Assessment of the Valemount Drinking Water Supply: Source Water Characteristics

James Jacklin, March 2004[1]

Introduction

In British Columbia, drinking water quality is becoming a significant public issue. We all want to have confidence in the quality of the water we consume. Its protection is also important to local purveyors, who act as our water suppliers, and to provincial government ministries responsible for water management. Within the Omineca-Peace region of B.C., our most common potable source is ground water, although many communities do make use of rivers, streams or lakes. Our basic drinking water quality is determined by a number of factors including local geology, climate and hydrology. In addition to these, human land use activities such as urbanization, agriculture and forestry, and the pollution they may cause, are becoming increasingly important influences. Environmental managers have a responsibility to control land use development so as to minimise the effects of these activities on source water quality.

The province's Drinking Water Protection Act, enacted in October, 2002, places the responsibility for drinking water quality protection with the B.C. Ministry of Health and local water purveyors. However, through the B.C. Environmental Management Act, the British Columbia Ministry of Environment (MOE) is responsible for managing and regulating activities in watersheds that have a potential to affect water quality. Accordingly, the Ministry plans to take an active role in protecting drinking water quality at its source.

Plate 1. An upstream view of the Swift Creek sampling location, just above the Valemount pump house.

MOE implemented a raw water quality and stream sediment monitoring program at selected communities in the Omineca-Peace region in 2002. Community sites were selected using a risk assessment process that considered:

- whether the source supply was surface water or ground water,
- the level of water treatment,
- the population size served,
- the potential for upstream diffuse and point-source pollution,
- the availability of current, high-quality and representative data on each raw water source,
- whether past outbreaks of waterborne illness had been reported,
- the ability/willingness of local purveyors to assist with sampling.

Through this process and with available funding, a total of 18 community water supplies in the Omineca-Peace region were selected for monitoring during 2002/03.

This brief report will summarise water quality data collected from the Village of Valemount's raw potable water source, Swift Creek (Plate 1). The data are compared to current provincial drinking water quality guidelines meant to protect finished water if no treatment other than disinfection is present. This comparison should identify parameters with concentrations that represent a risk to human health. It is intended that this program will lead to the identification of human activities responsible for unacceptable source water quality, and that it will assist water managers to develop measures to improve raw water quality where needed.

[1]A template report was prepared for the author by Todd D. French of TDF Watershed Solutions, Research & Management and Bruce Carmichael, Ministry of Environment.

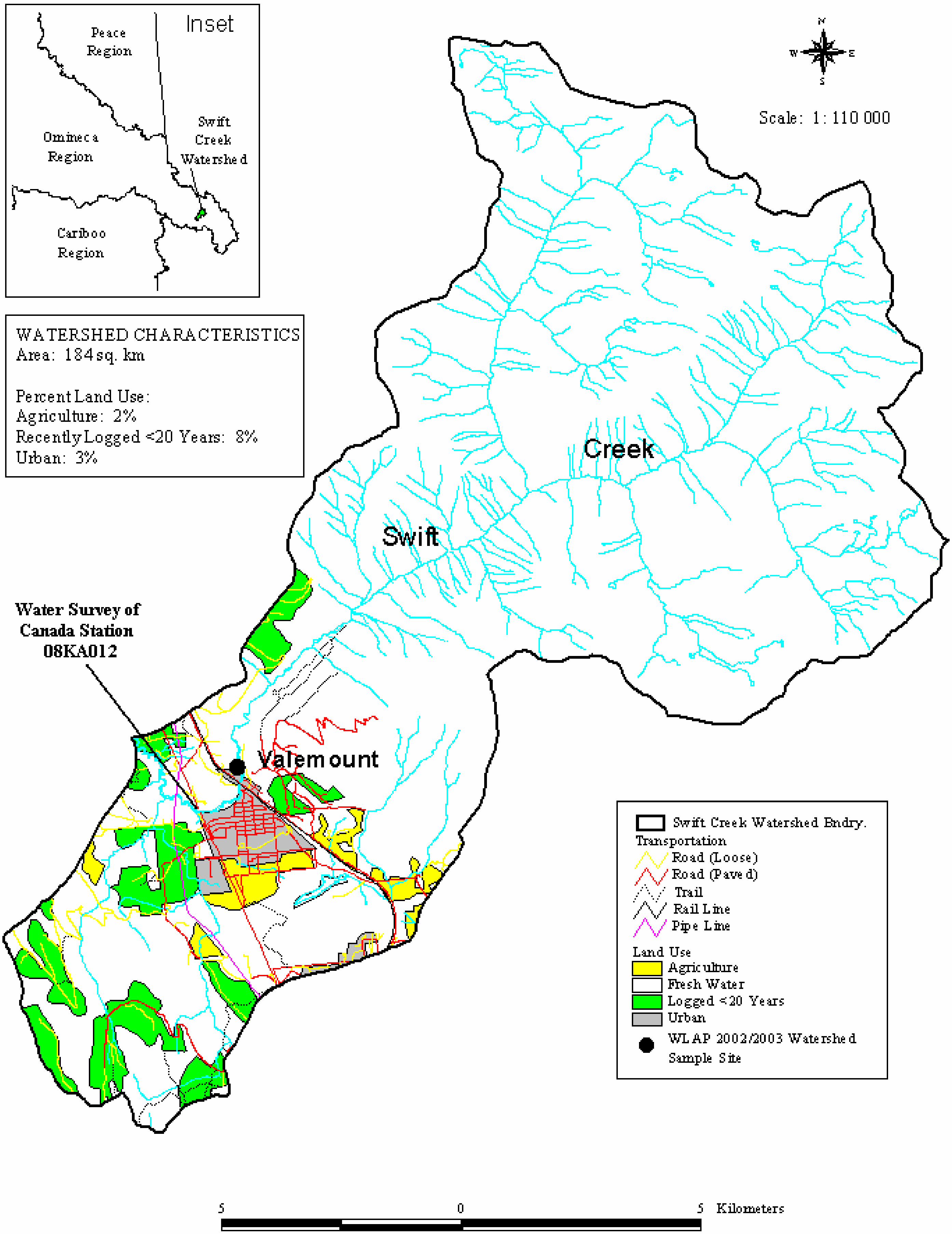

Figure 1. Swift Creek watershed and associated land-use practices around the Village of Valemount.

Site Description

Watershed Overview

The Swift Creek watershed lies within three biogeoclimatic zones including the Sub-Boreal Spruce, Engleman Spruce-Subalpine Fir, and Alpine Tundra. The Sub-Boreal Spruce zone has gently rolling terrain, dense coniferous forests, and extremes in the annual temperature range of -40°C - 30°C. The Engleman Spruce-Subalpine Fir zone has more hilly, mountainous terrain, cold and snowy conditions (a snowpack of 2-3 m) for 5-7 months of the year, and short cool summers. The Alpine Tundra zone is characterized by a rugged, treeless environment, amid tall cliffs and snow capped peaks. Much of the landscape is dominated by snow, ice and rock, with shallow bedrock weathered soils covering much of the ground. This zone normally experiences abundant precipitation, and temperatures are usually cold for most of the year (the mean annual temperature range is 0°C to 4°C) (B.C. Ministry of Forests, 1998).

The Swift Creek watershed is located within the Rocky Mountain Trench and drains the westward slope of the Selwyn Range (Makowecki and Yaremko 1997). The moderate to high gradient generates a high stream velocity that is dominated by a cobble-boulder substrate. There are frequent low magnitude, mass movement events along the banks of Swift Creek, indicated by the abundance of materials deposited by soil creep, minor slumps and earth flows (Makowecki and Yaremko, 1997).

At the Water Survey of Canada (WSC) station 08KA012 (Figure 1), Swift Creek drains approximately 184 km^2 and has a total length of 26 km. The river flows to the southwest, with the mainstem originating to the north of the Village of Valemount. Downstream of the WSC sampling station, Swift Creek flows into the McLennan River, which then flows into the Fraser River. Named tributaries to Swift Creek include Barrett Creek and Cranberry Creek.

The predominant land-use in the watershed is forestry, with agriculture also having potential effects on regional water quality. With a relatively low proportion of the land in the watershed being cleared for forestry and agriculture (Figure 1), it is believed that the timing of flow (Figure 2) has not been largely affected, as is evident by the hydrograph that shows similar trends to most interior British Columbia streams. Current land use activities are mostly located downstream of Valemount's water intake system, therefore major impacts on water quality/quantity were not expected.

At present, no major waste disposal permits in the Swift Creek watershed have been issued; however, two water withdrawal projects have been proposed on Swift Creek above Valemount's water withdrawal site (Water Licensing System, 2003). These applications total approximately 6.99 m^3/s and will be used for power generation. The amount of water withdrawn by the village totals 0.019 m^3/s. In comparison, the annual mean discharge measured downstream of the village intake is 3.25 m^3/s (this value ranges as low as 0.39 m^3/s in the winter to 13.5 m^3/s during freshet).

Basic Hydrology

Flows in Swift Creek are lowest during the winter months (December through March) and highest during spring melt and mid-summer (generally May-July) (Figure 2). To ensure that sufficient water is available to support the Village of Valemount and associated water users during low-flow periods, storage capacity has been increased by the installation of a cross-channel weir (Plate 2; Murray Capstick, Village of Valemount, pers. comm.). The 1988 to 1998 hydrograph suggests that much of the water that enters the channel during the spring does so via overland flow, which causes direct channel response (Capstick, p.c.). Given the low winter flows and the liklihood that overland flow inputs to the channel are more significant than groundwater inputs, water quality in Swift Creek is particularly sensitive to landscape-level activities. Thus, in terms of hydrologic processes, particular care should be taken when managing land-use activities and water withdrawal rates in the Swift Creek watershed and riparian habitats.

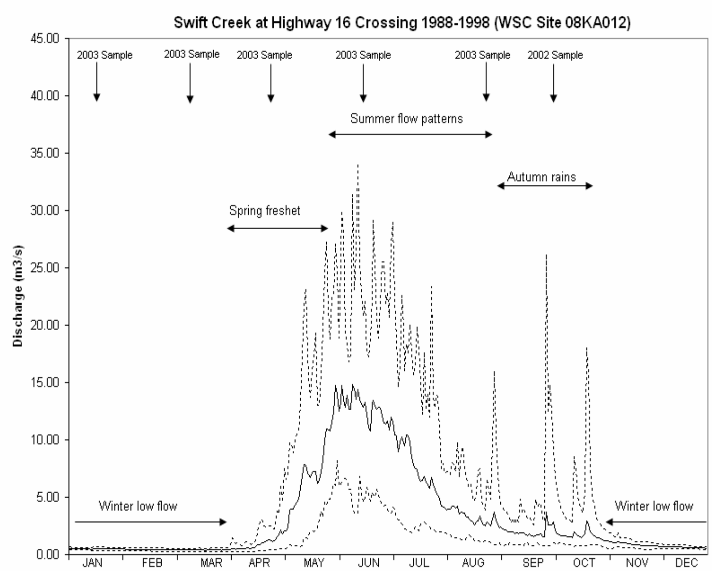

Figure 2. Lowest (bottom line), average (middle line) and maximum (upper line) daily flows observed in Swift Creek over the period 1988-1998.

Drinking Water Supply & Treatment

The Village of Valemount draws its domestic water supply from Swift Creek, upstream of the water discharge station located on the Highway 16 bridge. As measured with a GPS, the geographic co-ordinates of the pump house are 52°50’00”N/119°15’00”W. At the pump house, the water is treated by chlorination and is subsequently transported to approximately 1,500 Valemount water users (Capstick, p.c.).

Plate 2. A cross-section view of the weir in Swift Creek. This weir has helped to increase water storage capacity in Swift Creek.

The village has no current concerns with the existing water system, regarding both source and treatment (Capstick, p.c.). Daily turbidity readings will be taken at the pump house commencing April 1st, 2003. Due to the high frequency of low magnitude mass movements within the Swift Creek watershed (Makowecki and Yaremko, 1997), these daily turbidity readings will detect increasing sediment levels within Swift Creek.

Materials & Methods

Review of Previous Data

All historic data relevant to the Village of Valemount raw water supply assessment have been included in this report. The data were copied from MOE computer and paper files: Swift Creek at Valemount Village water intake (EMS ID 206975).

Sample Collection & Analyses for the 2002/03 Water Monitoring Program

Water Quality

An experienced consultant and/or MOE staff member collected water samples in laboratory certified polyethylene bottles for a variety of chemical and bacterial analyses. Representative grab samples were collected directly from Swift Creek adjacent to the water pump house (site E249366 - Water Source ID Tag 1330). The chemical results, analytical detection levels and drinking water quality guidelines are provided in Table 1, Appendix A.

Bottles used for general ion analyses were rinsed three times with source water prior to sample collection. Metal and bacterial bottles were not rinsed and metal samples were lab preserved. Water samples were shipped by overnight courier in coolers with ice packs to CanTest Ltd. (from September 2002-March 2003) and JR Laboratories Inc. (April 2003 to September 2003) for bacteria and PSC Environmental Services Ltd. for chemistry. Bacterial samples were analysed using membrane filtration. Metals analysis made use of ICPMS technology. Dissolved metal samples were lab filtered within 24 hours after collection through a 0.45 µm membrane filter. Samples for the analysis of cysts and oocysts of the *Giardia* and *Cryptosporidium* parasites were collected using the high volume filtering method described in EPA (1995) (Plate 3 and Figure 3). The filtration equipment could not be used during freezing conditions. Filters were shipped by overnight courier in a cooler with ice packs to the B.C. Centre for Disease Control’s Enhanced Water Laboratory for analysis.

Plate 3. The parasite filtration kit on the bank of Swift Creek beside the water pump house.

Bottom Sediment Quality

Bottom sediments were collected from Swift Creek during the October, 2002 low flow. Stream sediment was analyzed to determine the possible presence of upstream sources of contaminants that were not detected in the water samples. Where follow up is deemed to be necessary, additional monitoring will depend on the type and level of contamination. Samples were collected from several submerged silt/clay areas in the stream using two acetone washed stainless steel spoons for organic analysis, and plastic spoons for metal/grain size analysis. At least one 3-5 cm deep sediment sample was gently scooped from each of a number of these depositional areas with the large spoon. Each of these scoops was sub-divided from the larger spoon into jars for grain size, total organic carbon, hydrocarbons and pesticides, using a second, smaller spoon. Sampling proceeded in an upstream direction with each depositional zone contributing a small amount of fine sediment to each container. Sediment samples were kept cool and shipped to PSC Environmental Laboratories Ltd. for analysis within three days of collection. Samples for metals analysis were dried with heat, disaggregated, sieved at 2 mm and leached with a strong acid. Samples for organic analysis were processed wet and without screening. Results are expressed in dry weight. The sample date and sample parameter concentrations are provided in Table 2, Appendix A.

For further details on the analytical methods abbreviated above, refer to Greenberg *et al*. (1992), EPA (1995), PSC (2002) and British Columbia Field Sampling Manual (2003).

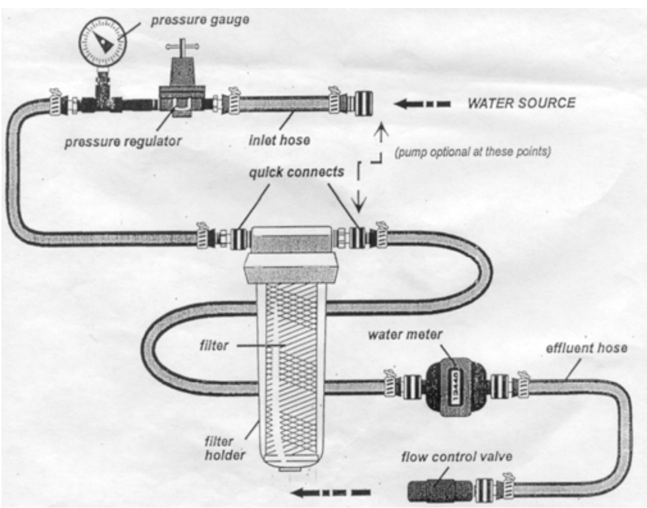

Figure 3. Schematic of the high-volume filtration unit used to sample raw water for Cryptosporidium oocysts and Giardia cysts (from EPA 1995)

Quality Assessment (QA)

To ensure accuracy and precision of data, quality assurance and control (QA/QC) procedures were incorporated into the monitoring program. This included use of rigorous sampling protocols, proper training of field staff, setting of data quality objectives and the submission of QA samples to the lab. Field QA included duplicate and blind blank samples. Blank samples detect contamination introduced in the field and/or in the lab. A comparison of duplicate results measures the effect of combined field error, laboratory error and real between-sample variability. The blind blank and duplicate program accounted for roughly 20% of the overall chemistry and bacterial sample numbers.

Duplicate sediment samples were collected by distributing sediment from each scoop into both sample jars. Differences between duplicate results indicate collection and/or analytical inconsistency and/or natural variability in physical and chemical properties.

Results

Review of Previous Data

Bacteriology

The Ministry sampled the Village of Valemount's raw water supply at the water intake on Swift Creek four times between 1987 and 1988 for fecal coliforms. The results of this raw water bacterial program are presented in Table 3, Appendix A.

All four samples collected from Swift Creek during this time period showed no trace of fecal coliform contamination. However, this data set only represents a small time period and should not be used to draw long term conclusions on bacterial counts.

Water Chemistry

The historical chemistry data collected by the Ministry during the 1987/1988 sampling program showed no parameters that were over provincial drinking water guidelines (19 parameters were tested for). Most existed at below detectable concentrations. Given the small sample size of the data set, it is not possible to make strong conclusions regarding the chemical's presence in the system; however the data do suggest that the parameter concentrations were generally very low when tested. For a complete list of the parameters tested and their results, refer to Table 4 in Appendix A.

Water Monitoring Program (2002/03)

Quality Assessment (QA)

The field blank and duplicate results indicate that no field or lab contamination of samples with bacteria occurred and that acceptable precision in bacterial sampling and analysis was observed. The parasite analysis provided duplicate precision results for *Giardia* of between 7 and 26%. No duplicate *Cryptosporidium* oocyst analysis produced detectable results.

The five water chemistry field blank samples that were prepared either the same day or within one day of the Swift Creek collections tested positive for some parameters. The concentration of most of these parameters was either very close to or less than 5-fold the minimum detectable concentration, an acceptable threshold as per the lab acceptance criteria. Eight parameters exceeded these acceptance criteria significantly and are listed below in Table 5.

All of the blank concentrations that exceeded five times the MDL were still well below their respective provincial raw drinking water guideline, usually by greater than two orders of magnitude. The contamination that did occur may have resulted during the deionization process in the lab or during the transfer of the deionized water between bottles in the field. Regardless, these levels of blank contamination should not limit the comparison of data to water quality guidelines.

Table 5. Blind blank samples that tested strongly positive ($\geq$ 5-fold MDL) for chemical contamination.

Date	Parameter	Measured Concentration	MDL
Sept. 25/02	Total Dissolved Phosphorus	0.031 mg/L	0.002 mg/L
Sept. 25/02	Total Phosphorus	0.038 mg/L	0.002 mg/L
Sept. 25/02	Strontium-Dissolved	0.047 µg/L	0.005 µg/L
Sept. 25/02	Tin-Dissolved	0.23 µg/L	0.1 µg/L
Jan. 21/03	Zinc-Total	1.5 µg/L	0.1 µg/L
Mar. 17/03	Copper-Total	0.33 µg/L	0.05µg/L
Mar. 17/03	Zinc-Total	0.7 µg/L	0.1 µg/L
May 6/03	Copper-Total	0.36 µg/L	0.05 µg/L

The four water chemistry duplicate samples that were prepared either the same day or within one day of the Swift Creek collections did have some values outside the lab acceptance criteria of 25% relative percent difference (Table 6, Appendix A). The differences that are present may be due to problems with collection and/or analytical precision. Of particular concern is the imprecision of copper, which is well above its respective detection level. All of the parameters that did have differences greater than 25% between the duplicates were well below recommended drinking water guidelines.

The duplicate sediment samples indicated that the variations between duplicates were most likely the result of natural in-stream variations rather than collection and/or analytical inconsistencies (Table 7, Appendix A). The lab acceptance criteria for duplicate variation is 35% for metals and other inorganics. All duplicate values, as indicated in Table 7, are within this range.

Bacteriology

The 2002/03 bacterial data are summarised in Table 8. Drinking water quality guidelines for *E. coli*, *Enterococci* and fecal coliforms are $\leq$10 CFU/100 mL (90th perc.), $\leq$3 CFU/100 mL (90th perc.), and $\leq$10 CFU/100 mL (90th perc.) respectively, in raw water supplies that undergo disinfection only.

The analysis of the September 26th, 2002 and the June 10th, 2003 samples produced single hits for *Enterococci* and total coliforms respectively. The August 12th, 2003 sample produced positive results for all of the tested parameters. The September 26th, 2002 and August 12th, 2003 *Enterococci* samples were the only samples above a current drinking water guideline. The remainder of the positive results are below the guidelines, however do have potential to cause human-related illness should treatment become ineffective.

Care must be taken when comparing these data to B.C. water quality guidelines, as the recommended guidelines for raw water using disinfection as treatment require five samples to be collected in a 30 day period. The 90th percentile of these samples would then need to exceed the stated guideline. This study did not sample five times in a 30 day period, but rather six times throughout the entire year. While these data do not technically exceed the B.C. water quality guidelines, the two very significant *Enterococci* values suggest that further monitoring should be considered.

Table 8. Results of bacterial analyses for the Village of Valemount's raw water supply (samples directly from Swift Creek). Units are CFU/100mL.

Date	Total Coliform	*E. coli*	*Enterococci*	Fecal Coliform
Provincial Guideline	No Provincial Guideline	≤10 CFU/100 mL (90th perc.)	*≤3 CFU/100 mL* (90th perc.)	≤10 CFU/100 mL (90th perc.)
Sep. 26/02	<1	<1	**14**	<1
Jan. 22/03	<1; 1	-	<1; <1	<1; <1
Mar. 17/03	<1; <1	<1; <1	<8; <8	<1; <1
May 7/03	<2	<2	<2	<2
June 10/03	18	**1**	<1	**1**
Aug. 12/03	160	**2**	**83**	**5**

Parasitology

The 2002/03 parasite data are summarised in Table 9. No *Cryptosporidium* oocysts were detected in any of the five samples collected during the 2002/03 program. By comparison, *Giardia* cysts were detected on two occasions, June 10th and August 12th, when 6.9 and 10.2 cysts/100L were detected respectively. While these densities were low relative to several other sites in the program, the data indicate that there is potential for human illness resulting from *Giardia* infection during summer months should treatment become ineffective. Care should be taken when interpreting these results, as only five samples have been collected.

The B.C. Ministry of Health, as well as the U.S. Environmental Protection Agency (EPA), recommend a minimal removal or deactivation of 3 log (99.9%) for *Giardia* cysts through filtration and/or disinfection between raw and tap water. The EPA further suggests that it is important to consider multiple barriers of protection: watershed management, filtration, disinfection, and the protection of the integrity of the distribution system. The Valemount water treatment system currently uses disinfection as the method of treatment.

Table 9. Parasite densities observed in the Village of Valemount's raw water supply over the period October 16th, 2002 to August 12th, 2003 (samples collected directly from Swift Creek).

Date	Detection Limit (number/100L)	*Cryptosporidium* (oocysts/100L)	*Giardia* (cysts/100L)
Oct. 16/2002	<1.9	NPD	NPD
Mar. 17/2003	<2.6	NPD	NPD
May 7/2003	<1.5	NPD	NPD
Jun. 10/2003	<3.4	NPD	**6.9**
Aug. 12/03	<3.4	NPD	**10.2**

NPD - No Parasites Detected

Water Chemistry

In 2002/03, Swift Creek was sampled on six different dates. The water samples were analysed for 15 general parameters as well as for the ICPMS low level metals package that includes 27 metals in both the total and dissolved form.

Of the chemical parameters tested through the duration of this study, none exceeded the provincial guidelines for raw drinking water. Additionally, all values were less than 75 % of their respective guidelines. These data, as well as the historical data, indicate that chemical parameter concentrations in Swift Creek are generally low for drinking water use.

A complete list of the results as well as their corresponding guideline is attached in Table 1, Appendix A. The 2002/03 raw water data set is attached in Table 10, Appendix A.

Bottom Sediment Chemistry

Of the 29 sediment metals analyzed, 22 were detected (Table 2, Appendix A). However, water samples collected throughout the duration of this project showed very low concentrations relative to existing drinking water guidelines.

No compounds in the following classes (which are or could be man made) were detected in Swift Creek sediments:

- Total oil & grease
- Chlorinated phenols
- Phenoxy acid herbicides
- Organochlorine pesticides
- Polychlorinated biphenyls
- Organophosphorus pesticides
- Polycyclic aromatic hydrocarbons

Conclusions & Recommendations

Review of the Swift Creek data indicates an overall good raw drinking water quality. Water soluble contaminants were present at concentrations well below drinking water guidelines. Some bacterial and *Giardia* densities are high enough to cause human illness at certain times of the year should water treatment become ineffective. The presence of bacteria and parasites suggest that warm-blooded animals or runoff from animal waste may be accessing Swift Creek or tributaries upstream of the water supply intake. The presence of these organisms is likely due to wildlife as little upstream agricultural activity exists. Continued sampling may help to identify when these parameters are of greatest concern, and when the village water system should be most carefully managed. Particular care should be taken during late summer, when stream flows are low and bacterial concentrations likely have minimal dilution. This apparently critical time of year may be appropriate for high frequency bacterial sampling.

Data from the recently installed turbidity monitor should be assessed daily, as they will help identify increased levels of suspended sediment, which may be problematic to water quality. It may also be useful to determine a correlation between the new turbidity results and precipitation data provided by Environment Canada. A strong correlation may help identify when turbidity problems will occur.

Acknowledgements

We thank Mr. Murray Capstick (Village of Valemount) for his useful insight and his direction around the Valemount water supply. Mr. Todd French is recognized for his help in designing and implementing the project (TDF Watershed Solutions, Research & Management). Mr. Mohamad Khan (Enhanced Water Laboratory, B.C. Centre for Disease Control, Vancouver) provided us with the *Cryptosporidium* and *Giardia* sampling equipment, documentation on parasite collection methodologies and information critical to data interpretation. We are grateful to Water Survey of Canada for making their hydrometric data on Swift Creek available to us.

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Contact Information

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Appendix A

Table 1. 2002/03 sample parameters, summaries of current results and associated B.C. drinking water guidelines.

Parameter	# of Values	Min.	Max.	Mean	Std. Dev.	MDL	D.W. Guideline	Guideline Type
General								
pH	6	7.4	8	7.8	0.23	0.1	6.5-8.5	aesthetic objective
Colour (TCU)	6	5	5	5	0.0	5	≤ 15	aesthetic objective
Specific Conductance (µS/cm)	6	52	178	127	47.1	1	≤ 700	maximum acceptable concentration
Turbidity (NTU)	5	0.13	2.43	0.63	1.007	0.1	≤ 5	maximum acceptable concentration
Hardness Total (mg/L)	6	25.5	92.25	64.57	25.314			
Hardness Total -Diss. (mg/L)	6	24.2	94.45	65.23	26.130		≤ 500 $CaCO_3$	aesthetic objective
Alkalinity (mg/L)	6	23.1	74	53.4	20.28	0.5		
Residue Non-Filterable (mg/L)	6	4	17	6	5.3	4		
Total Organic Carbon (mg/L)								
TOC	5	0.6	1.9	1.1	0.49	0.5	≤ 4	maximum, to control THM production
Anions (mg/L)								
Chloride Dissolved	6	0.5	0.55	0.51	0.020	0.5	≤ 250	aesthetic objective
Fluoride Dissolved	6	0.01	0.025	0.014	0.007	0.01	≤ 1.5	maximum acceptable concentration
Bromide Dissolved	6	0.1	0.1	0.1	0.00	0.1		
Nutrients (mg/L)								
Nitrate+Nitrite	6	0.051	0.332	0.167	0.124	0.002	≤ 45 (Nitrate)	maximum acceptable concentration
Phosphorus Total	6	0.002	0.008	0.004	0.002	0.002		
Phosphorus Total-Diss.	6	0.002	0.006	0.004	0.002	0.002		
Sulphate (mg/L)								
Sulphate	6	3.6	16.9	11.47	4.838	0.5	≤ 500	aesthetic objective
Metals Total (ug/L)								
Aluminum-T	6	1.6	73.1	15.3	28.39	0.3		
Aluminum-D	6	0.6	12.6	3.7	4.46	0.3	≤ 200	maximum acceptable concentration
Antimony-T	6	0.005	0.009	0.007	0.002	0.005	≤ 6	interim maximum acceptable concentration
Antimony-D	6	0.005	0.011	0.006	0.002	0.005		
Arsenic-T	6	0.1	0.3	0.2	0.09	0.1	≤ 25	interim maximum acceptable concentration
Arsenic-D	6	0.1	0.2	0.1	0.06	0.1		
Barium-T	6	1.57	2.71	2.15	0.448	0.02	≤ 1000	maximum acceptable concentration
Barium-D	6	1.04	2.66	2.03	0.600	0.02		
Beryllium-T	6	0.02	0.02	0.02	0.000	0.02		
Beryllium-D	6	0.02	0.02	0.02	0.000	0.02		
Bismuth-T	6	0.02	0.03	0.02	0.004	0.02		
Bismuth-D	6	0.02	0.02	0.02	0.000	0.02		
Cadmium-T	6	0.01	0.01	0.01	0.000	0.01	≤ 5	maximum acceptable concentration
Cadmium-D	6	0.01	0.01	0.01	0.000	0.01		
Calcium-T (mg/L)	6	5.72	21.7	15.08	6.254	0.05		
Calcium-D (mg/L)	6	5.38	22.7	15.23	6.488	0.05		
Chromium-T	6	0.2	0.3	0.2	0.04	0.2	≤ 50	maximum acceptable concentration
Chromium-D	6	0.2	0.5	0.2	0.12	0.2		
Cobalt-T	6	0.005	0.208	0.044	0.081	0.005		
Cobalt-D	6	0.005	0.009	0.006	0.002	0.005		
Copper-T	6	0.055	0.68	0.27	0.219	0.05	≤ 1000	aesthetic objective
Copper-D	6	0.05	0.33	0.20	0.109	0.05		
Iron-T (mg/L)	5	0.005	0.486	0.107	0.212	0.005	≤ 0.3	aesthetic objective
Iron-D (mg/L)	5	0.005	0.013	0.007	0.003	0.005		
Lead-T	6	0.01	0.45	0.09	0.176	0.01	≤ 10	maximum acceptable concentration
Lead-D	6	0.01	0.05	0.02	0.016	0.01		
Lithium-T	6	0.19	2.22	1.52	0.823	0.05		
Lithium-D	6	0.05	2.195	1.33	0.829	0.05		
Magnesium-T (mg/L)	6	2.73	9.24	6.53	2.366	0.05		
Magnesium-D (mg/L)	6	2.62	9.18	6.61	2.429	0.05	≤ 100	aesthetic objective

Table 1 Continued.

Parameter	# of Values	Min.	Max.	Mean	Std. Dev.	MDL	D.W. Guideline	Guideline Type
Manganese-T	6	0.25	16.2	3.57	6.226	0.008	≤ 50	aesthetic objective
Manganese-D	6	0.066	0.599	0.341	0.190	0.008		
Molybdenum-T	6	0.05	0.09	0.06	0.017	0.05	≤ 250	maximum acceptable concentration
Molybdenum-D	6	0.05	0.085	0.056	0.014	0.05		
Nickel-T	6	0.05	0.54	0.13	0.200	0.05		
Nickel-D	6	0.05	0.3	0.09	0.102	0.05		
Selenium-T	6	0.2	0.5	0.28	0.117	0.2	≤ 10	maximum acceptable concentration
Selenium-D	6	0.2	0.25	0.22	0.026	0.2		
Silver-T	6	0.02	0.02	0.02	0.000	0.02		
Silver-D	6	0.02	0.02	0.02	0.000	0.02		
Sodium-T (mg/L)	5	0.24	1.15	0.77	0.399	0.05	≤ 200	aesthetic objective
Strontium-T	6	35.4	126	90.6	32.89	0.005		
Strontium-D	6	34.9	125	90.13	34.283	0.005		
Thallium-T	6	0.002	0.003	0.002	0.000	0.002	≤ 2	maximum acceptable concentration
Thallium-D	6	0.002	0.002	0.002	0.000	0.002		
Tin-T	6	0.01	0.055	0.02	0.018	0.01		
Tin-D	6	0.01	0.015	0.012	0.003	0.01		
Uranium-T	6	0.322	1.815	0.967	0.631	0.002	≤ 100	maximum acceptable concentration
Uranium-D	6	0.155	1.8	0.9	0.63	0.002		
Vanadium-T	6	0.06	0.54	0.16	0.189	0.06	≤ 100	maximum acceptable concentration
Vanadium-D	6	0.06	0.35	0.17	0.117	0.06		
Zinc-T	6	0.1	0.9	0.4	0.333	0.1	≤ 5000	aesthetic objective
Zinc-D	6	0.1	0.45	0.225	0.133	0.1		

Table 2. Sediment sampling results from October 16^{th}, 2002.

Parameter	Unit	Value	Parameter	Unit	Value	Parameter	Unit	Value
% Moisture	(% W/W)	25.4	Pentachlorophenol	(µg/g)	<0.005	Dimethoate	(µg/g)	<0.02
Gravel (2.0 mm)	(% W/W)	9.7	Bromoxynil	(µg/g)	<0.01	Ethion	(µg/g)	<0.05
Solid Content	(%)	75	2,4-D	(µg/g)	<0.01	Fenitrothion	(µg/g)	<0.02
Coarse Sand (0.59 mm)	(% W/W)	15.1	Dicamba	(µg/g)	<0.005	Fensulfothion	(µg/g)	<0.01
Medium Sand (0.297 mm)	(% W/W)	19.6	Dichlorprop	(µg/g)	<0.01	Fenthion	(µg/g)	<0.02
Fine Sand (0.149 mm)	(% W/W)	28.1	Dinoseb	(µg/g)	<0.1	Fonofos	(µg/g)	<0.02
Very Fine Sand (0.053 mm)	(% W/W)	21.5	MCPA	(µg/g)	<0.01	Iodofenphos	(µg/g)	<0.01
Silt (0.037 mm)	(% W/W)	2.7	Picloram	(µg/g)	<0.01	Malathion	(µg/g)	<0.01
Clay (<0.037 mm)	(% W/W)	3.3	2,4,5-T	(µg/g)	<0.005	Mevinphos-cis	(µg/g)	<0.05
Carbon - Tot. Inorg.	(µg/L)	<500	2,4,5-TP	(µg/g)	<0.005	Methamidophos	(µg/g)	<0.05
Carbon - Tot. Org.	(µg/L)	3700	Triclopyr	(µg/g)	<0.005	Naled	(µg/g)	<0.01
Carbon - Tot.	(µg/g)	3700	Aldrin	(µg/g)	<0.002	Omethoate	(µg/g)	<0.02
Phosphorus - Tot.	(µg/g)	582	BHC, Alpha-	(µg/g)	<0.002	Parathion	(µg/g)	<0.01
Aluminum - Tot.	(µg/g)	5550	BHC, Beta-	(µg/g)	<0.002	Parathion Methyl	(µg/g)	<0.02
Antimony - Tot.	(µg/g)	<0.1	BHC, Delta-	(µg/g)	<0.002	Phorate	(µg/g)	<0.02
Arsenic - Tot.	(µg/g)	12.3	Chlordane, Alpha-	(µg/g)	<0.01	Phosalone	(µg/g)	<0.05
Barium - Tot.	(µg/g)	12.5	Chlordane, Gamma-	(µg/g)	<0.01	Phosmet	(µg/g)	<0.03
Beryllium - Tot.	(µg/g)	<0.1	DDD,p,p'-	(µg/g)	<0.01	Phosphamidon	(µg/g)	<0.05
Bismuth - Tot.	(µg/g)	0.2	DDE-p,p'	(µg/g)	<0.005	Sulfotep	(µg/g)	<0.02
Cadmium - Tot.	(µg/g)	0.05	DDT-o,p'-	(µg/g)	<0.01	Tetrachlorvinphos	(µg/g)	<0.02
Calcium - Tot.	(µg/g)	1830	DDT-p,p'-	(µg/g)	<0.02	Oil & Grease - Tot.	(µg/g)	<100
Chromium - Tot.	(µg/g)	9.2	Dieldrin	(µg/g)	<0.01	Acenaphthene	(µg/g)	<0.01
Cobalt - Tot.	(µg/g)	7.5	Endosulfan I	(µg/g)	<0.01	Acenaphthylene	(µg/g)	<0.01
Copper - Tot.	(µg/g)	22.1	Endosulfan II	(µg/g)	<0.01	Anthracene	(µg/g)	<0.01
Iron - Tot.	(µg/g)	17600	Endosulfan Sulphate	(µg/g)	<0.02	Benzo(a)anthracene	(µg/g)	<0.01
Lead - Tot.	(µg/g)	8.7	Endrin	(µg/g)	<0.02	Benzo(b)fluoranthene	(µg/g)	<0.01
Magnesium - Tot.	(µg/g)	3740	Hepatachlor	(µg/g)	<0.002	Benzo(k)fluoranthene	(µg/g)	<0.01
Manganese - Tot.	(µg/g)	242	Hepatachlor epoxide	(µg/g)	<0.004	Benzo(g,hi)perylene	(µg/g)	<0.02
Molybdenum - Tot.	(µg/g)	0.1	Lindane, BHC, Gamma-	(µg/g)	<0.002	Benzo(a)pyrene	(µg/g)	<0.01
Nickel - Tot.	(µg/g)	18.5	Methidathion	(µg/g)	<0.02	Chrysene	(µg/g)	<0.01
Potassium - Tot.	(µg/g)	297	Methoxychlor	(µg/g)	<0.02	Dibenz(a,h)anthracene	(µg/g)	<0.02
Selenium - Tot.	(µg/g)	<0.5	Mirex	(µg/g)	<0.02	Fluoranthene	(µg/g)	<0.01
Silver - Tot.	(µg/g)	<0.05	Nonchlor, Trans-	(µg/g)	<0.01	Fluorene	(µg/g)	<0.01
Sodium - Tot.	(µg/g)	<100	Oxychlordane	(µg/g)	<0.01	Indeno(1,2,3-c,d)pyrene	(µg/g)	<0.02
Strontium - Tot.	(µg/g)	13.4	PCBs- Tot.	(µg/g)	<0.05	Naphthalene	(µg/g)	<0.01
Tellurium - Tot.	(µg/g)	<0.1	Acephate	(µg/g)	<0.05	C1-Naphthalenes	(µg/g)	<0.01
Thallium - Tot.	(µg/g)	0.07	Azinphos Methyl	(µg/g)	<0.05	C2-Naphthalenes	(µg/g)	<0.02
Tin - Tot.	(µg/g)	0.2	Bromophos	(µg/g)	<0.01	Phenanthrene	(µg/g)	<0.01
Titanium - Tot.	(µg/g)	152	Carbophenothion	(µg/g)	<0.01	C1-Phen/Anthracene	(µg/g)	<0.02
Vanadium - Tot.	(µg/g)	7	Chlorfenvinphos(e)	(µg/g)	<0.01	C2-Phen/Anthracene	(µg/g)	<0.02
Zinc - Tot.	(µg/g)	37.3	Chlorpyrifos	(µg/g)	<0.01	Pyrene	(µg/g)	<0.01
Zirconium - Tot.	(µg/g)	<0.5	Demeton	(µg/g)	<0.02	Total PAHs	(µg/g)	<0.01
2,3,4,5 - Tetrachlorophenol	(µg/g)	<0.01	Diazinon	(µg/g)	<0.02	Total Low MW PAHs	(µg/g)	<0.01
2346+2356-TeClPhenol	(µg/g)	<0.01	Dichlorvos	(µg/g)	<0.01	Total High MW PAHs	(µg/g)	<0.01

Table 3. Historical bacteriological data for the Village of Valemount raw water supply.

Provincial Guidelines	*≤ 10CFU/100mL (90th perc.)
Date	Fecal Coliforms (CFU/100mL)
June 2/1987	<2
September 23/1987	<2.2
November 24/1987	<2
January 14/1988	<2

*Guideline for raw water receiving disinfection treatment only.

Table 4. Historical parameters tested that were of no concern (observed "totals" concentration always ≤ 75% guideline concentration; n based on number of historical samples collected by the Province).

Parameter	*n*	Concentration Range (mg/L)	Average Concentration (mg/L)	*Provincial Guidelines (mg/L)
Ammonia-D	4	<0.005	<0.005	
Calcium-T	2	17.6-19.9	18.8	
Cadmium-T	2	<0.01	<0.01	0.005
Cobalt-T	2	<0.01	<0.01	
Chromium-T	2	<0.01	<0.01	0.05
Copper-T	2	<0.01	<0.01	≤1
Iron-T	2	0.04-0.06	0.05	≤0.3
Magnesium-T	2	7.17-7.99	7.58	100
Manganese-T	2	<0.01	<0.01	≤50
Molybdenum-T	2	<0.01	<0.01	0.25
Nickel-T	2	<0.05	<0.05	
Nitrate+Nitrite-D	4	0.1-0.23	0.16	45
Ortho-P-D	4	<0.003	<0.003	
Lead-T	2	<0.01	<0.01	10
TSS	4	<1-2	1	
Sp. Cond. (µS/cm)	4	82-166	132	700
Vanadium-T	2	<0.01	<0.01	0.1
Zinc	2	<0.01-0.02	0.015	≤5
pH	4	7.5-8.0	7.8	6.5-8.5

Table 6. Duplicate samples that exceeded precision acceptability criteria (≤25% difference when >5-fold MDL). All concentrations in µg/L.

Parameter	MDL (µg/L)	September/02			January/03			March/03			August/03		
		Conc. 1	Conc. 2	RPD %	Conc. 1	Conc. 2	RPD %	Conc. 1	Conc. 2	RPD %	Conc. 1	Conc. 2	RPD %
Antimony-T	0.005	0.057	0.034	**50**									
Copper-T	0.05	4.85	8.97	**59.6**							15	6.7	**76.5**
Copper-D	0.05	6.19	3.49	**55.8**							8.53	2.75	**102**
Lithium-D	0.05				0.69	2.15	**103**						
Lead-T	0.01	0.38	0.69	**58**									
Lead-D	0.01										0.52	0.39	**29**
Manganese-T	0.008										1.86	1.42	**26.8**
Tin-T	0.01	0.04	0.09	**77**	0.01	0.1	**164**				0.1	0.06	**50**
Zinc-T	0.1				<0.1	1.7	**178**	0.1	0.7	**150**			
Zinc-D	0.1				<0.1	0.8	**155**						

RPD %=Relative Percent Difference
**Data are presented for the purpose of batch specific QA assessment. Most QA samples were not collected at Valemount.*

Table 7. Percent difference in measures taken from duplicate sediment samples.

Parameter	Unit of Measure	% Difference	Parameter	Unit of Measure	% Difference
PART I: PHYSICAL PROPERTIES			PART III. TOTAL METALS		
Moisture	% (W/W)	15%	Aluminum - Total	µg/g	21%
Percent Gravel	% (W/W)	68%	Arsenic - Total	µg/g	11%
Solid Content	%	7%	Barium - Total	µg/g	25%
Percent Coarse Sand	% (W/W)	41%	Calcium - Total	µg/g	2%
Percent Medium Sand	% (W/W)	8%	Chromium - Total	µg/g	34%
Percent Fine Sand	% (W/W)	15%	Cobalt - Total	µg/g	20%
Percent Very Fine Sand	% (W/W)	10%	Copper - Total	µg/g	29%
Percent Silt	% (W/W)	8%	Iron - Total	µg/g	20%
Percent Clay	% (W/W)	8%	Lead - Total	µg/g	20%
PART II. CARBON AND PHOSPHORUS			Magnesium - Total	µg/g	18%
Organic Carbon - Total	µg/g	20%	Manganese - Total	µg/g	20%
Carbon - Total	µg/g	20%	Molybdenum - Total	µg/g	0%
Phosphorus - Total	µg/g	12%	Nickel - Total	µg/g	23%
			Potassium - Total	µg/g	21%
			Strontium - Total	µg/g	1%
			Tin - Total	µg/g	25%
			Titanium - Total	µg/g	20%
			Vanadium - Total	µg/g	0%
			Zinc - Total	µg/g	17%

Table 10. 2002/03 raw water quality data collected from the Valemount drinking water supply.

Date	Cryptosporidium (oocysts/100L)	Giardia (cysts/100L)	Total Coliform (CFU/100mL)	Fecal Coliform (CFU/100mL)	Enterococci (CFU/100mL)
26-Sep-02			<1	<1	14
16-Oct-02	<1.9	<1.9			
22-Jan-03			<1	<1	<1
22-Jan-03			1	<1	<1
17-Mar-03	<2.6	<2.6	<1	<1	8
17-Mar-03			<1	<1	8
07-May-03			<2	<2	<2
10-Jun-03	<3.4	6.9	18	1	<1
12-Aug-03	<3.4	10.2	160	5	83
12-Aug-03					84

E. Coli (CFU/100mL)	pH (pH Units)	True Colour (Col. Unit)	Specific Conductance (µS/cm)	Residues - NonFilt. (mg/L)	Turbidity (NTU)
<1	7.6	5	105	<4	
	7.9	5	178	<4	0.13
	7.9	5	178	<4	0.15
<1	7.9	<5	172	<4	0.14
<1	7.9	5	172	<4	0.16
<2	7.9	5	141	4	0.13
1	7.4	5	52	17	2.43
2	8	<5	114	<4	0.32

Hardness - Total (mg/L)	Hardness - Dissolved (mg/L)	Alkalinity - T as $CaCO_3$ (mg/L)	Bromide - Diss. (mg/L)	Chloride - Diss. (mg/L)	Fluoride - Diss. (mg/L)
50.8	53.1	42	<0.1	0.5	0.01
91.9	88.6	74	<0.1	0.6	0.03
92.6	89.5	74	<0.1	<0.5	0.02
89.5	94.9	74	<0.1	<0.5	0.02
89	94	73	<0.1	<0.5	0.02
72.3	74.3	63.5	<0.1	<0.5	0.01
25.5	24.2	23.1	<0.1	<0.5	<0.01
57.3	56.3	44.6	<0.1	<0.5	0.01

Carbon - Tot. Org. (mg/L)	$NO_2 + NO_3$ (mg/L)	Phosphorus - Tot. Diss. (mg/L)	Phosphorus - Tot. (mg/L)	Sulfate (mg/L)	Aluminum - Tot. (µg/L)
1.1	0.058	<0.002	<0.002	12.7	5.5
	0.255	0.005	0.005	17.2	2.1
	0.25	0.007	0.006	16.7	1.3
0.9	0.248	0.005	<0.002	14.8	1.6
0.8	0.244	<0.002	<0.002	16.7	1.6
1.2	0.332	0.005	<0.002	9.5	3.1
1.9	0.051	0.006	0.008	3.6	73.1
0.6	0.062	0.003	0.003	10.3	6.8

Aluminum - Diss. (µg/L)	Antimony - Tot. (µg/L)	Antimony - Diss. (µg/L)	Arsenic - Tot. (µg/L)	Arsenic - Diss. (µg/L)	Barium - Tot. (µg/L)
3.4	<0.005	<0.005	0.2	<0.1	1.7
0.6	0.012	0.007	0.2	0.2	2.67
0.6	<0.005	<0.005	0.2	0.2	2.75
1.3	0.012	<0.005	<0.1	<0.1	2.58
1.4	<0.005	<0.005	0.1	0.1	2.48
2.1	<0.005	<0.005	0.3	0.2	2.21
12.6	0.008	0.011	0.3	0.2	1.57
2.1	<0.005	<0.005	<0.1	<0.1	2.19

Barium - Diss. (µg/L)	Beryllium - Tot. (µg/L)	Beryllium - Diss. (µg/L)	Bismuth - Tot. (µg/L)	Bismuth - Diss. (µg/L)	Cadmium - Tot. (µg/L)
1.8	<0.02	<0.02	<0.02	<0.02	<0.01
2.67	<0.02	<0.02	0.04	<0.02	<0.01
2.65	<0.02	<0.02	<0.02	<0.02	<0.01
2.59	<0.02	<0.02	<0.02	<0.02	<0.01
2.66	<0.02	<0.02	<0.02	<0.02	<0.01
2.12	<0.02	<0.02	<0.02	<0.02	<0.01
1.04	<0.02	<0.02	<0.02	<0.02	<0.01
1.94	<0.02	<0.02	<0.02	<0.02	<0.01

Cadmium - Diss. (µg/L)	Calcium - Tot. (mg/L)	Calcium - Diss. (mg/L)	Chromium - Tot. (µg/L)	Chromium - Diss. (µg/L)	Cobalt - Tot. (µg/L)
<0.01	11.3	11.7	<0.2	<0.2	<0.005
<0.01	21.6	20.8	<0.2	<0.2	0.015
<0.01	21.8	21	<0.2	<0.2	<0.005
<0.01	21.5	22.8	<0.2	<0.2	<0.005
<0.01	21.4	22.6	<0.2	<0.2	<0.005
0.01	17.3	17.9	<0.2	<0.2	<0.005
<0.01	5.72	5.38	<0.2	<0.2	0.208
<0.01	13	12.8	0.3	0.5	0.033

Cobalt - Diss. (µg/L)	Copper - Tot. (µg/L)	Copper - Diss. (µg/L)	Iron - Tot. (mg/L)	Iron - Diss. (mg/L)	Lead - Tot. (µg/L)
<0.005	0.16	0.23			0.01
0.008	0.06	<0.05	<0.005	<0.005	<0.01
0.007	0.05	<0.05	<0.005	<0.005	<0.01
<0.005	0.18	0.16	<0.005	<0.005	<0.01
<0.005	0.18	0.13	0.005	<0.005	<0.01
<0.005	0.33	0.31	0.02	0.006	0.03
0.005	0.68	0.33	0.486	0.013	0.45
0.009	0.22	0.14	0.019	<0.005	0.04

Lead - Diss. (µg/L)	Lithium - Tot. (µg/L)	Lithium - Diss. (µg/L)	Magnesium - Tot. (mg/L)	Magnesium - Diss. (mg/L)	Manganese - Tot. (µg/L)
<0.01	0.19	<0.05	5.48	5.81	1.74
<0.01	1.95	0.69	9.21	8.91	0.241
<0.01	2.14	2.15	9.27	9	0.259
<0.01	2.33	2.29	8.7	9.23	0.445
<0.01	2.11	2.1	8.63	9.13	0.381
0.02	2.03	2	7.07	7.18	0.888
0.05	0.81	0.64	2.73	2.62	16.2
<0.01	1.81	1.67	6.02	5.9	1.91

Manganese - Diss. (µg/L)	Molybdenum - Tot. (µg/L)	Molybdenum - Diss. (µg/L)	Nickel - Tot. (µg/L)	Nickel - Diss. (µg/L)	Selenium - Tot. (µg/L)
0.599	<0.05	<0.05	<0.05	<0.05	0.3
0.207	0.1	0.09	<0.05	<0.05	0.5
0.194	0.08	0.08	<0.05	<0.05	0.5
0.358	0.06	0.05	<0.05	<0.05	<0.2
0.356	0.07	0.05	<0.05	<0.05	<0.2
0.35	0.08	0.05	<0.05	<0.05	<0.2
0.475	<0.05	<0.05	0.54	0.3	0.3
0.066	<0.05	<0.05	<0.05	0.05	<0.2

Selenium - Diss. (µg/L)	Silver - Tot. (µg/L)	Silver - Diss. (µg/L)	Sodium - Tot. (mg/L)	Strontium - Tot. (µg/L)	Strontium - Diss. (µg/L)	Thallium - Tot. (µg/L)	Thallium - Diss. (µg/L)
<0.2	<0.02	<0.02		81.4	80.7	<0.002	<0.002
0.2	<0.02	<0.02	1.13	125	126	<0.002	<0.002
0.3	<0.02	<0.02	1.14	127	124	<0.002	<0.002
<0.2	<0.02	<0.02	1.16	122	125	<0.002	<0.002
0.3	<0.02	<0.02	1.14	118	125	<0.002	<0.002
<0.2	<0.02	<0.02	0.84	99.5	99.7	<0.002	<0.002
0.2	<0.02	<0.02	0.24	35.4	34.9	0.003	<0.002
<0.2	<0.02	<0.02	0.5	81.6	75.5	<0.002	<0.002

Tin - Tot. (µg/L)	Tin - Diss. (µg/L)	Uranium - Tot. (µg/L)	Uranium - Diss. (µg/L)	Vanadium - Tot. (µg/L)	Vanadium - Diss. (µg/L)	Zinc - Tot. (µg/L)	Zinc - Diss. (µg/L)
<0.01	<0.01	0.552	0.523	0.1	0.27	<0.1	<0.1
0.01	<0.01	1.82	1.81	<0.06	<0.06	<0.1	<0.1
0.1	0.02	1.81	1.79	<0.06	<0.06	1.7	0.8
<0.01	<0.01	1.68	1.31	0.52	0.35	0.7	0.3
0.01	0.02	1.63	1.57	0.56	0.35	0.1	<0.1
0.02	<0.01	0.946	0.913	0.08	0.11	<0.1	0.3
<0.01	<0.01	0.322	0.155	<0.06	0.07	0.6	0.2
<0.01	<0.01	0.51	0.453	0.1	0.15	<0.1	<0.1