operating at 75% power provide sufficient UV to meet the dosage requirement for 2 log reduction of *Cryptosporidium* and *Giardia.*

Table 5 summarizes the performance of the SCFP UV system in 2015.

Table 5: Percent of Volume UV Dosage Met Requirements at SCFP

Month	Percent of Monthly Volume UV ≥ 2 log Giardia Inactivation
Jan.	99.974
Feb.	99.978
Mar.	99.984
Apr.	99.975
May	99.944
Jun.	99.975
Jul.	99.874
Aug.	99.864
Sep.	99.808
Oct.	99.824
Nov.	99.993
Dec.	99.984

5.3 COQUITLAM WATER TREATMENT PLANT

The Coquitlam Ultraviolet (UV) Disinfection facility commenced full operation in June 2014. The Coquitlam UV facility provides for primary disinfection capability (3-log reduction) of *Cryptosporidium* and *Giardia*. Ozonation provides pre-treatment, and chlorination is used for secondary disinfection at the source as well as at secondary disinfection stations servicing Coquitlam water, to minimize bacterial regrowth in the distribution system. Ozonation and chlorination each provide 4-log virus inactivation. Soda ash is added for pH and alkalinity adjustment to combat corrosion.

Ozone helps remove micro-organisms from the water, reduces disinfection by-products and improves water clarity, which increases the efficiency of the subsequent UV process. The water is directed into eight ultraviolet units, each containing 40 ultraviolet lamps encased in protective sleeves. As water flows through the units, UV light emitted from the lamps passes through the water, and aids in achieving 3-log inactivation of chlorine-resistant micro-organisms, such as *Cryptosporidium* and *Giardia*. The US EPA requires that the UV disinfection process results in target *Cryptosporidium* and *Giardia* inactivation in at least 95% of the treated water volume on a monthly basis (the US EPA standard is used because there isn't a similar Canadian standard).

Table 6 summarizes the performance of the COQ UV system in 2015.

Table 6: Performance of Coquitlam Primary Disinfection Facilities

Facility	Performance	Discussion
Ozonation	In operation 99.8% of time	As the UV facility took over the primary disinfection in June 2014, the role of ozone was changed to pretreatment, enhancing the removal of organics.
Ultra Violet	99.7 % of volume on spec	UV performance met US EPA requirements. (95% of monthly volume required)
Chlorination	This facility provides secondary disinfection most of the time but during UV outages it is used for primary disinfection. The chlorine residual was > 1.0 mg/L 100% of the time when the facility was used for primary disinfection.	When Coquitlam Chlorination was used as primary disinfection facility, Cl_2 residual was increased by 0.2 mg/L to partially offset the loss of UV treatment.

Table 7: Percent of Volume UV Dosage Met Requirements at CWTP

Month	Percent of Monthly Volume UV ≥ 3 log Giardia Inactivation Minimum 95% Required
Jan.	99.881%
Feb.	99.828%
Mar.	99.740%
Apr.	99.576%
May	99.677%
Jun.	99.810%
Jul.	99.669%
Aug.	99.743%
Sep.	99.698%
Oct.	99.499%
Nov.	99.828%
Dec.	99.867%

5.4 SECONDARY DISINFECTION

There are eight secondary disinfection stations operated by Metro Vancouver. The purpose of these stations is to increase the chlorine residual in the water flowing through the stations to meet a target residual based on a number of factors including source water turbidity, the amount of bacterial regrowth detected in the municipal distribution system samples and the chlorine demand in the water. With filtered water supplied, the rate of chlorine decay has been reduced to a level that the amount of chlorine required to maintain a residual in the distribution system is significantly lower. This has allowed reduction of the target chlorine dose leaving the secondary facilities (receiving filtered water) to between 0.6 to 0.8 mg/L. The secondary disinfection stations receiving the filtered water rarely have an incoming chlorine residual low enough to require boosting, thus the amount of sodium hypochlorite being used at these stations has been considerably reduced. Many secondary disinfection stations are running in stand-by mode when supplied with filtered water. When supplied with unfiltered Coquitlam water, the secondary disinfection stations activate to boost chlorine.

Table 8: Performance of Secondary Disinfection Facilities

Facility	Performance*	Discussion
Clayton	Whalley/Clayton: 99.6% Jericho/Clayton: 99.6%	Supplied by Coquitlam source. No operational issues.
Chilco	99.3%	Supplied by SCFP water. No operational issues.
Pitt River Secondary	Haney Main No.2: 99.5% Haney Main No.3: 99.5%	Supplied by Coquitlam source. No operational issues.
Newton	100%	Primarily supplied by Coquitlam source. No operational issues.
Kersland	99.4%	Supplied by SCFP water. No operational issues.
Central Park	South Burnaby Main No.1: 99.4% South Burnaby Main No.2: 99.4%	Primarily supplied by SCFP water. No operational issues.
Cape Horn	Coquitlam Main No.2: 99.5% Coquitlam Main No.3: 99.5%	Supplied by Coquitlam source. No operational issues.
Vancouver Heights	99.6%	Supplied by SCFP water. No operational issues.

*Percent of time that free chlorine residual in water leaving facility met target when operating.

5.5 CORROSION CONTROL

Before 1998, the delivered water from all three sources had a pH lower than the aesthetic limit of the GCDWQ of pH 6.5. As part of the upgrade of the water treatment of the Seymour source water, a corrosion control facility using soda ash (sodium carbonate) was put into service at Rice Lake in 1998. A similar facility was added at Coquitlam in 2000 simultaneously with the ozonation facility.

Since early 2010 corrosion control for the Seymour source was moved to the SCFP. In the SCFP process, filtered water receives a lime/water slurry to raise its pH and boost its alkalinity before it enters the clearwells; it is finally adjusted with the addition of carbon dioxide gas (CO_2).

Starting in 2015, Capilano water was treated at the SCFP and underwent the lime/CO_2 treatment process for pH and alkalinity adjustment. The average pH of the treated water from Capilano, Seymour and Coquitlam was approximately 7.5 during 2015 and met the aesthetic objective.

Table 9: Performance of Corrosion Control Facilities

Facility	Performance	Discussion
Seymour Capilano - Corrosion Control	Excellent	Online pH values ranged from 7.3 – 7.9 during 2015 with a brief low pH of 7.0 for one hour due to a mechanical issue.
Coquitlam - Corrosion Control	Excellent	The pH was <6.5 for 27.6 hours (0.3% of the time) in 2015 due to soda ash system maintenance and chlorine system preventive maintenance.

The chemical and physical characteristics of the Metro Vancouver treated water are summarized in Appendix 1 of this report; detailed analytical results are provided in Volume II.

6 DISTRIBUTION SYSTEM WATER QUALITY

Schedule A of the BC Drinking Water Protection Regulation contains standards for the bacteriological quality of potable water in the province. There are three components of this standard that apply to large utilities such as the GVWD and its members.

Part 1: no sample should be positive for *E. coli*

Part 2: not more than 10% of the samples in a 30 day period should be positive for total coliform bacteria when more than 1 sample is collected

Part 3: no sample should contain more than 10 total coliform bacteria per 100 mL

The BC Regulation does not contain any water standards other than the three limits for *E. coli* and total coliform bacteria. Information on the significance of the detection of these organisms can be found in the Guidelines for Canadian Drinking Water Quality - Supporting Documents.

"E. coli is a member of the total coliform group of bacteria and is the only member that is found exclusively in the faeces of humans and other animals. Its presence in water indicates not only recent faecal contamination of the water but also the possible presence of intestinal disease-causing bacteria, viruses, and protozoa." "The presence of total coliform bacteria in water in the distribution system (but not in water leaving the treatment plant) indicates that the distribution system may be vulnerable to contamination or may simply be experiencing bacterial regrowth."

To summarize, the detection of an *E. coli* bacteria in a sample of treated water is an indication of a potentially serious risk. The detection of total coliform bacteria may indicate intrusion into the system or it may indicate that these bacteria are growing in the distribution system itself (regrowth).

The number of *E. coli* detected in both the GVWD and the municipal drinking water samples is typically very low – out of approximately 28,000 samples collected from the GVWD and municipal systems, analyzed in 2015, no samples were positive for *E. coli*. The detection of an *E. coli* triggers a protocol which involves immediate notification of health and municipal officials, re-sampling and a thorough investigation into the possible causes. Only 53 of the approximately 20,000 samples collected from the municipal distribution systems tested positive for total coliforms in 2015. The majority of the coliforms in the municipal system appeared in the warmer water months (72% in July through October) and at sites with a measurable free chlorine residual.

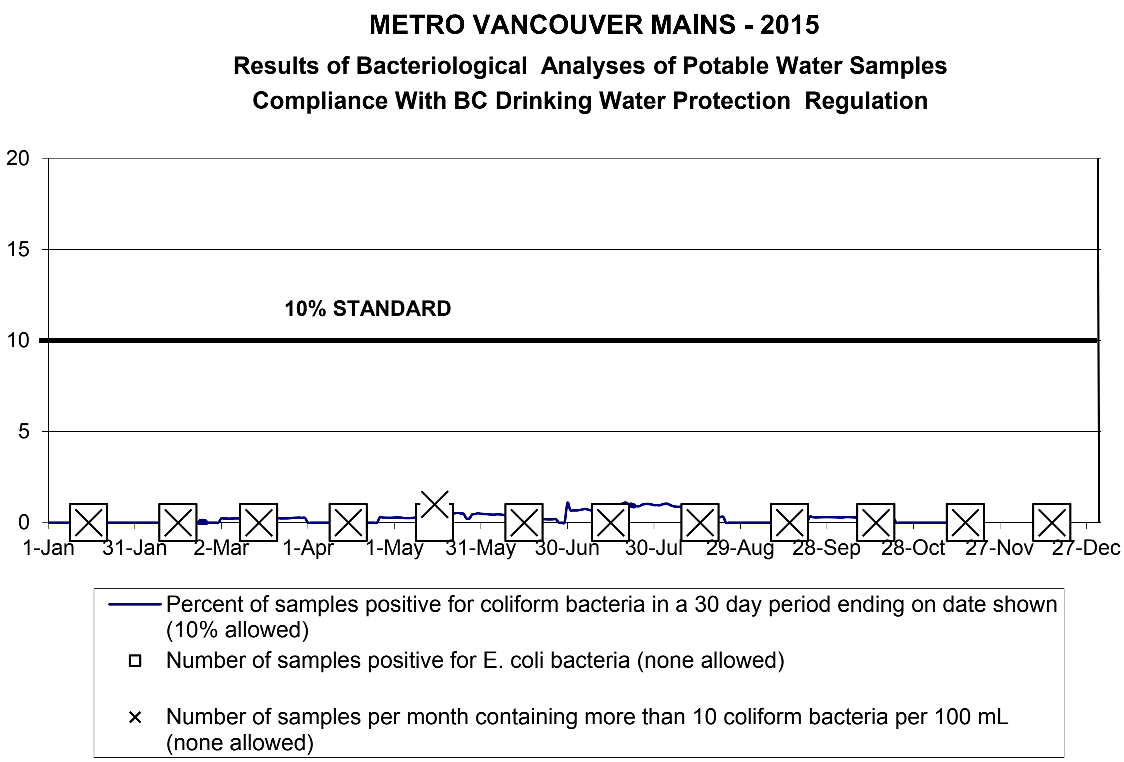
The most likely source of these organisms can be attributed to bacterial regrowth. The one fact that should be emphasized is that 99.8% of the samples in 2015 had no coliforms present – a good indicator of effective water treatment and good distribution water quality.

6.1 MICROBIOLOGICAL WATER QUALITY IN THE GVWD SYSTEM

6.1.1 GVWD Water Mains

Over 4400 GVWD water main samples were collected and tested for the presence of indicator bacteria. The compliance of monitoring results from GVWD transmission mains with the criteria in the BC Drinking Water Protection Regulation is shown below in Figure 5. There were another 2100 samples collected from the chlorine evaluation stations and the 10-minute chlorine line at each source but these samples are not included in the calculations for compliance monitoring.

Figure 5: Bacteriological Quality of Water in GVWD Mains, 2015



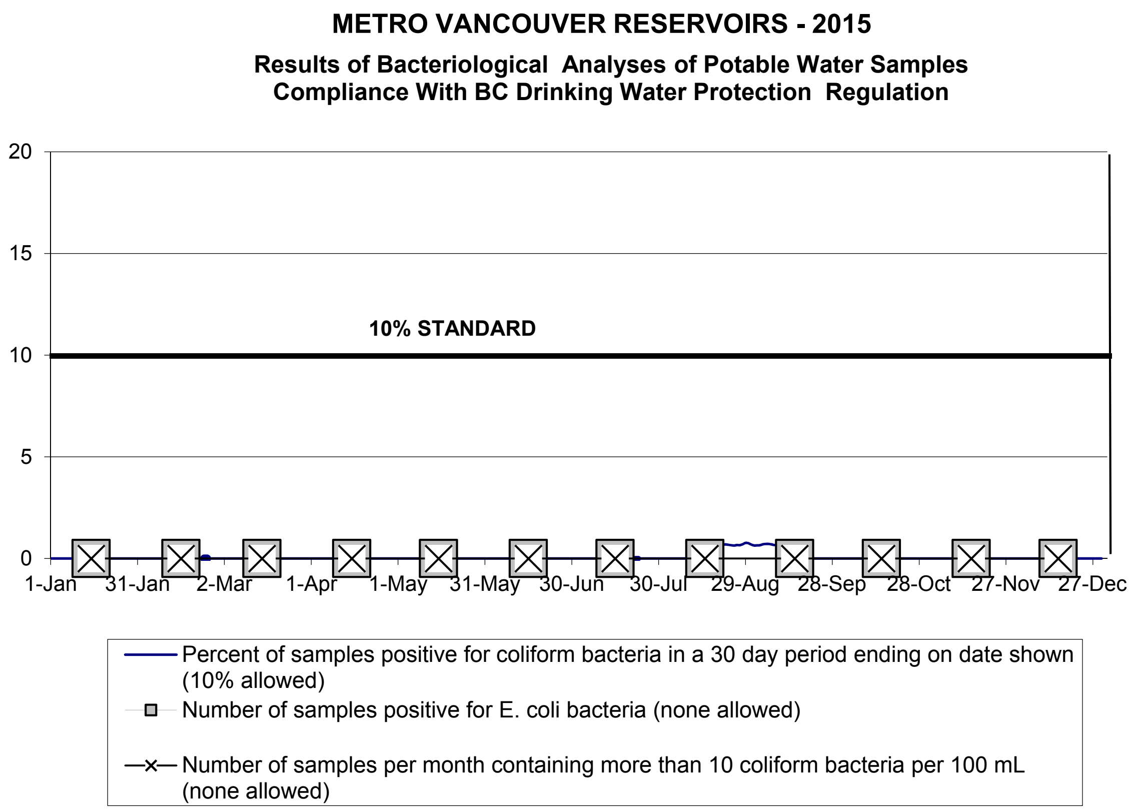
In 2015 the percentage of samples positive for total coliform bacteria from the GVWD mains was very low, well below the 10% standard. Of the more than 4400 samples processed, only 11 samples tested positive for total coliforms and none of the samples were positive for *E. coli* bacteria.

6.1.2 GVWD Reservoirs

In 2015, over 2,100 samples were collected from the 21 reservoirs and tanks that are located throughout the GVWD water system. Only 1 sample was positive for total coliforms. No sample from a reservoir was positive for *E. coli.*

The compliance of monitoring results from GVWD reservoirs with the criteria in the BC Drinking Water Protection Regulation is shown below in Figure 6.

Figure 6: Bacteriological Quality of Water in GVWD Reservoirs, 2015



Reservoir water quality is optimized by the use of secondary disinfection coupled with an active reservoir exercising program that includes a minimum of weekly monitoring of the chlorine residuals and bacteriology results which can result in changes to filling levels if necessary. Table 10 provides an overview of the status of the GVWD reservoirs. During certain times of the year, it is not possible to cycle reservoirs as much as would be desired due to operational constraints. Despite these constraints, water quality as determined by coliform bacteria was satisfactory in all reservoirs.

Table 10: Status of GVWD Reservoirs 2015

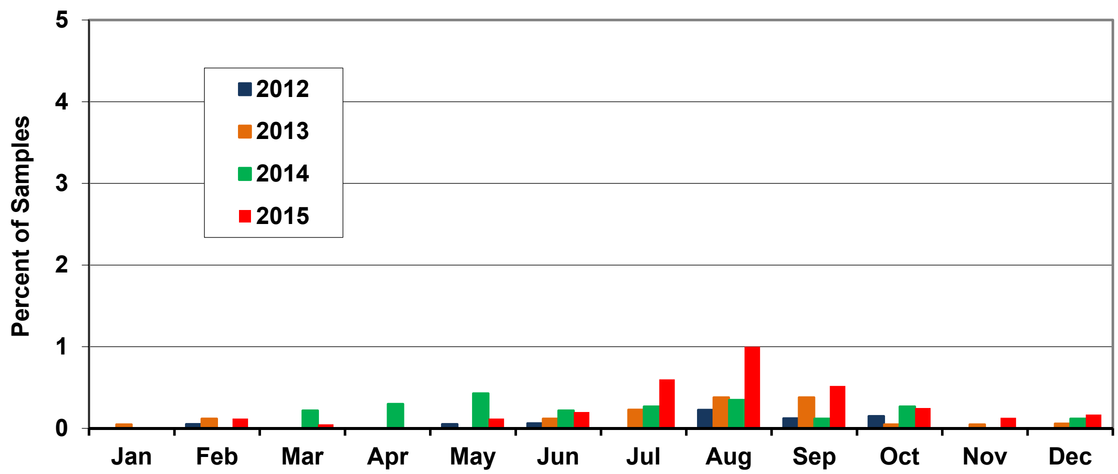
Reservoir (Capacity in Million Litres)	**Average Free Chlorine (mg/L)**				**2015 Comments** (if applicable)
	2012	**2013**	**2014**	**2015**	
Burnaby Mtn. Reservoir (14.1)	0.49	0.47	0.47	0.45	Cleaned, disinfected and returned to service in October.
Burnaby Tank (2.4)	0.62	0.51	0.50	0.50	
Cape Horn Reservoir (42.2)	0.44	0.40	0.42	0.42	
Clayton Tank (7.3)	0.62	0.54	0.69	0.71	
Central Park (37.0)	0.44	0.50	0.55	0.58	Cleaned, disinfected, and returned to service in November.
Glenmore Tanks (1.0)	0.59	0.53	0.52	0.62	
Grandview Reservoir (14.3)	0.70	0.72	0.70	0.59	
Greenwood Reservoir (9.2)	0.69	0.59	0.55	0.60	
Hellings Tank (4.4)	0.44	0.42	0.40	0.46	Seismic upgrades began in October. Tank remained out of service the rest of the year.
Kennedy Reservoir (17.3)	0.47	0.48	0.47	0.49	
Kersland Reservoirs (78.7)	0.55	0.52	0.56	0.52	Cell 1 was cleaned, disinfected, and returned to service in March.
Little Mountain Reservoirs (177.4)	0.68	0.66	0.70	0.66	
Maple Ridge Reservoir (24.2)	0.63	0.57	0.53	0.49	Cleaned by divers in December.
Newton Reservoirs (33.6)	0.47	0.42	0.42	0.45	
Pebble Hill Reservoirs (44.8)	0.57	0.48	0.42	0.50	Cells 1 & 2 were cleaned and disinfected before peak usage season. Due to low chlorine residuals and low water use in late summer, cells 1 & 2 were removed from service earlier than normal. In November cell 1 was cleaned and disinfected and cell 3 was removed from service to reduce storage and improve local chlorine residuals.
Prospect Reservoir (4.6)	0.70	0.62	0.63	0.60	
Sasamat Reservoir (27.6)	0.51	0.45	0.46	0.53	Structural repairs were carried out in the fall from October thru December. Reservoir was disinfected and tested prior to return to service.
Sunnyside Reservoirs (28.8)	0.55	0.60	0.49	0.47	Cell 2 was cleaned, disinfected, and returned to service in November.
Vancouver Heights Reservoir (45.6)	0.75	0.68	0.65	0.66	
Westburnco Reservoir (77.1)	0.59	0.58	0.55	0.62	
Whalley Reservoir (35.7)	0.47	0.66	0.63	0.56	

6.2 MICROBIOLOGICAL WATER QUALITY IN MUNICIPAL SYSTEMS

For samples collected from municipal systems, the percent positive per month for total coliform bacteria from 2012 - 2015 is shown in

Figure 7:

Figure 7: Percent of Samples per Month Positive for Total Coliform Bacteria 2012 to 2015



The percentage of samples positive for total coliform bacteria in 2015 slightly increased compared to 2014.

Schedule A of the BC Drinking Water Protection Regulation contains standards for the bacteriological quality of potable water in the province. There are three components of this standard that apply to municipalities:

Part 1: no sample should be positive for *E. coli*

Part 2: not more than 10% of the samples in a 30 day period should be positive for total coliform bacteria when more than 1 sample is collected

Part 3: no sample should contain more than 10 total coliform bacteria per 100 mL

For samples from municipal systems, this requirement was met in 2015 with the following exceptions:

Part 2:

- Two municipalities (which take a low number of samples per month) had >10% positive samples in July and October.

Part 3:

- Three samples in June contained more than 10 total coliform bacteria.
- Two samples in July contained more than 10 total coliform bacteria.
- One sample in August contained more than 10 total coliform bacteria.
- One sample in September contained more than 10 total coliform bacteria.
- One sample in November contained more than 10 total coliform bacteria.

Table 11 shows the compliance of the samples collected in the member municipal distribution systems with the three bacteriological standards in the BC DWPR.

Table 11: Municipal Water Quality Compared to the Bacteriological Standards of the BC DWPR for 2015 for 20 Member Jurisdictions.

Month	Number that met Part 1	Number that met Part 2	Number that met Part 3	Number meeting all DWPR
January	20	20	20	20
February	20	20	20	20
March	20	20	20	20
April	20	20	20	20
May	20	20	20	20
June	20	20	**18**	**18**
July	20	**19**	**18**	**18**
August	20	20	**19**	**19**
September	20	20	**19**	**19**
October	20	**19**	20	**19**
November	20	20	**19**	**19**
December	20	20	20	20

6.3 DISINFECTION BY-PRODUCTS IN THE DISTRIBUTION SYSTEM

As the treated water moves through the GVWD and later the municipal infrastructure of pipes and reservoirs, changes in water quality occur mainly due to the reaction between the chlorine in the water (added during primary and secondary disinfection) and naturally occurring organic matter in the water.

One of the most significant changes is the production of chlorinated disinfection by-products (DBPs). DBP is a term used to describe a group of organic and inorganic compounds formed during water disinfection.

Reactions between dissolved natural organic matter and chlorine can lead to the formation of a variety of halogenated DBPs. There are two major groups of chlorinated DBPs: the total trihalomethanes (TTHMs) and the total haloacetic acids ($THAA_5$). Factors that affect DBP formation are: amount of chlorine added to water, reaction time, concentration and characteristics of dissolved organic materials (precursors), water temperature, and water pH. In general, DBPs continue to form as long as chlorine and reactive DBP precursors are present in the water.

The maximum acceptable concentration (MAC) in the Canadian Guidelines for TTHMs is a locational yearly running average of 100 µg/L (0.1 mg/L) based on quarterly samples. Comparison of TTHM levels in 2009 and 2015 is shown in Figures 8 & 9. All TTHM results were below the MAC of 100 µg/L.

The other group of disinfection by-products of interest is the Haloacetic Acid ($THAA_5$) group. The maximum acceptable concentration (MAC) in the Canadian Guidelines for Total HAAs ($THAA_5$) is a locational yearly running average of 80 µg/L (0.08 mg/L) based on quarterly samples. Comparison of $THAA_5$ levels for 2009 and 2015 is shown in Figures 10 & 11. All $THAA_5$ results were below the MAC of 80 µg/L from sites within the GVWD system; there was one municipal site that had a running average of 81 µg/L.

Figure 8: Average Total Trihalomethane Levels in Municipal Samples 2009

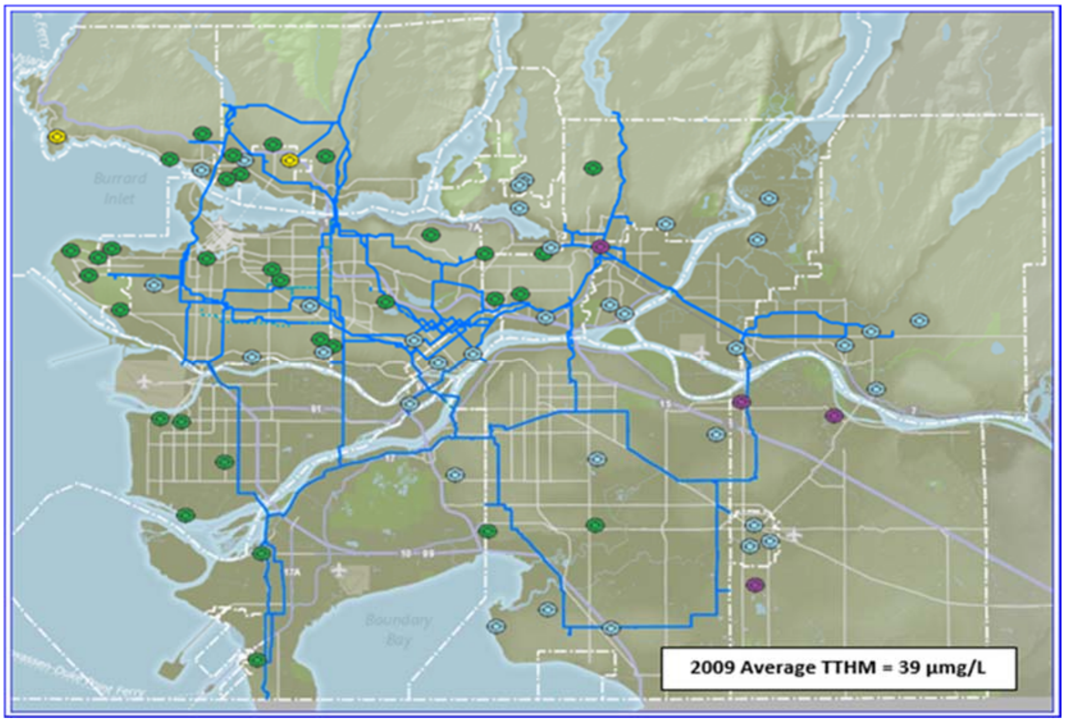
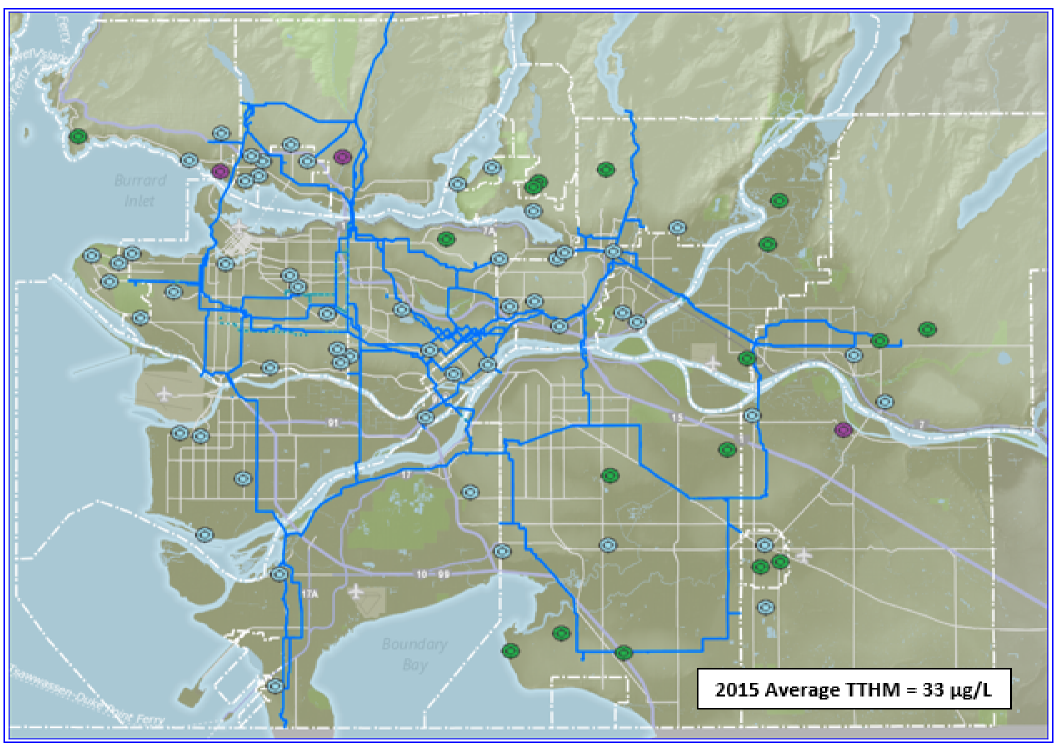


Figure 9: Average Total Trihalomethane Levels in Municipal Samples 2015



0 - 19 µg/L | 40 – 59 µg/L | 80 – 99 µg/L
20 – 39 µg/L | 60 – 79 µg/L | >100 µg/L

MAC for Total THM values is 100 µg/L (or ppb)

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Figure 10: Average Total Haloacetic Acid Levels in Municipal Samples 2009

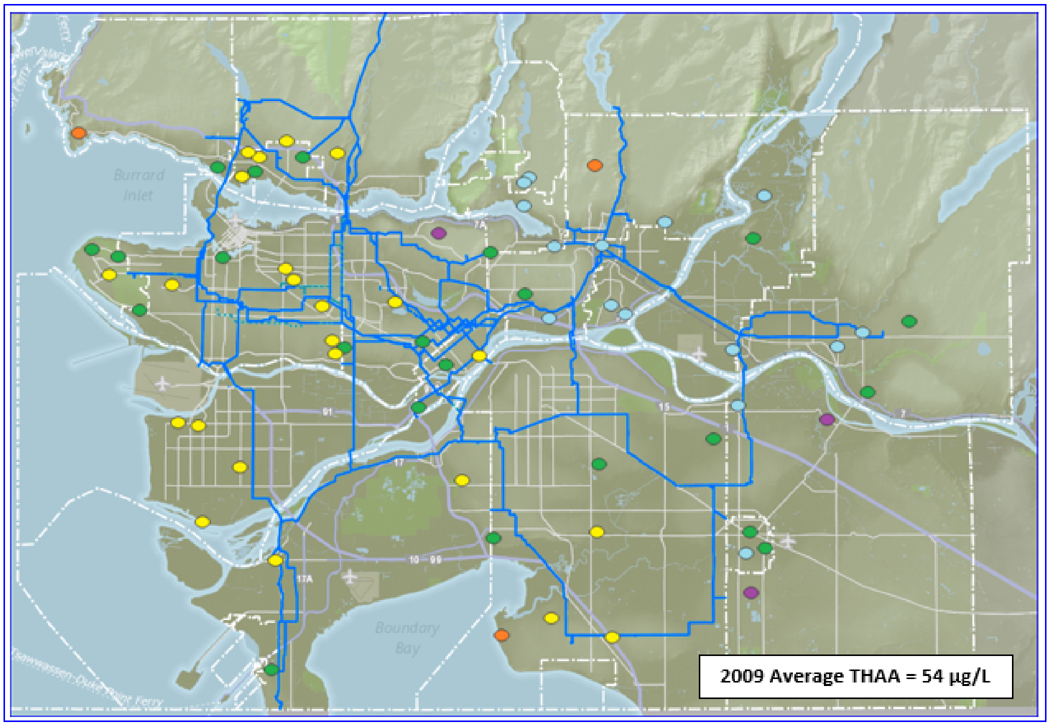
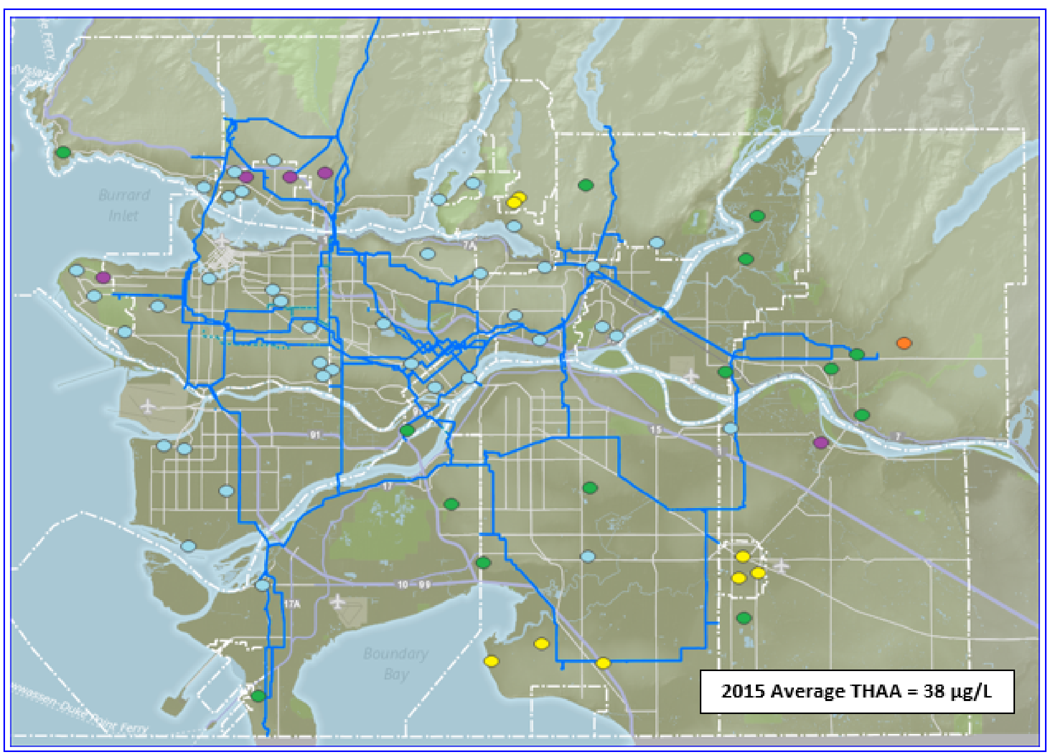


Figure 11: Average Total Haloacetic Acid Levels in Municipal Samples 2015



0 - 19 µg/L
20 – 39 µg/L
40 – 59 µg/L
60 – 79 µg/L
80 – 99 µg/L
>100 µg/L
MAC for Total HAA values is 80 µg/L (or ppb)

QUALITY CONTROL / QUALITY ASSURANCE

In 1994, as required by a new Ministry of Health program, the Bacteriology Section of the Metro Vancouver laboratory received approval from the Provincial Medical Health Officer to perform bacteriological analysis of potable water as required in the B.C. Safe Drinking Water Regulation (changed to the BC Drinking Water Protection Regulation in 2001). An ongoing requirement of this approval is successful participation in the Clinical Microbiology Proficiency Testing (CMPT) program or its equivalent. The bacteriological laboratory has successfully participated in this program since 1994. Representatives of the Approval Committee for Bacteriology Laboratories carried out an inspection of the Metro Vancouver laboratory facilities at LCOC in the fall of 2012 as part of the process leading up to approval of the laboratory by the Provincial Health Officer which has been received. The next inspection is scheduled for 2016.

In addition to the approval process discussed above, the Metro Vancouver Laboratory is accredited by the Canadian Association for Laboratory Accreditation (CALA) for the analysis of parameters for which the laboratory has requested certification. The MV Laboratory has been inspected by representatives from CALA bi-annually since 1995, and most recently in 2015 as required by the accreditation process. Accreditation for the laboratory from the Standards Council of Canada was first received early in 1996 and continued until the middle of 2005, when accreditation was granted by CALA directly. Based on the September 2015 inspection, CALA issued the latest accreditation for the Metro Vancouver Laboratory in early 2016. Details are available in the Quality Control office. The next CALA inspection will take place in the fall of 2017.

Appendix 1. Chemical & Physical Analysis Summaries

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SERVICES AND SOLUTIONS FOR A LIVABLE REGION

Physical and Chemical Analysis of Water Supply

Greater Vancouver Water District

2015 - Capilano Water System

Parameter	Untreated Average	SCFP Treated Average	SCFP Treated Range	Days Guideline Exceeded	Canadian Guideline Limit	Reason Guideline Established
Alkalinity as $CaCO_3$ (mg/L)	3.1	7.8	6.1-10.8		none	
Aluminium Dissolved (µg/L)	83	26	15-40		none	
Aluminium Total (µg/L)	167	31	17-42		none	
Antimony Total (µg/L)	<0.5 (0.021)	<0.5	<0.5	0	6	Health
Arsenic Total (µg/L)	<0.5 (0.095)	<0.5	<0.5	0	10	Health
Barium Total (µg/L)	3.0	3.1	2.9-3.2	0	1000	Health
Boron Total (mg/L)	<0.01	<10	<10		5	
Bromate (mg/L)	<0.01	<0.01	<0.01	0	0.01	Health
Bromide (mg/L)	<0.01	<0.01	<0.01	0	none	Health
Cadmium Total (µg/L)	<0.2 (0.008)	<0.2	<0.2	0	5	Health
Calcium Total (mg/L)	1.35	3.57	2.93-4.40		none	
Carbon Organic Dissolved (mg/L)	1.97	0.72	0.5-0.9		none	
Carbon Organic Total (mg/L)	1.99	0.82	0.62-1.2		none	
Chlorate (mg/L)	<0.01	0.04	0.01 - 0.10	0	1.0	Health
Chloride Total (mg/L)	0.59	2.6	2.3-3.1	0	≤ 250	Aesthetic
Chromium Total (µg/L)	<0.05	<0.05	<0.05 - 0.05	0	50	Health
Color Apparent (ACU)	23	<1	<1		none	
Color True (TCU)	14	<1	<1	0	≤ 15	Aesthetic
Conductivity (umhos/cm)	12	28	21-34		none	
Copper Total (µg/L)	5.3	<0.5(0.13)	<0.5	0	≤ 1000	Aesthetic
Cyanide Total (mg/L)	<0.02	<0.02	<0.02	0	0.2	Health
Fluoride (mg/L)	<0.05	<0.05	<0.05	0	1.5	Health
Hardness as $CaCO_3$ (mg/L)	4.12	9.6	7.9-11.8		none	
Iron Dissolved (µg/L)	83	5.7	5.0-6.0		none	
Iron Total (µg/L)	192	9.7	5.0-27.0	0	≤ 300	Aesthetic
Lead Total (µg/L)	<0.5 (0.095)	<0.5	<0.5	0	10	Health
Magnesium Total (µg/L)	182	168	134-225		none	
Manganese Dissolved (µg/L)	9.5	5.6	3.8-10.1		none	
Manganese Total (µg/L)	11.7	7.3	4.0-15.1	0	≤ 50	Aesthetic
Mercury Total (µg/L)	<0.05	<0.05	<0.05	0	1.0	Health
Molybdenum Total (µg/L)	<0.5 (0.179)	<0.5	<0.5		none	
Nickel Total (µg/L)	<0.5 (0.100)	<0.5	<0.5		none	
Nitrogen - Ammonia as N (mg/L)	<0.02	<0.02	<0.02		none	
Nitrogen - Nitrate as N (mg/L)	0.09	0.08	0.03-0.15	0	45	Health
Nitrogen - Nitrite as N (mg/L)	<0.01	<0.01	<0.01	0	3.0	Health
pH	6.5	7.5	7.3-7.7	0	6.5 to 8.5	Aesthetic
Phenols (µg/L)	<5	<5	<5		none	
Phosphorus Total (µg/L)	<5	<5	<5		none	
Potassium Total (mg/L)	169	169	163-175		none	
Residue Total (mg/L)	19	27	22-40		none	
Residue Total Dissolved (mg/L)	17	22	16-27	0	≤ 500	Aesthetic
Residue Total Fixed (mg/L)	11	18	13-31		none	
Residue Total Volatile (mg/L)	8	8.1	6-10		none	
Selenium Total (µg/L)	<0.5 (<0.040)	<0.5	<0.5	0	50	Health
Silica as SiO_2 (mg/L)	3.2	3.1	2.7-3.5		none	
Silver Total (µg/L)	<0.5 (<0.005)	<0.5	<0.5		none	
Sodium Total (mg/L)	0.619	1.53	1.26-1.94	0	≤ 200	Aesthetic
Sulphate (mg/L)	0.87	1.12	0.90-1.30	0	≤ 500	Aesthetic
Turbidity (NTU)	1.23	0.058	0.042-0.116	0	≤ 1.0	Health
Uranium Total (µg/L)	0.033	0.011		0	20	Health
UV254 (Abs/cm)	0.088	0.012	0.009-0.015		none	
UV254 App. (Abs/cm)	-	0.012	0.009-0.015		none	
Zinc Total (µg/L)	<3 (0.69)	<3(0.83)	<3	0	≤ 5000	Aesthetic

These figures are average values from a number of laboratory analyses done throughout the year. Where the range is a single value no variation was measured for the samples analysed. Methods and terms are based on those of "Standard Methods for the Examination of Water and Waste Water" 22nd Edition 2012. Less than (<) denotes not detectable with the technique used for determination. Untreated water is from the intake prior to the raw water tunnel, treated water is from a single site in the GVWD distribution system downstream of SCFP clearwell. Guidelines are taken from "Guidelines for Canadian Drinking Water Quality - Sixth Edition" Health and Welfare Canada 1996, updated to Oct 2014. reated turbidity guideline applies to Indivual Filter Effluent readings. Capilano source was out of service from January 1- Feb 24. Filtering of Capilano source at SCFP began on Feb 25 and delivery of filtered water thru treated water tunnel started on April 15. Values in parenthesis ( ) are lower analytical results from a private Lab.

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SERVICES AND SOLUTIONS FOR A LIVABLE REGION

Physical and Chemical Analysis of Water Supply

Greater Vancouver Water District

2015 - Seymour Water System

Parameter	Untreated Average	SCFP Treated Average	SCFP Treated Range	SCFP Treated Days Guideline Exceeded	Canadian Guideline Limit	Reason Guideline Established
Alkalinity as $CaCO_3$ (mg/L)	3.7	7.8	6.1-10.8		none	
Aluminium Dissolved (µg/L)	26.2	26	15-40		none	
Aluminium Total (µg/L)	165	31	17-42	0	200	Aesthetic
Antimony Total (µg/L)	<0.5	<0.5	<0.5	0	6	Health
Arsenic Total (µg/L)	<0.5	<0.5	<0.5	0	10	Health
Barium Total (µg/L)	4.7	3.1	2.9-3.2	0	1000	Health
Boron Total (mg/L)	<10	<10	<10		5	
Bromate (mg/L)	<0.01	<0.01	<0.01	0	0.01	Health
Bromide (mg/L)	<0.01	<0.01	<0.01	0	none	Health
Cadmium Total (µg/L)	<0.2	<0.2	<0.2	0	5	Health
Calcium Total (mg/L)	1.75	3.57	2.93-4.40		none	
Carbon Organic Dissolved (mg/L)	1.74	0.72	0.5-0.9		none	
Carbon Organic Total (mg/L)	2.25	0.82	0.62-1.2		none	
Chlorate (mg/L)	<0.01	0.04	0.01 - 0.10	0	1.0	Health
Chloride Total (mg/L)	0.5	2.6	2.3-3.1	0	≤ 250	Aesthetic
Chromium Total (µg/L)	0.08	<0.05	<0.05 - 0.05	0	50	Health
Color Apparent (ACU)	26	<1	<1		none	
Color True (TCU)	14	<1	<1	0	≤ 15	Aesthetic
Conductivity (umhos/cm)	14	28	21-34		none	
Copper Total (µg/L)	1.96	<0.5(0.13)	<0.5	0	≤1000	Aesthetic
Cyanide Total (mg/L)	<0.02	<0.02	<0.02	0	0.2	Health
Fluoride (mg/L)	<0.05	<0.05	<0.05	0	1.5	Health
Hardness as $CaCO_3$ (mg/L)	5.1	9.6	7.9-11.8		none	
Iron Dissolved (µg/L)	119	5.7	5.0-6.0		none	
Iron Total (µg/L)	278	9.7	5.0-27.0		≤ 300	Aesthetic
Lead Total (µg/L)	<0.5	<0.5	<0.5	0	10	Health
Magnesium Total (µg/L)	174	168	134-225		none	
Manganese Dissolved (µg/L)	7.38	5.6	3.8-10.1		none	
Manganese Total (µg/L)	11	7.3	4.0-15.1	0	≤ 50	Aesthetic
Mercury Total (µg/L)	<0.05	<0.05	<0.05	0	1.0	Health
Molybdenum Total (µg/L)	<0.5	<0.5	<0.5		none	
Nickel Total (µg/L)	<0.5	<0.5	<0.5		none	
Nitrogen - Ammonia as N (mg/L)	<0.02	<0.02	<0.02		none	
Nitrogen - Nitrate as N (mg/L)	0.08	0.08	0.03-0.15	0	45	Health
Nitrogen - Nitrite as N (mg/L)	<0.01	<0.01	<0.01	0	3.0	Health
pH	6.5	7.5	7.3-7.6	0	6.5 to 8.5	Aesthetic
Phenols (µg/L)	<5	<5	<5		none	
Phosphorus Total (µg/L)	<5	<5	<5		none	
Potassium Total (µg/L)	196	169	163-175		none	
Residue Total (mg/L)	22	27	22-40		none	
Residue Total Dissolved (mg/L)	19	22	16-27	0	≤ 500	Aesthetic
Residue Total Fixed (mg/L)	13	18	13-31		none	
Residue Total Volatile (mg/L)	9	8.1	6-10		none	
Selenium Total (µg/L)	<0.5	<0.5	<0.5	0	50	Health
Silica as SiO_2 (mg/L)	3.13	3.1	2.7-3.5		none	
Silver Total (µg/L)	<0.5	<0.5	<0.5		none	
Sodium Total (mg/L)	0.58	1.53	1.26-1.94	0	≤ 200	Aesthetic
Sulphate (mg/L)	1.36	1.12	0.90-1.30	0	≤ 500	Aesthetic
Turbidity (NTU)	1.56	0.058	0.042-0.116	0	≤ 1.0	Health
Uranium Total (µg/L)	0.038	0.011			20	Health
UV254 {cm^{-1} (% Trans)} App	83.9	94.2	90.6-95.5		none	
UV254 (cm^{-1}) True	0.081	0.012	0.009-0.015		none	
Zinc Total (µg/L)	<3(1.03)	<3(0.83)	<3	0	≤ 5000	Aesthetic

These figures are averaged values from a number of laboratory analyses done throughout the year. Where the range is a single value no variation was measured for the samples analysed. Methods and terms are based on those of "Standard Methods for the Examination of Water and Waste Water" 22nd Edition 2012. Less than (<) denotes not detectable with the technique used for determination. Untreated water is from the intake or a sample site prior to coagulation, treated water is from a sample site downstream of SCFP clearwell. Guidelines are taken from "Guidelines for Canadian Drinking Water Quality - Sixth Edition" Health and Welfare Canada 1996, updated to Oct 2014. Seymour source water is filtered, disinfected with UV light and sodium hypochlorite for primary disinfection, lime is added to increase pH and alkalinity while CO2 is added to adjust pH. Turbidity and pH for raw and treated waters were taken from SCADA. TOC and UV254 (cm-1 and % Transmittance) were taken from SCFP WQC Lab data. Treated turbidity guideline applies to Indivual Filter Effluent readings. Seymour Source was operational for 365 days in 2015. Values in parenthesis ( ) are lower analytical results from a private lab.

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SERVICES AND SOLUTIONS FOR A LIVABLE REGION

Physical and Chemical Analysis of Water Supply

Greater Vancouver Water District

2015 - Coquitlam Water System

Parameter	Untreated Average	Treated Average	Treated Range	Days Guideline Exceeded	Canadian Guideline Limit	Reason Guideline Established
Alkalinity as $CaCO_3$ (mg/L)	1.71	9.3	8.1-10.6		none	
Aluminium Dissolved (µg/L)	73.3	72	53-86		none	
Aluminium Total (µg/L)	102.6	113	68-216		none	
Antimony Total (µg/L)	<0.5	<0.5	<0.5	0	6	Health
Arsenic Total (µg/L)	<0.5 (0.026)	<0.5	<0.5	0	10	Health
Barium Total (µg/L)	2.6	2.5	2.1-2.9	0	1000	Health
Boron Total (mg/L)	<0.01	<0.01	<0.01	0	5	Health
Bromate (mg/L)	<0.01	<0.01	<0.01	0	0.01	Health
Bromide (mg/L)	<0.01	<0.01	<0.01		none	
Cadmium Total (µg/L)	<0.2 (0.006)	<0.2	<0.2	0	5	Health
Calcium Total (mg/L)	0.886	0.869	0.793-0.964		none	
Carbon Organic Dissolved (mg/L)	1.79	1.7	1.3-2.3		none	
Carbon Organic Total (mg/L)	2.05	1.72	1.3-2.3		none	
Chlorate (mg/L)	<0.01	<0.01	<0.01	0	1.0	Health
Chloride Total (mg/L)	0.55	2.05	1.8-2.4	0	≤ 250	Aesthetic
Chromium Total (µg/L)	<0.05	<0.05	<0.05	0	50	Health
Color Apparent (ACU)	17	2	1-6		none	
Color True (TCU)	11	1	1-3	0	≤ 15	Aesthetic
Conductivity (umhos/cm)	9	29	24-33		none	
Copper Total (µg/L)	7.2	<0.5	<0.5		≤ 1000	Aesthetic
Cyanide Total (mg/L)	<0.02	<0.02	<0.02	0	0.2	Health
Fluoride (mg/L)	<0.05	<0.05	<0.05	0	1.5	Health
Hardness as $CaCO_3$ (mg/L)	2.63	2.58	2.35-2.87		none	
Iron Dissolved (µg/L)	11.1	18.8	13-28		none	
Iron Total (µg/L)	48.3	49	32-116	0	≤ 300	Aesthetic
Lead Total (µg/L)	<0.5	<0.5	<0.5		10	Health
Magnesium Total (µg/L)	102	100	88-122		none	
Manganese Dissolved (µg/L)	3.64	2.55	2.0-3.2		none	
Manganese Total (µg/L)	4.28	3.38	2.4-5.4	0	≤50	Aesthetic
Mercury Total (µg/L)	<0.05	<0.05	<0.05	0	1.0	Health
Molybdenum Total (µg/L)	<0.5	<0.5	<0.5		none	
Nickel Total (µg/L)	<0.5 (0.062)	<0.5	<0.5		none	
Nitrogen - Ammonia as N (mg/L)	<0.02	<0.02	<0.02		none	
Nitrogen - Nitrate as N (mg/L)	0.092	0.098	0.05-0.14	0	45	Health
Nitrogen - Nitrite as N (mg/L)	<0.01	<0.01	<0.01	0	3.0	Health
pH	6.3	7.5	7.3-7.7	0	6.5 to 8.5	Aesthetic
Phenols (µg/L)	<5	<5	<5		none	
Phosphorus Total (µg/L)	<5	<5	<5		none	
Potassium Total (µg/L)	116	115	111-118		none	
Residue Total (mg/L)	14	32	27-42		none	
Residue Total Dissolved (mg/L)	14	24	14-29	0	≤ 500	Aesthetic
Residue Total Fixed (mg/L)	8	22	17-30		none	
Residue Total Volatile (mg/L)	7	11	111-118		none	
Selenium Total (µg/L)	<0.5 (<0.040)	<0.5	<0.5	0	50	Health
Silica as SiO_2 (mg/L)	2.27	2.3	2.1-2.5		none	
Silver Total (µg/L)	<0.5 (<0.005)	<0.5	<0.5		none	
Sodium Total (mg/L)	0.472	5.6	5.0-6.4	0	≤200	Aesthetic
Sulphate (mg/L)	0.65	0.67	0.60-0.70	0	≤500	Aesthetic
Turbidity (NTU)	0.56	0.54	0.22-3.5			
Uranium Total (µg/L)	0.049	-	-	0	20	Health
UV254 (Abs/cm)	0.076	0.024	0.015-0.038		none	
UV254 App (Abs/cm)	0.083	0.029	0.019-0.039			
UV254 {cm^{-1} (% Trans)} App	82.9	93.5	91.4-95.7			
Zinc Total (µg/L)	<3 (1.54)	<3	<3	0	≤ 5000	Aesthetic

These figures are average values from a number of laboratory analyses done throughout the year. Where the range is a single value no variation was measured for the samples analysed. Methods and terms are based on those of "Standard Methods for the Examination of Water and Waste Water" 22nd Edition 2012. Less than (<) denotes not detectable with the technique used for determination. Untreated water is from the intake prior to treatment, treated water is from a single site in the GVWD distribution system downstream of CWTP. Guidelines are taken from "Guidelines for Canadian Drinking Water Quality - Sixth Edition" Health and Welfare Canada 1996,updated to Oct 2014. Coquitlam water is treated with ozone, then UV for primary disinfection. Soda ash is added to increase pH. Chlorine is added for secondary disinfection. Coquitlam source was operational for 365 days in 2015. Values in parenthesis ( ) are lower analytical results from a private Lab.

Appendix 2. Analysis of Water for Selected Organic Components and Radionuclides

Analysis of Source Waters for Herbicides, Pesticides, Volatile Organic Compounds and Uranium

	Units	Date Sampled	MAC	AO	Seymour	Capilano	Coquitlam
Atrazine	µg/L	16-Oct-15	5		<1	<1	<1
Azinphos-Methyl	µg/L	16-Oct-15	20		<1.0	<1.0	<1.0
Bendiocarb	µg/L	16-Oct-15	40		<2	<2	<2
Benzene	µg/L	16-Oct-15	5		<0.4	<0.4	<0.4
Benzo(a)pyrene	µg/L	16-Oct-15	0.01		<0.0050	<0.0050	<0.0050
Bromoxynil	µg/L	16-Oct-15	5		<0.50	<0.50	<0.50
Carbaryl	µg/L	16-Oct-15	90		<5	<5	<5
Carbofuran	µg/L	16-Oct-15	90		<5	<5	<5
Carbon Tetrachloride	µg/L	16-Oct-15	2		<0.50	<0.50	<0.50
Cyanobacterial toxins—Microcystin-LR	µg/L	Jul-Oct-15	1.5		<0.20	<0.20	<0.20
Chloramines (Monochloramine)	mg/L	31-Dec-15	3.0		<0.20	<0.20	<0.20
Chlorpyrifos	µg/L	16-Oct-15	90		<2.0	<2.0	<2.0
Diazinon	µg/L	16-Oct-15	20		<2	<2	<2
Dicamba	µg/L	16-Oct-15	120		<1.0	<1.0	<1.0
Dichlofop-Methyl	µg/L	16-Oct-15	9		<0.90	<0.90	<0.90
Dichlorobenzene, 1,2-	µg/L	16-Oct-15	200	≤ 3	<0.50	<0.50	<0.50
Dichlorobenzene, 1,4-	µg/L	16-Oct-15	5	≤ 1	<0.50	<0.50	<0.50
Dichloroethane, 1,2-	µg/L	16-Oct-15	5		<0.50	<0.50	<0.50
Dichloroethylene, 1,1-	µg/L	16-Oct-15	14		<0.50	<0.50	<0.50
Dichloromethane	µg/L	16-Oct-15	50		<2.0	<2.0	<2.0
Dichlorophenol, 2,4-	µg/L	16-Oct-15	900	≤ 0.3	<0.10	<0.10	<0.10
Dichlorophenoxyacetic acid, 2,4-(2,4-D)	µg/L	16-Oct-15	100		<1.0	<1.0	<1.0
Dimethoate	µg/L	16-Oct-15	20		<2	<2	<2
Diquat	µg/L	16-Oct-15	70		<7	<7	<7
Diuron	µg/L	16-Oct-15	150		<10	<10	<10
Ethylbenzene	µg/L	16-Oct-15	140	≤ 1.6	<0.40	<0.40	<0.40
Glyphosate	µg/L	16-Oct-15	280		<10	<10	<10
Malathion	µg/L	16-Oct-15	190		<2.0	<2.0	<2.0
2-Methyl-4-chlorophenoxyacetic acid (MCPA)	µg/L	16-Oct-15	100		<2.0	<2.0	<2.0
Methyl t-butyl ether (MTBE)	µg/L	16-Oct-15		≤ 15	<4	<4	<4
Metolachlor	µg/L	16-Oct-15	50		<5	<5	<5
Metribuzin	µg/L	16-Oct-15	80		<2.5	<2.5	<2.5
Monochlorobenzene	µg/L	16-Oct-15	80	≤ 30	<0.50	<0.50	<0.50

	Units	Date Sampled	MAC	AO	Seymour	Capilano	Coquitlam
N-Nitroso dimethylamine (NDMA)	µg/L	17-Nov-15	0.04		<0.002	<0.002	<0.002
Nitrilotriacetic Acid (NTA)	mg/L	16-Oct-15	400		<0.050	<0.050	<0.050
Paraquat (as Dichloride)	µg/L	16-Oct-15	10		<1	<1	<1
Pentachlorophenol	µg/L	16-Oct-15	60	≤30	<0.10	<0.10	<0.10
Phorate	µg/L	16-Oct-15	2		<1	<1	<1
Picloram	µg/L	16-Oct-15	190		<5.0	<5.0	<5.0
Simazine	µg/L	16-Oct-15	10		<2	<2	<2
Terbufos	µg/L	16-Oct-15	1		<1	<1	<1
Tetrachloroethylene	µg/L	16-Oct-15	30		<0.50	<0.50	<0.50
Tetrachlorophenol, 2,3,4,6-	µg/L	16-Oct-15	100	≤ 1	<0.10	<0.10	<0.10
Toluene	µg/L	16-Oct-15	60	24	<0.40	<0.40	<0.40
Trichloroethylene	µg/L	16-Oct-15	5		<0.50	<0.50	<0.50
Trichlorophenol, 2,4,6-	µg/L	16-Oct-15	≤2	≤ 2	<0.10	<0.10	<0.10
Trifluralin	µg/L	16-Oct-15	45		<5	<5	<5
Uranium	µg/L	16-Oct-15	20		0.038	0.033	0.049
Vinyl Chloride	µg/L	16-Oct-15	2		<0.50	<0.50	<0.50
Xylene (Total)	µg/L	16-Oct-15	90	≤ 20	<0.40	<0.40	<0.40

Analysis of Source Water for PAH's

Parameters	Units	Capilano		Seymour		Coquitlam	
		23-Jun	17-Nov	23-Jun	17-Nov	23-Jun	16-Nov
Acenaphthene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Acenaphthylene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Anthracene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(a)anthracene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(b)fluoranthene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(k)fluoranthene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(g,h,i)perylene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(a)pyrene[1]	µg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Chrysene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Dibenzo(a,h)anthracene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Fluoranthene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Fluorene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Indeno(1,2,3-c,d)pyrene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Naphthalene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phenanthrene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Pyrene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050

Analysis of Source Water for Radioactivity

		Date		Seymour		Capilano		Coquitlam	
Radioactivity	**Units**	**Sampled**	MAC[1]	MDA[3]	Activity	MDA[3]	Activity	MDA[3]	Activity
Gross Alpha	Bq/L	25-Sep-15	**<0.5**	0.03	<0.03	0.03	<0.03	0.03	<0.03
Gross Beta	Bq/L	25-Sep-15	**<1.0**	0.06	<0.06	0.06	<0.06	0.06	<0.06
Cobalt-60	Bq/L	28-Sep-15	**2** [2]	0.21	<0.21	0.20	<0.20	0.22	<0.22
Cesium-134	Bq/L	28-Sep-15	**7** [2]	0.20	<0.20	0.19	<0.19	0.21	<0.21
Cesium-137	Bq/L	28-Sep-15	**10**	0.18	<0.18	0.18	<0.18	0.17	<0.17
Iodine-131	Bq/L	28-Sep-15	**6**	0.27	<0.27	0.27	<0.27	0.29	<0.29
Lead-210	Bq/L	28-Sep-15	**0.2**	0.04	<0.04	0.05	<0.05	0.04	<0.04
Radium-226	Bq/L	28-Sep-15	**0.5**	0.02	<0.02	0.02	<0.02	0.02	<0.02
Radon-222	Bq/L	28-Sep-15	**none**	1.04	<1.04	1.02	<1.02	1.07	<1.07
Strontium-90	Bq/L	25-Sep-15	**5**	0.05	<0.05	0.05	<0.05	0.06	<0.06
Tritium (H-3)	Bq/L	25-Sep-15	**7000**	3.05	<3.05	2.76	<2.76	2.80	<2.80

Footnotes:
[1]MAC from Guidelines for Canadian Drinking Water Quality (GCDWQ), Oct. 2014
[2]MAC from Guidelines for Canadian Drinking Water Quality (GCDWQ), 6th Ed. 1996
[3]MDA Minimum Detectable Activity

Monitoring of Selected GVWD Water Mains for BTEXs

Parameters	Units	Date Sampled	MAC µg/L	AO µg/L	Maple Ridge Main at Reservoir	Barnston Island Main at Willoughby PS	Jericho-Clayton Main	South Burnaby Main #2
Benzene	µg/L	10-Nov-15	5		<0.4	<0.4	<0.4	<0.4
Ethylbenzene	µg/L	10-Nov-15	140	1.6	<0.4	<0.4	<0.4	<0.4
Toluene	µg/L	10-Nov-15	60	24	<0.4	<0.4	<0.4	<0.4
Xylenes (Total)	µg/L	10-Nov-15	90	20	<0.4	<0.4	<0.4	<0.4

MAC = Maximum Acceptable Concentration
AO=Aesthetic Objective

Monitoring of Selected GVWD Mains for PAHs

Parameters	Units	Coquitlam Main #2 & #3		Westburnco Reservoir		Barnston Island		Queens-borough		Whalley Kennedy Link Main		Haney Main #2		36th Ave Main	
		22-Jun	18-Nov	23-Jun	18-Nov	24-Jun	17-Nov	22-Jun	17-Nov	23-Jun	17-Nov	24-Jun	18-Nov	23-Jun	17-Nov
Acenaphthene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Acenaphthylene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Anthracene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(a)anthracene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(b)fluoranthene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(k)fluoranthene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(g,h,i)perylene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(a)pyrene[1]	µg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Chrysene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Dibenzo(a,h)anthracene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Fluoranthene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Fluorene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Indeno(1,2,3,c,d)pyrene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Naphthalene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phenanthrene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Pyrene	µg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050

[1]Benzopyrene is the only PAH compound that has guideline limit. Maximum Acceptable Concentration of Benzopyrene is 0.01µg/L.

Appendix 3

Analysis of Source Waters for the Reservoir Limnology Program

Table 1 shows the (mean) chlorophyll-a concentration, water temperature and concentration or value of chemical analytes in each reservoir during monitoring in April through November in 2014 and 2015. Temperature, specific conductivity, and dissolved oxygen data are from Conductivity/Temperature/Depth (CTD) Sonde casts throughout complete water columns at all stations.

Table 1: Comparison of Chlorophyll-a and Chemical Analyte Concentrations for Reservoirs 2014 to 2015

		Capilano		**Seymour**		**Coquitlam**	
	Units	2014	**2015**	2014	**2015**	2014	**2015**
Chlorophyll-a	µg/L	0.21	0.40	0.26	0.72	0.17	0.42
Nitrate	µg/L	60.3	66.6	52.3	56.7	70.9	71.4
Total Nitrogen	µg/L	156.4	170.2	161.9	153.4	142.0	168.7
Total Dissolved Phosphorus	µg/L	2.1	2.1	2.2	2.2	<2.0	<2.0
Total Phosphorus	µg/L	*	2.6	3.6	3.0	2.4	2.2
Dissolved Organic Carbon	mg/L	2.0	2.1	1.9	2.1	1.7	2.5
Alkalinity	mg/L	2.9	3.4	3.8	4.2	1.8	1.7
pH		6.6	6.8	6.7	6.7	6.5	6.4
Specific conductivity	µS/cm	10.2	12.9	12.2	14.7	10.7	12.6
Dissolved Oxygen	mg/L	10.7	9.8	10.1	8.8	9.5	8.4
Temperature	°C	12.7	14.2	12.1	13.8	13.7	15.9
		6.5	5.0	7.1	4.8	8.7	7.8

Figure 1: Seasonal Average Density of Major Phytoplankton Groups in Capilano Reservoir

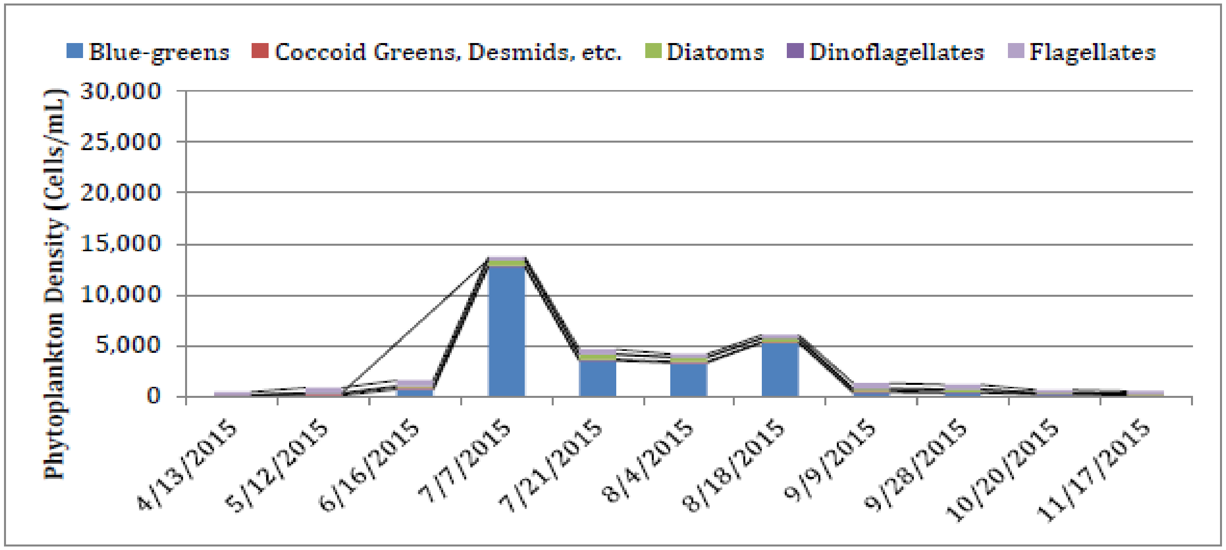

Figure2:Seasonal average density of major phytoplankton groups in Seymour Reservoir

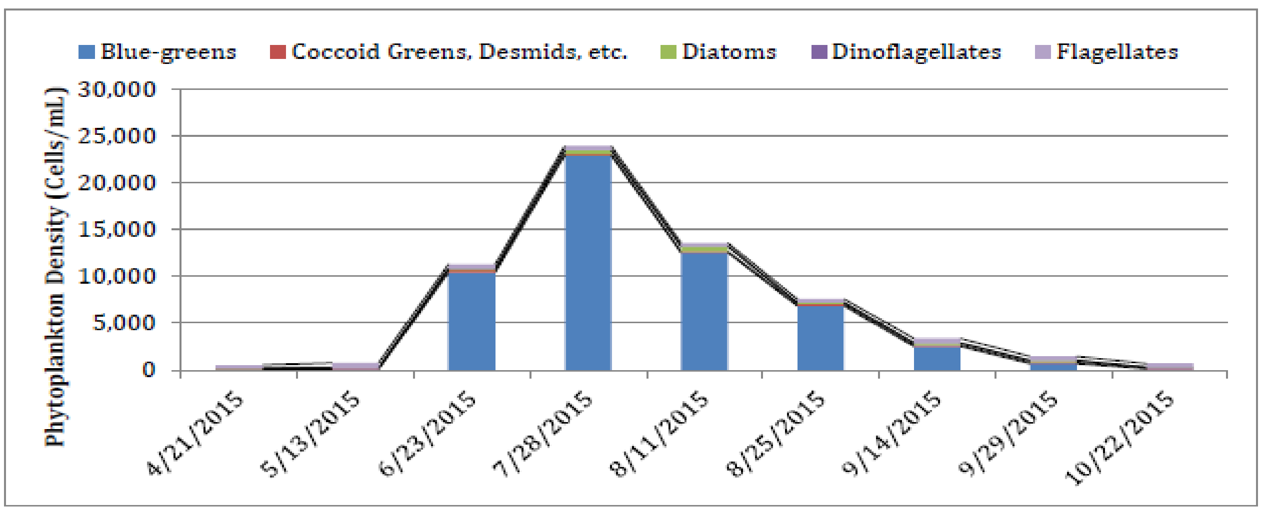

Figure 3: Seasonal Average Density of Major Phytoplankton Groups in Coquitlam Reservoir

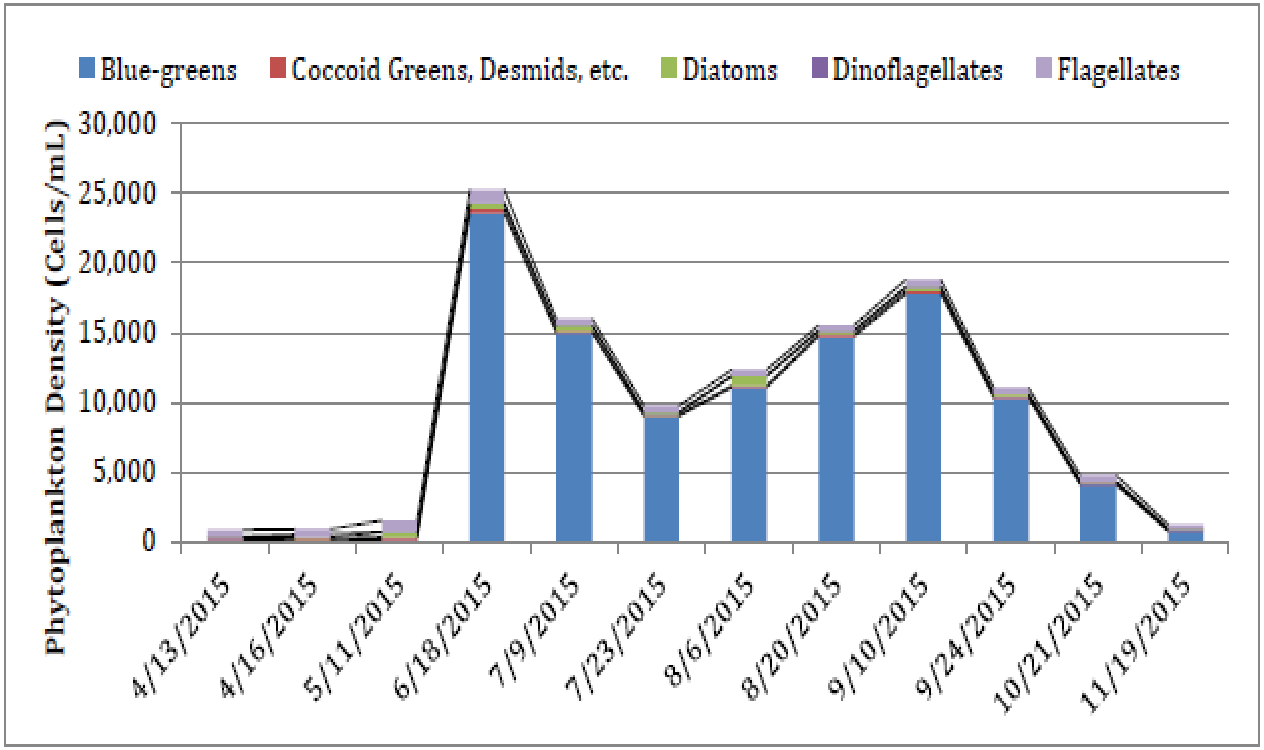

Table 2: Annual Rate of Zooplankton Production in Compared Lakes and Reservoirs

Parameter		Trophic classification by Wetzel (2001)*				Capilano Reservoir**	Seymour Reservoir**	Coquitlam Reservoir**	Status of Reservoirs
		Ultra-oligotrophic	Oligotrophic	Mesotrophic	Eutrophic				
TP ($\mu g \cdot L^{-1}$)	mean		8.0	27	84	2.6	3.3	2.3	All ultraoligotrophic
	range	<1 – 5	3 – 18	11 - 96	16 – 386	<2 - 5	<2 – 6.5	<2 – 3.5	All ultraoligotrophic
TN ($\mu g \cdot L^{-1}$)	mean		661	753	1875	163	158	155	All ultraoligotrophic
	range	<1 – 250	307 - 1630	361 - 1387	393 - 6100	81 - 539	80 - 319	98 - 274	All ultraoligotrophic
Chl-a ($\mu g \cdot L^{-1}$)	mean		1.7	4.7	14.3	0.31	0.49	0.30	All ultraoligotrophic
	range	0.01 – 0.5	0.3 – 4.5	3 - 11	3 - 78	0.06 – 0.55	0.06 – 1.31	0.01 – 0.70	All ultraoligotrophic
Secchi depth (m)	mean		9.9	4.2	2.5	5.8	6.0	8.3	All oligotrophic
	range		5.4 – 28.3	1.5 – 8.1	0.8 – 7.0	0.25 - 13	2 -11	5 - 12	All oligotrophic but with episodes indicating mesotrophic or eutrophic status***

*based on annual means.
**mean from 2014 and 2015.
***affected by turbidity from allochonous sources

Table 3: Trophic State of Metro Vancouver Reservoirs based on Criteria by Wetzel (2001)

Parameter		Trophic classification by Wetzel (2001)*				Capilano Reservoir**	Seymour Reservoir**	Coquitlam Reservoir**	Status of Reservoirs
		Ultra-oligotrophic	Oligotrophic	Mesotrophic	Eutrophic				
TP ($\mu g \cdot L^{-1}$)	mean		8.0	27	84	2.6	3.3	2.3	All ultraoligotrophic
	range	<1 – 5	3 – 18	11 - 96	16 – 386	<2 - 5	<2 – 6.5	<2 – 3.5	All ultraoligotrophic
TN ($\mu g \cdot L^{-1}$)	mean		661	753	1875	163	158	155	All ultraoligotrophic
	range	<1 – 250	307 - 1630	361 - 1387	393 - 6100	81 - 539	80 - 319	98 - 274	All ultraoligotrophic
Chl-a ($\mu g \cdot L^{-1}$)	mean		1.7	4.7	14.3	0.31	0.49	0.30	All ultraoligotrophic
	range	0.01 – 0.5	0.3 – 4.5	3 - 11	3 - 78	0.06 – 0.55	0.06 – 1.31	0.01 – 0.70	All ultraoligotrophic
Secchi depth (m)	mean		9.9	4.2	2.5	5.8	6.0	8.3	All oligotrophic
	range		5.4 – 28.3	1.5 – 8.1	0.8 – 7.0	0.25 - 13	2 -11	5 - 12	All oligotrophic but with episodes indicating mesotrophic or eutrophic status***

*based on annual means.
**mean from 2014 and 2015.
***affected by turbidity from allochonous sources

Appendix 4 Report to Metro Vancouver-*Giardia* and *Cryptosporidium* Study

January – December, 2015

REPORT

to

METRO VANCOUVER

GIARDIA and CRYPTOSPORIDIUM STUDY
January – December, 2015

January 26, 2016

BCCDC Public Health Laboratories
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ATTACHED GRAPHS AND TABLES

1. Graphs and Tables of Metro Vancouver Weekly *Giardia* and *Cryptosporidium* Filter Results 2015.xls
   a. Graph 1 – 2015 Capilano Reservoir *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 Litres of Raw Water
   b. Graph 2 – 2015 Coquitlam Reservoir *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 Litres of Raw Water
   c. Graph 3 – 2015 SCFP-RCW *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 Litres of RCW
   d. Table 3 – 2015 Metro Vancouver Capilano Reservoir Weekly Filter Results
   e. Table 4 – 2015 Metro Vancouver Coquitlam Reservoir Weekly Filter Results
   f. Table 5 – 2015 Metro Vancouver SCFP - RCW Weekly Filter Results

2. 2015 Metro Vancouver Slide Examination Results - *Cryptosporidium*.xls
   a. Table 6 – Metro Vancouver Capilano Reservoir 2015 Slide Examination *Cryptosporidium* Results
   b. Table 7 – Metro Vancouver Coquitlam Reservoir 2015 Slide Examination *Cryptosporidium* Results
   c. Table 8 – Metro Vancouver SCFP - RCW 2015 Slide Examination *Cryptosporidium* Results

3. 2015 Metro Vancouver Slide Examination Results – *Giardia*.xls
   a. Table 9 – Metro Vancouver Capilano Reservoir 2015 Slide Examination *Giardia* Results
   b. Table 10 – Metro Vancouver Coquitlam Reservoir 2015 Slide Examination *Giardia* Results
   c. Table 11 – Metro Vancouver SCFP - RCW 2015 Slide Examination *Giardia* Results

Report to Metro Vancouver
Detection of Waterborne *Giardia* and *Cryptosporidium* Study
January - December, 2015

PURPOSE

To detect and quantify *Giardia* cysts and *Cryptosporidium* oocysts present in Filta-Max filters submitted regularly by Metro Vancouver from each of Capilano and Coquitlam reservoirs, as well as Recycled Clarified Water from Seymour-Capilano Filtration Plant (SCFP-RCW).

INTRODUCTION

Giardia cysts and *Cryptosporidium* oocysts are parasites that infect the intestinal tracts of a wide range of animals. In humans, infection with *Giardia lamblia* or *Cryptosporidium* species can cause gastroenteritis. As the cyst and oocyst forms of *Giardia* and *Cryptosporidium* are resistant to chlorination, they are of great concern for drinking water purveyors (1-3). On behalf of Metro Vancouver, Environmental Microbiology Laboratory at BCCDC Public Health Laboratories is currently examining the source water of Capilano and Coquitlam reservoirs, as well as Recycled Clarified Water at the Seymour Capilano Filtration Plant for presence of *Giardia* cysts and *Cryptosporidium* oocysts. All sample collection, testing, analysis and reporting occurred on a monthly basis.

METHODS

The Environmental Microbiology Laboratory at BCCDC Public Health Laboratories uses the United States Environmental Protection Agency (USEPA) Method 1623: *Cryptosporidium* and *Giardia* in Water by Filtration/IMS/FA (4) for the detection of oocysts and cysts in water. Method 1623 is a performance-based method applicable to the determination of *Cryptosporidium* and *Giardia* in aqueous matrices. It requires the filtration of a large volume of water and immunomagnetic separation (IMS) to further concentration and purification the oocysts and cysts from sample material captured. Immunofluorescence microscopy is performed after the IMS procedure for identification and enumeration of oocysts and cysts, with confirmation using 4'-6-diamidino-2-phenylindole (DAPI) staining and differential interference contrast (DIC) microscopy.

Raw water samples were collected by Metro Vancouver staff at specific locations in each of the Metro Vancouver sampling sites. Water was filtered at designated sites in the reservoirs and filtration plant using IDEXX Filta-Max foam filter modules. Filters were transported to the Environmental Microbiology Laboratory at BCCDC Public Health Laboratories, by Metro Vancouver staff, where they were processed and analysed.

RESULTS & DISCUSSIONS

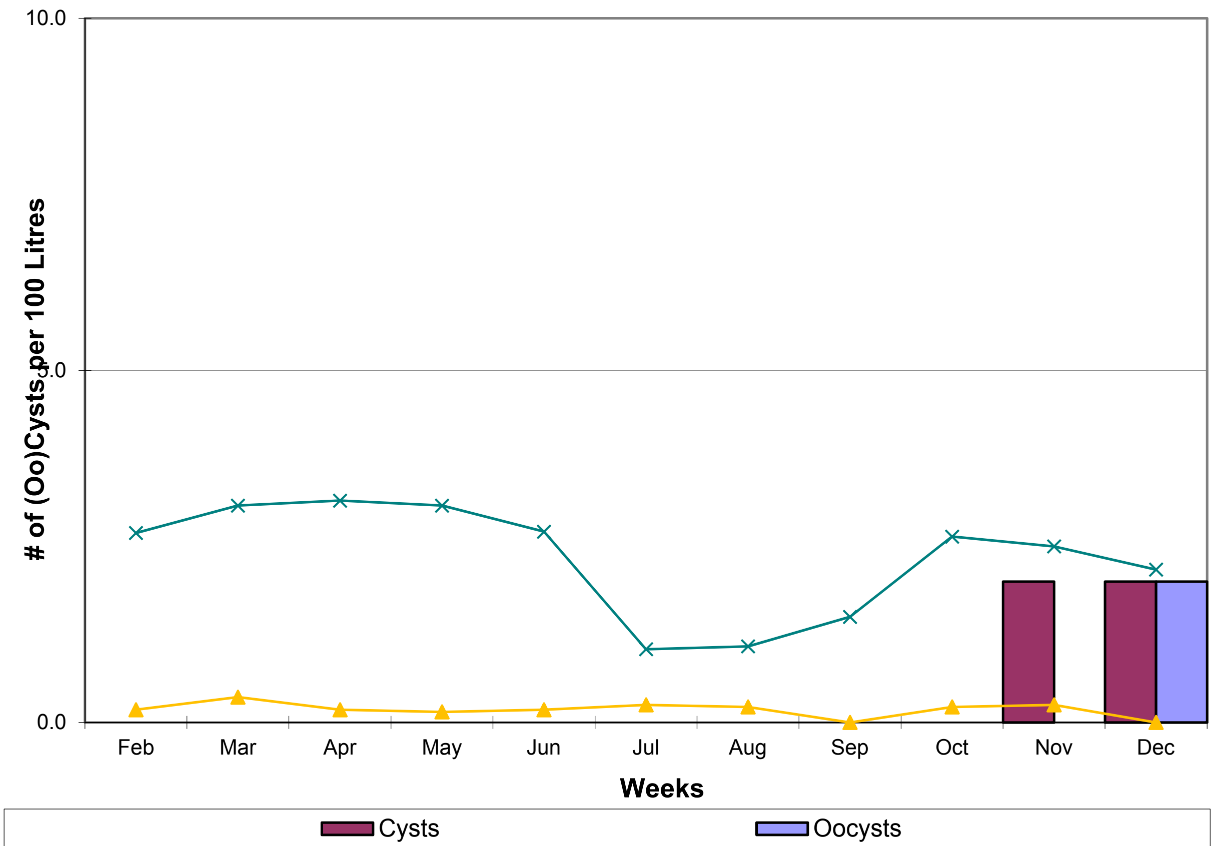
During 2015, a total of 35 Filta-Max filters were examined (excluding matrix spikes). These included:

- 11 filters from the Capilano reservoir
- 12 filters from the Coquitlam reservoir
- 12 filters from SCFP-RCW

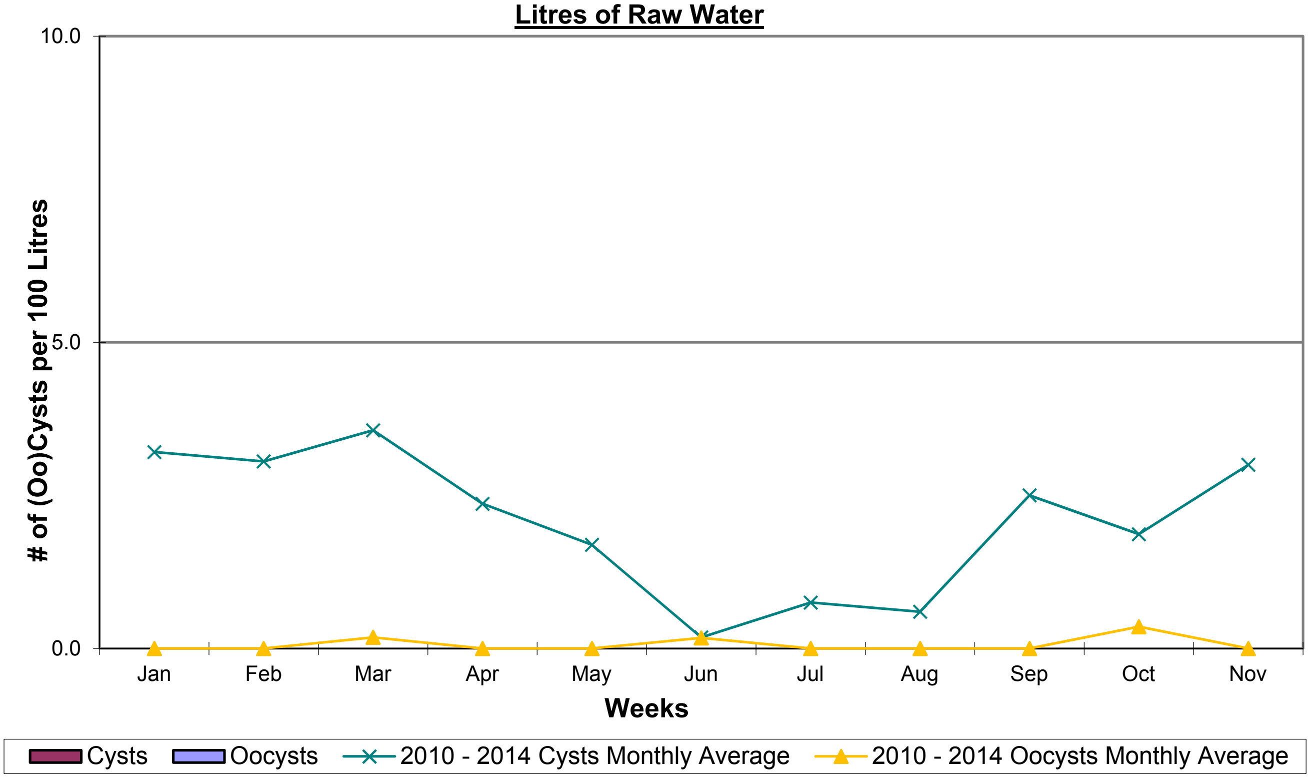
Negative and positive controls were tested as required by the Environmental Microbiology Laboratory's Quality Assurance program. Summary of our findings are presented in Graphs 1-3 and Tables 1-5. An average of 50.0 L of raw water was filtered for both Capilano and Coquitlam reservoir. Average detection limit for Capilano and Coquitlam were <2.0 and <2.0 (oo)cysts per 100 L respectively. Average volume of water filtered and detection limit for SCFP-RCW were 261.6 L and 0.5 (oo)cysts per 100 L respectively.

Giardia cysts were detected more frequently than *Cryptosporidium* oocysts. Capilano had the highest positive detection rate amongst all of the sampling sites, with *Giardia* cysts and *Cryptosporidium* oocysts at 18.2% and 9.1% respectively. In contrast, Coquitlam Reservoir has the lowest incidence of *Cryptosporidium* oocysts and *Giardia* cysts, with none detected over 12 sampling events.

Graph 1
2015 Capilano Reservoir *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 Litres of Raw Water



Graph 2
2015 Coquitlam Reservoir *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 Litres of Raw Water



Graph 3
2015 Seymour Capilano Filtration Plant - Recycled Clarified Water *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 Litres of Raw Water

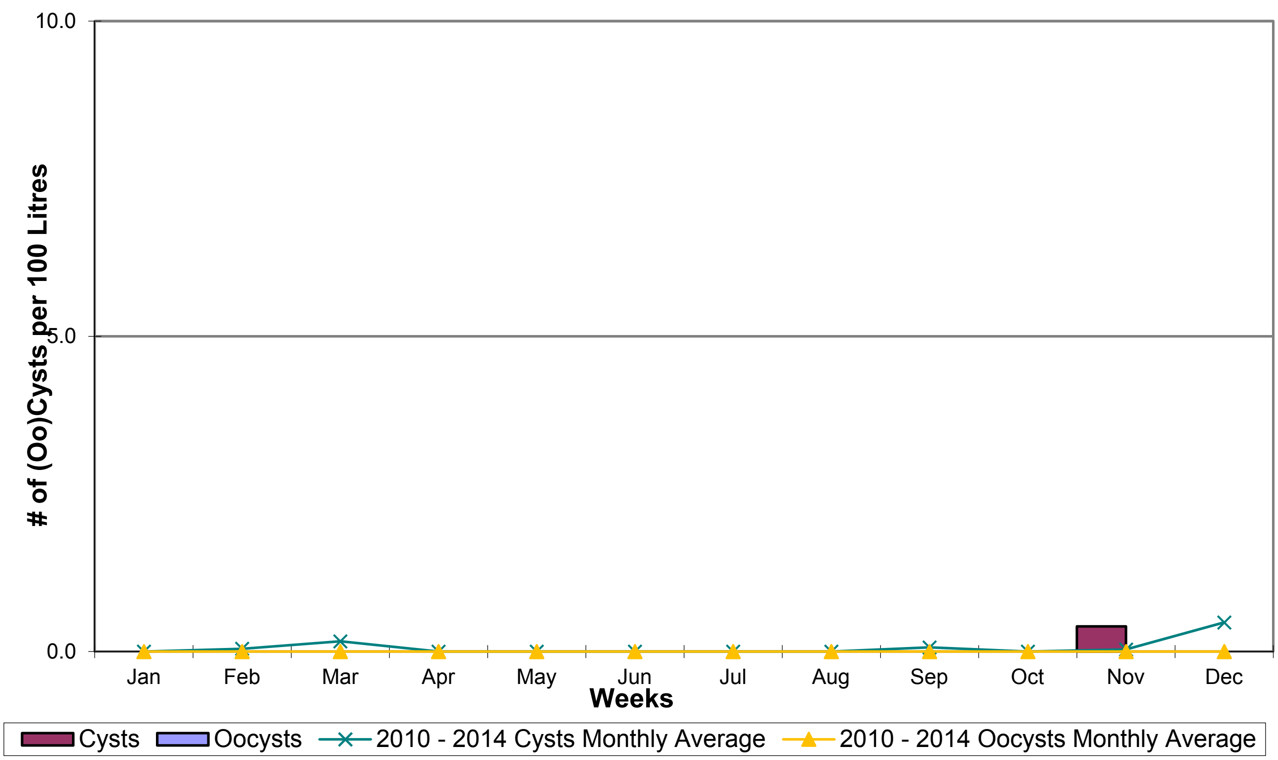


Table 1: *Giardia* and *Cryptosporidium* Percent Positives for Metro Vancouver Water Filters – 2015

	Capilano Reservoir	Coquitlam Reservoir	SCFP - RCW
Number of Water Filter Tested	11	12	12
% Filters – *Giardia* Positive	18.2%	0.0%	8.3%
% Filters – *Cryptosporidium* Positive	9.1%	0.0%	0.0%
% Filters – *Giardia* AND *Cryptosporidium* Positive	9.1%	0.0%	0.0%
% Filters – *Giardia* OR *Cryptosporidium* Positive	18.2%	0.0%	8.3%

Table 2: *Giardia* Cyst and *Cryptosporidium* Oocyst Concentrations for Positive Water Filters – 2015

Sampling Sites	# of Water Filters Tested	Average Detection Limit (oo)cysts/ 100 L	Max Detection Limit (oo)cysts/ 100L	Min Detection Limit (oo)cysts/ 100L	# of *Giardia* Positive Filters	Max # of Giardia cysts/ 100L	# of *Crypto* Positive Filters	Max # of Crypto oocysts/ 100L
All Sites	35	1.5	2.0	0.2	3	2.0	1	2.0
Capilano Reservoir	11	2.0	2.0	2.0	2	2.0	1	2.0
Coquitlam Reservoir	12	2.0	2.0	2.0	0	0.0	0	0.0
SCFP - RCW	12	0.5	1.0	0.2	1	0.4	0	0.0

Table 3: 2015 Metro Vancouver Capilano Reservoir Weekly Filter Results.

	WF#	Site Location	Sampling Date	Month	Detection Limit (per 100L)	No. of Cysts per 100L	No. of Oocysts per 100L	Volume of Water Filtered (L)	2010 - 2014 Monthly Average	
									No. of Cysts per 100L	No. of Oocysts per 100L
1	7661	Capilano Reservoir	16-Feb-15	Feb	<2.0	0.0	0.0	50.0	2.7	0.2
2	7663	Capilano Reservoir	2-Mar-15	Mar	<2.0	0.0	0.0	50.0	3.1	0.4
3	7674	Capilano Reservoir	7-Apr-15	Apr	<2.0	0.0	0.0	50.0	3.2	0.2
4	7685	Capilano Reservoir	4-May-15	May	<2.0	0.0	0.0	50.0	3.1	0.2
5	7701	Capilano Reservoir	8-Jun-15	Jun	<2.0	0.0	0.0	50.0	2.7	0.2
6	7716	Capilano Reservoir	6-Jul-15	Jul	<2.0	0.0	0.0	50.0	1.0	0.3
7	7727	Capilano Reservoir	5-Aug-15	Aug	<2.0	0.0	0.0	50.0	1.1	0.2
8	7736	Capilano Reservoir	8-Sep-15	Sep	<2.0	0.0	0.0	50.0	1.5	0.0
9	7746	Capilano Reservoir	5-Oct-15	Oct	<2.0	0.0	0.0	50.0	2.6	0.2
10	7761	Capilano Reservoir	2-Nov-15	Nov	<2.0	2.0	0.0	50.0	2.5	0.3
11	7780	Capilano Reservoir	7-Dec-15	Dec	<2.0	2.0	2.0	50.0	2.2	0.0
				Averages	<2.0	0.4	0.2	50.0		

Table 4: 2015 Metro Vancouver Coquitlam Reservoir weekly filter results.

	WF#	Site Location	Sampling Date	Month	Detection Limit (per 100L)	No. of Cysts per 100L	No. of Oocysts per 100L	Volume of Water Filtered (L)	2010 - 2014 Monthly Average	
									No. of Cysts per 100L	No. of Oocysts per 100L
1	7643	Coquitlam Reservoir	05-Jan-15	Jan	<2.0	0.0	0.0	50.0	3.2	0.0
2	7652	Coquitlam Reservoir	02-Feb-15	Feb	<2.0	0.0	0.0	50.0	3.1	0.0
3	7664	Coquitlam Reservoir	05-Mar-15	Mar	<2.0	0.0	0.0	50.0	3.6	0.2
4	7675	Coquitlam Reservoir	08-Apr-15	Apr	<2.0	0.0	0.0	50.0	2.4	0.0
5	7686	Coquitlam Reservoir	05-May-15	May	<2.0	0.0	0.0	50.0	1.7	0.0
6	7702	Coquitlam Reservoir	09-Jun-15	Jun	<2.0	0.0	0.0	50.0	0.2	0.2
7	7717	Coquitlam Reservoir	10-Jul-15	Jul	<2.0	0.0	0.0	50.0	0.8	0.0
8	7728	Coquitlam Reservoir	07-Aug-15	Aug	<2.0	0.0	0.0	50.0	0.6	0.0
9	7737	Coquitlam Reservoir	09-Sep-15	Sep	<2.0	0.0	0.0	50.0	2.5	0.0
10	7747	Coquitlam Reservoir	05-Oct-15	Oct	<2.0	0.0	0.0	50.0	1.9	0.4
11	7762	Coquitlam Reservoir	06-Nov-15	Nov	<2.0	0.0	0.0	50.0	3.0	0.0
12	7787	Coquitlam Reservoir	06-Dec-15	Dec	<2.0	0.0	0.0	50.0	2.2	0.3
				Averages	<2.0	0.0	0.0	50.0		

Table 5: 2015 Metro Vancouver Seymour Capilano Filtration Plant - Recycled Clarified Water (SCFP-RCW) weekly filter results.

	WF#	Site Location	Sampling Date	Month	Detection Limit (per 100L)	No. of Cysts per 100L	No. of Oocysts per 100L	Volume of Water Filtered (L)	2010 - 2014 Monthly Average	
									No. of Cysts per 100L	No. of Oocysts per 100L
1	7645	SCFP - RCW	07-Jan-15	Jan	<0.5	0.0	0.0	198.5	0.0	0.0
2	7653	SCFP - RCW	04-Feb-15	Feb	<0.3	0.0	0.0	346.0	0.0	0.0
3	7672	SCFP - RCW	18-Mar-15	Mar	<0.4	0.0	0.0	225.8	0.2	0.0
4	7677	SCFP - RCW	09-Apr-15	Apr	<0.6	0.0	0.0	178.5	0.0	0.0
5	7688	SCFP - RCW	06-May-15	May	<1.0	0.0	0.0	95.7	0.0	0.0
6	7704	SCFP - RCW	10-Jun-15	Jun	<0.2	0.0	0.0	432.3	0.0	0.0
7	7718	SCFP - RCW	08-Jul-15	Jul	<0.2	0.0	0.0	567.8	0.0	0.0
8	7729	SCFP - RCW	06-Aug-15	Aug	<0.3	0.0	0.0	353.5	0.0	0.0
9	7739	SCFP - RCW	10-Sep-15	Sep	<0.2	0.0	0.0	402.0	0.1	0.0
10	7748	SCFP - RCW	07-Oct-15	Oct	<1.0	0.0	0.0	97.5	0.0	0.0
11	7763	SCFP - RCW	04-Nov-15	Nov	<0.4	0.4	0.0	239.3	0.0	0.0
12	7782	SCFP - RCW	09-Dec-15	Dec	<0.4	0.0	0.0	242.2	0.5	0.0
				Averages	<0.5	0.0	0.0	281.6		

Results for staining by IFA, DAPI and internal morphology, as determined through DIC microscopy, for every identified cyst and oocyst were recorded. Shown in (Tables 6-11).

Table 6: Metro Vancouver Capilano Reservoir 2015 Slide Examination *Cryptosporidium* Results.

Lab No.	Site Sampled	Sampling Date	Object located by FA	Shape (oval or round)	Size L x W (µm)	DAPI –	DAPI +		D.I.C.		
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty oocysts	Oocysts with amorphous structure	Oocysts with internal structure Number of sporozoites
7661	Capilano Reservoir	15-Feb-15	0								
7663	Capilano Reservoir	01-Mar-15	0								
7674	Capilano Reservoir	06-Apr-15	0								
7685	Capilano Reservoir	03-May-15	0								
7701	Capilano Reservoir	07-Jun-15	0								
7716	Capilano Reservoir	05-Jul-15	0								
7727	Capilano Reservoir	03-Aug-15	0								
7736	Capilano Reservoir	07-Sep-15	0								
7746	Capilano Reservoir	04-Oct-15	0								
7761	Capilano Reservoir	01-Nov-15	0								
7780	Capilano Reservoir	06-Dec-15	1	oval	5.6x4.8			3		√	

Table 7: Metro Vancouver Coquitlam Reservoir 2015 Slide Examination *Cryptosporidium* Results.

Lab No.	Site Sampled	Sampling Date	Object located by FA	Shape (oval or round)	Size L x W (µm)	DAPI –	DAPI +		D.I.C.		
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty oocysts	Oocysts with amorphous structure	Oocysts with internal structure Number of sporozoites
7643	Coquitlam Reservoir	04-Jan-15	0								
7652	Coquitlam Reservoir	01-Feb-15	0								
7664	Coquitlam Reservoir	01-Mar-15	0								
7675	Coquitlam Reservoir	06-Apr-15	0								
7686	Coquitlam Reservoir	03-May-15	0								
7702	Coquitlam Reservoir	07-Jun-15	0								
7717	Coquitlam Reservoir	05-Jul-15	0								
7728	Coquitlam Reservoir	03-Aug-15	0								
7737	Coquitlam Reservoir	07-Sep-15	0								
7747	Coquitlam Reservoir	04-Oct-15	0								
7762	Coquitlam Reservoir	01-Nov-15	0								
7781	Coquitlam Reservoir	06-Dec-15	0								

Table 8: Metro Vancouver Seymour Capilano Filtration Plant - Recycled Clarified Water 2015 Slide Examination Cryptosporidium Results.

Lab No.	Site Sampled	Sampling Date	Object located by FA	Shape (oval or round)	Size L x W (µm)	DAPI –	DAPI +		D.I.C.		
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty oocysts	Oocysts with amorphous structure	Oocysts with internal structure: Number of sporozoites
7645	SCFP-RCW	06-Jan-15	0								
7653	SCFP-RCW	03-Feb-15	0								
7672	SCFP-RCW	17-Mar-15	0								
7677	SCFP-RCW	08-Apr-15	0								
7688	SCFP-RCW	05-May-15	0								
7704	SCFP-RCW	09-Jun-15	0								
7718	SCFP-RCW	07-Jul-15	0								
7729	SCFP-RCW	05-Aug-15	0								
7739	SCFP-RCW	09-Sep-15	0								
7748	SCFP-RCW	06-Oct-15	0								
7763	SCFP-RCW	03-Nov-15	0								
7782	SCFP-RCW	08-Dec-15	0								

Table 9: Metro Vancouver Capilano Reservoir 2015 Slide Examination *Giardia* Results.

Lab No.	Site Sampled	Sampling Date	Object located by FA	Shape (oval or round)	Size L x W (µm)	DAPI –	DAPI +		D.I.C.				
											Cysts with internal structure		
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty cysts	Cysts with amorphous structure	Number of nuclei	Median Body	Axoneme
7661	Capilano	Feb 15, 15	0										
7663	Capilano	Mar 01, 15	0										
7674	Capilano	Apr 06, 15	0										
7685	Capilano	May 03,15	0										
7701	Capilano	Jun 07, 15	0										
7716	Capilano	Jul 05, 15	0										
7727	Capilano	Aug 03, 15	0										
7736	Capilano	Sep 07, 15	0										
7746	Capilano	Oct 04, 15	0										
7761	Capilano	Nov 01, 15	1	oval	10.4x 6.4			3			1		
7780	Capilano	Dec 06, 15	1	oval	12x8. 8		√			√			

Table 10: Metro Vancouver Coquitlam Reservoir 2015 Slide Examination *Giardia* Results.

Lab No.	Site Sampled	Sampling Date	Object located by FA	Shape (oval or round)	Size L x W (µm)	DAPI –	DAPI +		D.I.C.				
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty cysts	Cysts with amorphous structure	Cysts with internal structure		
											Number of nuclei	Median Body	Axoneme
7643	Coquitlam	Jan 04, 15	0										
7652	Coquitlam	Feb 01, 15	0										
7664	Coquitlam	Mar 01, 15	0										
7675	Coquitlam	Apr 06, 15	0										
7686	Coquitlam	May 03,15	0										
7702	Coquitlam	Jun 07, 15	0										
7717	Coquitlam	Jul 05, 15	0										
7728	Coquitlam	Aug 03, 15	0										
7737	Coquitlam	Sep 07, 15	0										
7747	Coquitlam	Oct 04, 15	0										
7762	Coquitlam	Nov 01, 15	0										
7781	Coquitlam	Dec 07, 15	0										

Table 11: Metro Vancouver Seymour Capilano Filtration Plant - Recycled Clarified Water 2015 Slide Examination *Giardia* Results.

Lab No.	Site Sampled	Sampling Date	Object located by FA	Shape (oval or round)	Size L x W (µm)	DAPI –	DAPI +		D.I.C.				
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty cysts	Cysts with amorphous structure	Cysts with internal structure		
											Number of nuclei	Median Body	Axoneme
7645	SCFP-RCW	Jan 06, 15	0										
7653	SCFP-RCW	Feb 03, 15	0										
7672	SCFP-RCW	Mar 17, 15	0										
7677	SCFP-RCW	Apr 08, 15	0										
7688	SCFP-RCW	May 05,15	0										
7704	SCFP-RCW	Jun 09, 15	0										
7718	SCFP-RCW	Jul 07, 15	0										
7729	SCFP-RCW	Aug 05, 15	0										
7739	SCFP-RCW	Sep 09, 15	0										
7748	SCFP-RCW	Oct 06, 15	0										
7763	SCFP-RCW	Nov 03, 15	1	oval	8.8x6.0	√							1
7782	SCFP-RCW	Dec 08, 15	0										

While the primary purpose of the DAPI stain was to confirm the presence of *Giardia* cyst and *Cryptosporidium* oocyst, it can also serve as an indicator of nuclei integrity of cyst/oocyst as it indicates the presence of DNA. DAPI staining results of the cysts differ between each sampling sites (Table 12).

Table 12: Summary of morphological results for *Giardia* cysts observed under fluorescence microscope.

Site	Total	DAPI -	DAPI +		D.I.C.				
		Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Nuclei stained sky blue	Empty cysts	Cysts with amorphous structure	Cysts with internal structure		
							Nuclei	Median body	Axoneme
Capilano	2	0 (0.0%)	1 (50.0%)	1 (50.0%)	0 (0.0%)	0 (0.0%)	1 (50.0%)	0 (0.0%)	0 (0.0%)
Coquitlam	0	-	-	-	-	-	-	-	-
SCFP-RCW	1	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0(0.0%)	0 (0.0%)	0 (0.0%)	1(100.0%)

Only one *Cryptosporidium* oocyst was recovered from Capilano and none from the other two sites (Table 13 &14). This sole oocyst for 2015 had visible stained nuclei and intact cytoplasm. As compared to previous years, 2015 had very few *Giardia* cysts and *Cryptosporidium* oocysts recovered from the three sites and it is uncertain currently what may have been the cause of it, though the lower snow precipitation in 2015 may have had an impact.

Table 13: Summary of morphological results for *Cryptosporidium* oocysts observed under fluorescence microscope.

Site	Total	DAPI -	DAPI +		D.I.C.		
		Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Nuclei stained sky blue	Empty oocysts	Oocysts with amorphous structure	Oocysts with internal structure
							Number of sporozoites
Capilano	1	0 (0.0%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	1 (100.0%)	0 (0.0%)
Coquitlam	0	-	-	-	-	-	-
SCFP-RCW	0	-	-	-	-	-	-

Table 14: Comparisons of number of nuclei in each *Giardia* cysts and *Cryptosporidium* Oocysts between different sites.

Number of Nuclei	*Giardia* Cysts			*Cryptosporidium* Oocysts		
	Capilano	Coquitlam	SCFP-RCW	Capilano	Coquitlam	SCFP-RCW
0*	1 (50.0%)	0 (0.0%)	1 (100.0%)	0 (0.0.0%)	-	-
1	0 (0.0%)	0 (0.0%)	-	0 (0.0%)	-	-
2	0 (0.0%)	0 (0.0%)	-	0 (0.0%)	-	-
3	1 (50.0%)	0 (0.0%)	-	1 (100.0%)	-	-
4	0 (0.0%)	0 (0.0%)	-	0 (0.0%)	-	-
Total # of (oo)cysts	2	0	1	1	0	0

* DAPI negative or only intense blue internal staining of cytoplasm.

Due to the variations of water chemistry and organic matters between geographical area and temporally within each sampling sites, a matrix spike that provides recovery rate estimation from each site was performed annually. The results of matrix spike recovery results are compiled in Table 15. As the results showed, matrix recovery rates fluctuate from year to year even within each site. This variation is not uncommon for the test and has been noted in EPA's Method 1623.

Table 15: Matrix water results from 2006 through 2015.

Year	Capilano		Coquitlam		SCFP-RCW	
	Cysts	Oocysts	Cysts	Oocysts	Cysts	Oocysts
2006	27.3%	7.1%	18.0%	10.0%	-	-
2007	37.4%	27.6%	54.0%	28.0%	-	-
2008	55.0%	25.0%	39.0%	28.0%	-	-
2009	40.0%	10.0%	37.0%	16.0%	-	-
2010	43.0%	28.0%	49.0%	26.0%	13.0%	17.0%
2011	44.0%	27.0%	47.0%	22.0%	0.0%	1.0%
2012	76.5%	38.4%	49.0%	35.0%	13.7%	7.0%
2013	59.4%	22.4%	64.4%	16.3%	14.9%	6.12%
2014	*-	*-	39.4%	55.0%	14.1%	18.0%
2015	40.4%	26.3%	60.6%	2.0%	26.5%	9.1%

*- no matrix sample collected

SUMMARY

These *semi-quantitative* data (reported oocyst and cyst levels) should be interpreted with caution as current standard laboratory methods for detecting and analysing parasites in water matrices are known to be imprecise, with recovery rates fluctuating widely depending on the water matrix.

In brief, we report that:

1. *Cryptosporidium* oocysts were detected sporadically from Capilano reservoir' raw water (9.1% of filters). *Cryptosporidium* oocysts were not detected in Coquitlam reservoir and SCFP-RCW.

2. *Giardia* cysts were detected in filters from Capilano and SCFP - RCW sampling sites. Cysts were present in 18.2% of raw water filtered from Capilano and 8.3% from SCFP - RCW. *Giardia* cysts were not detected from Coquitlam site.

3. The highest level of *Giardia* cysts detected during 2015 was from Capilano reservoir at 2.0 per 100 L. Concentrations of *Cryptosporidium* oocysts were low for all sample sites, with a maximum of only 1.0 per 100 L for Capilano

4. Compared to previous years, 2015 had very low rate of *Giardia* cysts and *Cryptosporidium* oocysts detected from Capilano and Coquitlam reservoir.

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