Assessment of the Fraser Lake Community 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. The Village of Fraser Lake's water pump house with Fraser Lake in the background.

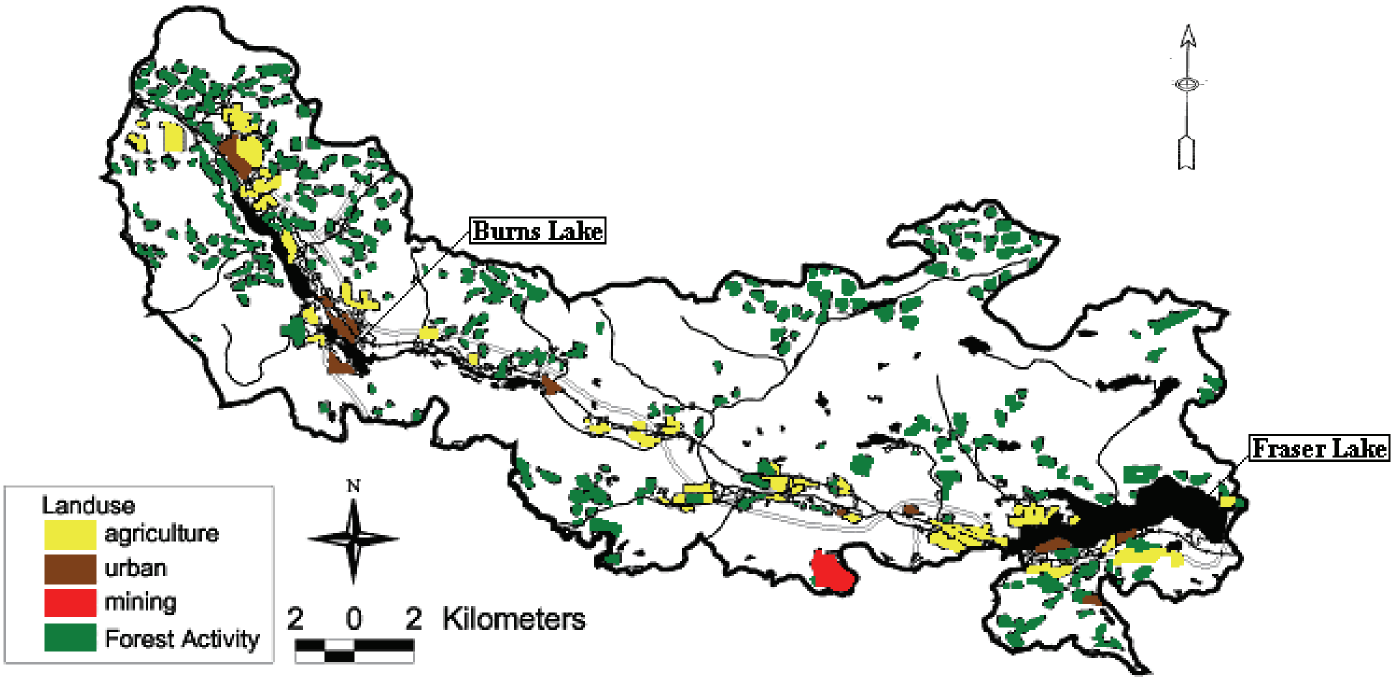
MOE implemented a raw water quality and stream sediment monitoring program at selected communities in the Omineca-Peace region in 2002. Community sites were selected using a risk assessment process that considered:

- 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 Fraser Lake's raw potable water source, Fraser Lake (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 any human activities responsible for unacceptable supply 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.



SUB-WATERSHED CHARACTERISTICS

Area: 2261 km^2

Percent Land Usage:

1.3% Residential (Urban)

4.0% Agricultural/Range

9.3% Forestry

0.4% Mining

Figure 1. Fraser Lake sub-watershed and associated land-use practices.

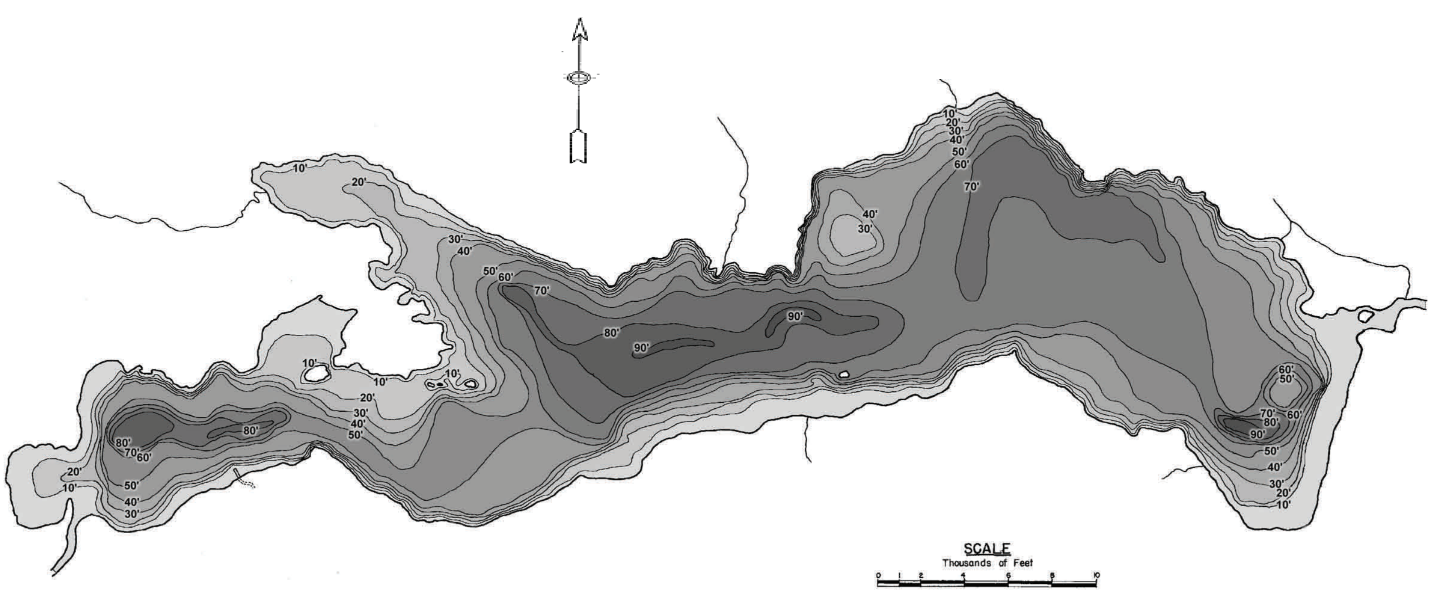


Figure 2. A bathymetric map of Fraser Lake showing the depth contours and lake shape.

Site Description

Watershed Overview

The Fraser Lake sub-watershed (Figure 1) lies within the Sub-Boreal Spruce biogeoclimatic zone with small sections in the Engleman Spruce-Subalpine Fir zone. The Sub-Boreal Spruce zone has gently rolling terrain, dense coniferous forests, and extremes in the annual temperature range of $^{-}$40°C to 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 (Ministry of Forests, 1998).

Fraser Lake is located 160 km west of Prince George on Highway 16. The lake is considered mesotrophic and has a surface area of 54.6 km^2, a volume of 7.25 x 10^8 m^3 and a mean depth of 13.4 m. A bathymetric map of Fraser Lake, which identifies the depth contours, is shown in Figure 2. The flushing rate of Fraser Lake, as calculated by Lyle Larson (Ministry of Water, Land and Air Protection), is 1.6 times/year. Water levels in the lake have been recorded to increase by up to two metres in the spring. There are many tributaries that drain into the lake including the Endako and Stellako Rivers, Ormond Creek, Perry Creek, Robertson Creek, Shotgun Creek and Stern Creek. The major outflow of the lake is the Nautley River. The Endako River has been noted to input large amounts of suspended sediment into the lake, especially during spring runoff.

The predominant land-use in the watershed is forestry, with agriculture and mining also having potential effects on regional water quality. The abundance of tributaries combined with the dense land-use activities surrounding the lake, show potential for a degradation in the lakes water quality.

At present, there is one major waste disposal permit with relevance to Fraser Lake, which has been issued to the village wastewater treatment facility. This facility is permitted to discharge up to 1,180 m^3/day of treated waste, and is located west of the drinking water intake.

Drinking Water Supply & Treatment

The Village of Fraser Lake draws its domestic water supply from a pump house adjacent to Fraser Lake. As measured with a GPS, the geographic co-ordinates of the pump house are 54.0622 N/124.8481 W. Water is pumped from the lake at a rate of 1500 L/min. Pump rates for 2002 indicated the lowest daily average to be 471,245 L/day in March and a maximum daily average of 739,105 L/day in December. At the pump house, the water is treated by chlorination and is subsequently transported throughout the village. Technopure, a water treatment company, also withdraws water from the village system. After providing further treatment, the water is sold throughout the region (Brian Malchow, Village of Fraser Lake, personal communication).

According to the village water works department, there are concerns with the existing water system. These concerns include: increased turbidity levels entering the lake via the Endako River (refer to Figure 3); possible contamination of the water source outside the control of the village; the possibility of untreated water being pumped into the system prior to chlorine reaching the water in the wet well; the lack of chlorine contact time prior to the water reaching the distribution system. Because of these concerns, the village is currently exploring options for upgrading the water treatment system.

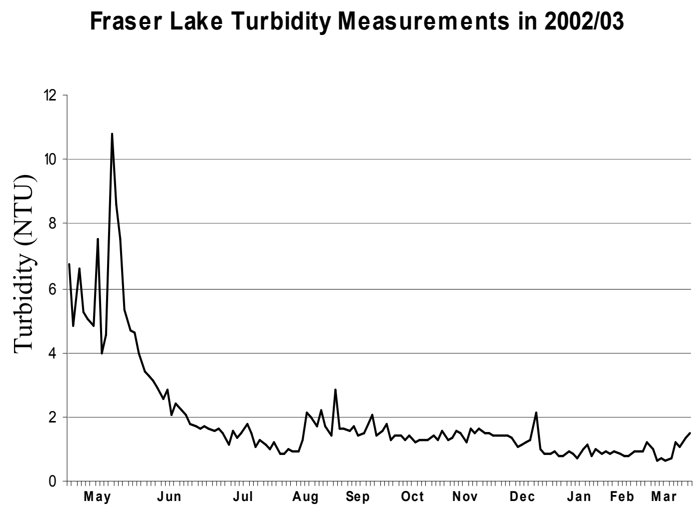


Figure 3. Fraser Lake pump house turbidity readings during 2002/2003.

Materials & Methods

Review of Previous Data

Historical data relevant to the Village of Fraser Lake raw water supply assessment have been included in this report. The data were copied from Northern Health Authority (NHA) as well as village computer and paper files and are from 2001 and 2002.

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 from the rawwater tap inside the Fraser Lake pump house (site E249358 - Water Source ID Tag 1332). The chemical results, analytical detection levels and drinking water quality guidelines are provided in Table 1, Appendix A.

Although sediment samples were collected from many of the surface water supplies during this program (mainly rivers), no sediment was collected from Fraser Lake.

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. Prior to sampling the raw water tap, the source was flushed for 5 minutes in order to minimize contamination by system piping. 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 2 and Figure 4). 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 2. The parasite filtration kit outside of the Fraser Lake pump station.

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,

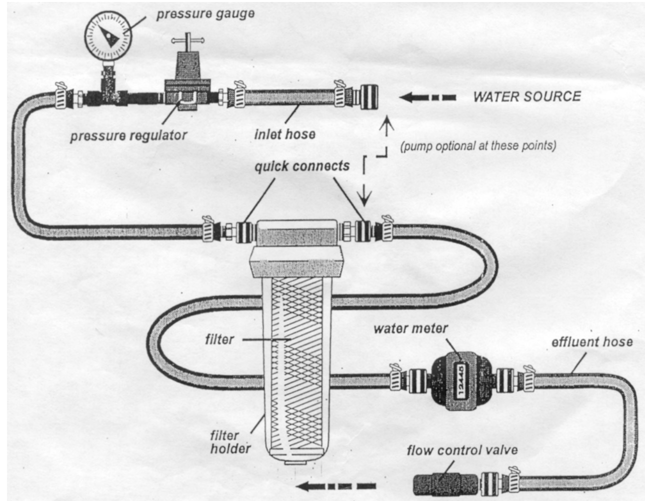


Figure 4. Schematic of the high-volume filtration unit used to sample raw water for Cryptosporidium oocysts and Giardia cysts (from EPA 1995)

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.

Results

Review of Previous Data

Bacteriology

The NHA sampled the Village of Fraser Lake's raw water supply eleven times between April, 2001 and June, 2002. The results of this bacterial program are presented in Table 2.

Table 2. Historical bacteriological data for the Village of Fraser Lake collected by the NHA. Samples were collected from multiple locations.

Date	Location	Total Coliform	Fecal Coliform
Provincial Guideline		No Guideline	<10 CFU/100mL (90th perc.)
Apr. 9/01	Tunasa Crescent (WS7)	<1	<1
May 22/01	Tunasa Crescent (WS7)	<1	<1
Jun. 12/01	Village Shop	<1	<1
Aug. 28/01	Village Shop	<1	<1
Sep. 24/01	Village Shop	<1	<1
Oct. 29/01	Village Shop	<1	<1
Dec. 17/01	Village Shop	<1	<1
Jan. 21/02	Village Shop	<1	<1
Feb. 18/02	Village Shop	<1	<1
Mar. 25/02	Village Shop	<1	<1
Jun. 4/02	Mouse Mountain School (Audit 2)	<1	<1

All historic bacterial data collected by the NHA showed no traces of coliform contamination.

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 six water chemistry field blank samples that were prepared either the same day or within one day of the Fraser Lake collections tested positive for some parameters. The concentration of most of these parameters was either very close to or less than fold the minimum detectable concentration, an acceptable threshold as per the lab acceptance criteria. Five parameters exceeded these acceptance criteria and are listed below in Table 3.

Table 3. Blind blank samples that tested strongly positive (≥ 5-fold MDL) for chemical contamination.

Date	Parameter	Measured Concentration	MDL
Sep. 25/02	Total Dissolved Phosphorus	0.031 mg/L	0.002 mg/L
Sep. 25/02	Total Phosphorus	0.038 mg/L	0.002 mg/L
Sep. 25/02	Strontium-Dissolved	0.047 µg/L	0.005 µg/L
Sep. 25/02	Tin-Dissolved	0.23 µg/L	0.01 µg/L
Jan. 20/03	Sulfate	14.6 mg/L	0.5 mg/L
Mar. 10/03	Lead-Total	0.19 µg/L	0.01 µg/L

Although the levels of some of these blank results are equal to or greater than the actual concentrations observed in Fraser Lake on some dates, they are also well below provincial raw drinking water guidelines. 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.

The five water chemistry duplicate samples that were prepared either the same day or within one day of the Fraser Lake collections did have some values outside the lab acceptance criteria of 25% relative percent difference (Table 4, 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 occurred 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.

Bacteriology

The 2002/03 bacterial data are summarised in Table 5. Drinking raw water quality guidelines for *E. coli, Enterococci* and fecal coliforms are ≤ 10/100 CFU/100mL (90th perc.), ≤ 3 CFU/100mL (90th perc.), and ≤ 10 CFU/100mL (90th perc.) respectively, in raw water supplies that undergo disinfection only.

As the table indicates, bacterial concentrations were low throughout the entire sampling program. The levels are well below drinking water guidelines, and on most dates concentrations were less than the detection level.

Table 5. Results of bacterial analyses of the Village of Fraser Lake's raw water supply.

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. 25/02	2;1	<1;<1	<1;1	2;1
Jan. 20/03	<1;2	<1;<1	<1;<1	<1;<1
Mar. 10/03	<1	<1	<1	<1
Apr. 23/03	<2	<2	<2	<2
May 22/03	1	<1	<1	<1
Sep. 4/03	<1	<1	<2	<1

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. 90% of these samples would then need to be over the stated guideline for that guideline to be exceeded. This study did not sample five times in a 30 day period, but rather six times throughout the entire year.

Parasitology

The 2002/03 parasite data are summarised in Table 6. *Giardia* cyst densities appear to be a problem in the raw water, especially during spring. The highest density of *Giardia* cysts was detected on May 22nd, 2003. Cryptosporidium oocysts were only detected on one occasion, May 22nd, 2003. Although there are currently no recommended guidelines for Protozoa, these levels have the potential to cause human illness should treatment become ineffective.

Table 6. Parasite densities observed in the Village of Fraser Lake's raw water supply over the period October 15th, 2002 to August 13th, 2003.

Date	*Cryptosporidium* (oocysts/100L)	*Giardia* (cysts/100L)
Oct. 15/02	<4.6	<4.6
Jan. 20/03	<4.9	**9.7**
Mar. 10/03	<3.3	**19.8**
Apr. 23/03	<4.3	**59.9**
May 22/03	**4.9**	**82.7**
Aug. 13/03	<4.4	**13.1**

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 Fraser Lake water treatment system currently uses disinfection as the method of treatment.

Water Chemistry

In 2002/03, Fraser Lake was sampled on six different dates. The water samples were analysed for 15 general parameters as well as 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, five were detected at concentrations exceeding the provincial guidelines for raw drinking water. The remainder of the tested parameters were all below 75 % recommended guidelines.

Colour (TCU) - The mean colour concentration for the year was 13 TCU with a maximum of 20 TCU (the recommended water quality guideline is 15 TCU). The colour of water is a measure of its dissolved compounds (attributed to the presence of organic and inorganic materials). High colour levels are regarded as a pollution problem in terms of aesthetics, and can be produced by agricultural and industrial effluents (RIC, 1998). Colour can also originate naturally from organic soils and wetlands.

Turbidity (NTU) - The maximum recorded turbidity measurement was 4.1 NTU. An annual average was 2.0 NTU. The maximum value is approaching the recommended provincial guideline of 5 NTU. Turbidity is a measure of the suspended particulate matter in the water, including silt, organic material and/or micro-organisms, that interfere with the passage of light. Turbidity can increase the available surface area of solids upon which bacteria grow and can interfere with disinfection and be aesthetically unpleasant. High levels also decrease light penetration which can affect vegetation and algal growth. Some possible sources of increased turbidity are forest harvesting, road building, agriculture and urban development (RIC, 1998).

Total Organic Carbon (mg/L) - The mean TOC concentration was 6.9 mg/L, over the recommended guideline of 4 mg/L. This is a measure of the dissolved and particulate organic carbon. TOC can be important in drinking water systems that use chlorination, as high levels can promote the formation of trihalomethanes which are considered carcinogens. Sources of TOC include agricultural, municipal and industrial waste discharges (RIC, 1998). Natural sources are similar to those for colour.

Iron, Total (mg/L) - The mean iron concentration was 0.19 mg/L with a maximum value of 0.49 mg/L, exceeding the aesthetic guideline of 0.3 mg/L. Only one sample exceeded this guideline limit. Insoluble iron is often found in waters as colloidal material which can be difficult to remove. Additionally, iron has the tendency to colour water.

Manganese, Total (µg/L) - The maximum manganese concentration was 62.8 µg/L, exceeding the aesthetic objective of 50 µg/L. Only one sample exceeded this guideline limit. Similar to iron, manganese can colour water and form colloidal material that can be difficult to remove.

A complete list of the Fraser Lake results, as well as their corresponding guidelines, is attached in Table 1, Appendix A. A list of the 2002/03 raw water quality data are attached in Table 7, Appendix A.

Conclusions & Recommendations

Review of the Fraser Lake data indicates a source water quality unsuitable for human consumption without treatment much of the year. *Giardia* cysts were detected on five of the six sampling dates, indicating that human illness is possible if treatment is not fully effective. As previously mentioned, the EPA recommend multiple barriers of protection for systems that show *Giardia* contamination, whereas the Village of Fraser Lake currently only uses disinfection. Monitoring of treated water for parasites may be beneficial to ensure that the current water treatment system is reducing cyst densities to a safe level. The sampling of multiple locations around the village may also be useful, as the Village waterworks department did indicate that there have been concerns over insufficient chlorine contact time in the past. Because such high densities of *Giardia* cysts were detected during this program, any source water that hasn't had sufficient chlorine contact time could induce illness.

The monitoring of trihalomethanes in the treated water may also be beneficial. High concentrations of TOC were found in all of the samples during the 2002/03 program, indicating that the production of carcinogenic bi-products during the chlorination process is possible.

The Village also indicated that there have been concerns regarding turbidity levels in the past, especially via inputs from the Endako River. It may be useful to do a sediment source assessment survey on the Endako River, to determine if the large amount of sediment is originating from natural slumps or from detrimental land-use activities. Actions could then be made regarding watershed management.

Acknowledgements

We thank the Village of Fraser Lake for their cooperation and direction around the village 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. Mr. Bruce Gaunt gave us access to historical water quality data collected by the NHA.

This project was funded by the B.C. Ministry of Environment.

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	7.7	7.9	7.8	0.08	0.1	6.5-8.5	aesthetic objective
Colour (TCU)	6	5	20	13	5.2	5	≤ 15	aesthetic objective
Specific Conductance (µS/cm)	6	104	128	112.5	8.71	1	≤ 700	maximum acceptable concentration
Turbidity (NTU)	4	0.5	4.07	2.02	1.541	0.1	≤ 5	maximum acceptable concentration
Hardness Total (mg/L)	6	43.85	55.9	49.99	4.035			
Hardness Total -Diss. (mg/L)	6	43.5	60.1	50.52	5.493		≤ 500 CaCO3	aesthetic objective
Alkalinity (mg/L)	6	43.5	50	47.1	2.30	0.5		
Residue Non-Filterable (mg/L)	6	4	5	4	0.41	4		
Total Organic Carbon (mg/L)								
TOC	6	5.8	8	6.9	0.88	0.5	≤ 4	maximum, to control THM production
Anions (mg/L)								
Chloride Dissolved	6	0.75	3	1.46	0.874	0.5	≤ 250	aesthetic objective
Fluoride Dissolved	6	0.07	0.08	0.07	0.004	0.01		
Bromide Dissolved	6	0.1	0.1	0.1	0.00	0.1		
Nutrients (mg/L)								
Nitrate+Nitrite	6	0.002	0.928	0.180	0.368	0.002	≤ 45 (Nitrate)	maximum acceptable concentration
Phosphorus Total	6	0.0135	0.027	0.019	0.006	0.002	≤ 0.01	Maximum (lakes only)
Phosphorus Total-Diss.	6	0.006	0.014	0.010	0.003	0.002		
Sulphate (mg/L)								
Sulphate	6	6	9.4	7.3	1.22	0.5	≤ 500	aesthetic objective
Metals Total (ug/L)								
Aluminum-T	6	6.1	50.3	20.71	18.920	0.3		
Aluminum-D	6	0.3	4.8	1.6	1.78	0.3	≤ 200	maximum acceptable concentration
Antimony-T	6	0.036	0.056	0.048	0.007	0.005	≤ 6	interim maximum acceptable concentration
Antimony-D	6	0.018	0.047	0.038	0.010	0.005		
Arsenic-T	6	0.4	0.6	0.5	0.07	0.1	≤ 25	interim maximum acceptable concentration
Arsenic-D	6	0.4	0.5	0.4	0.042	0.1		
Barium-T	6	15.1	20.1	17.3	1.89	0.02	≤ 1000	maximum acceptable concentration
Barium-D	6	14.45	19	16.24	1.517	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	0.02	0.02	0.000	0.02		
Bismuth-D	6	0.02	0.02	0.02	0.000	0.02		
Cadmium-T	6	0.02	0.06	0.034	0.014	0.01	≤ 5	maximum acceptable concentration
Cadmium-D	6	0.02	0.05	0.033	0.010	0.01		
Calcium-T (mg/L)	6	12.6	16.1	14.3	1.16	0.05		
Calcium-D (mg/L)	6	12.45	17.3	14.43	1.61	0.05		
Chromium-T	6	0.2	0.2	0.2	0.00	0.2	≤ 50	maximum acceptable concentration
Chromium-D	6	0.2	0.2	0.2	0.00	0.2		
Cobalt-T	6	0.005	0.077	0.031	0.029	0.005		
Cobalt-D	6	0.005	0.02	0.008	0.006	0.005		
Copper-T	6	0.875	39.1	8.916	14.953	0.05	≤ 1000	aesthetic objective
Copper-D	6	0.805	25.8	6.023	9.794	0.05		
Iron-T (mg/L)	5	0.065	0.493	0.188	0.183	0.005	≤ 0.3	aesthetic objective
Iron-D (mg/L)	5	0.006	0.114	0.041	0.042	0.005		
Lead-T	6	0.015	1.73	0.485	0.644	0.01	≤ 10	maximum acceptable concentration
Lead-D	6	0.01	0.06	0.04	0.021	0.01		
Lithium-T	6	0.165	0.95	0.609	0.262	0.05		
Lithium-D	6	0.095	0.79	0.573	0.243	0.05		

Table 1 Continued.

Parameter	# of Values	Min.	Max.	Mean	Std. Dev.	MDL	D. W. Guideline	Guideline Type
Magnesium-T (mg/L)	6	3.005	3.82	3.488	0.293	0.05		
Magnesium-D (mg/L)	6	3.02	4.11	3.52	0.358	0.05	$\leq$ 100	aesthetic objective
Manganese-T	6	6.68	62.8	26.29	21.027	0.008	$\leq$ 50	aesthetic objective
Manganese-D	6	0.436	12.8	5.367	5.011	0.008		
Molybdenum-T	6	9.33	17.3	12.07	3.404	0.05	$\leq$ 250	maximum acceptable concentration
Molybdenum-D	6	9.39	16.2	11.52	2.719	0.05		
Nickel-T	6	0.07	0.4	0.25	0.155	0.05		
Nickel-D	6	0.05	0.39	0.23	0.140	0.05		
Selenium-T	6	0.2	0.2	0.2	0.00	0.2	$\leq$ 10	maximum acceptable concentration
Selenium-D	6	0.2	0.2	0.2	0.00	0.2		
Silver-T	6	0.02	0.02	0.02	0.00	0.02		
Silver-D	6	0.02	0.02	0.02	0.00	0.02		
Sodium-T (mg/L)	5	3.94	4.31	4.14	0.157	0.05	$\leq$ 200	aesthetic objective
Strontium-T	6	105	145	117	14.6	0.005		
Strontium-D	6	97.2	145	115.6	16.96	0.005		
Thallium-T	6	0.002	0.005	0.003	0.001	0.002	$\leq$ 2	maximum acceptable concentration
Thallium-D	6	0.002	0.002	0.002	0.000	0.002		
Tin-T	6	0.01	0.33	0.08	0.125	0.01		
Tin-D	6	0.01	0.03	0.02	0.008	0.01		
Uranium-T	6	0.119	0.354	0.187	0.088	0.002	$\leq$ 100	maximum acceptable concentration
Uranium-D	6	0.099	0.334	0.174	0.083	0.002		
Vanadium-T	6	0.25	0.61	0.43	0.137	0.06	$\leq$ 100	maximum acceptable concentration
Vanadium-D	6	0.16	0.625	0.331	0.169	0.06		
Zinc-T	6	10.65	73.1	32.66	23.284	0.1	$\leq$ 5000	aesthetic objective
Zinc-D	6	7.7	64.2	27.4	20.45	0.1		

Table 4. Duplicate samples that exceeded precision acceptability criteria ($\leq$25% difference when >5-fold MDL). All concentrations in µg/L.

Parameter	MDL (µg/L)	Duplicate Acceptance Criteria (RPD%)	September/02			January/03			April/03			May/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	25%	0.034	0.057	**50.5**	0.03	0.042	**33.3**						
Copper-T	0.05	25%	4.85	8.97	**59.6**				0.36	0.78	**73.7**			
Copper-D	0.05	25%	6.19	3.49	**55.8**									
Lead-T	0.01	25%	0.38	0.69	**57.9**				0.01	0.09	**160**			
Lithium-T	0.05	25%	0.28	0.05	**139**							0.22	0.29	**27.4**
Tin-T	0.01	25%	0.04	0.09	**76.9**									
Zinc-T	0.1	25%							0.9	1.4	**43.5**			

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

Table 7. 2002/03 raw water quality data collected from the Fraser Lake drinking water supply.

Date	Cryptosporidium (oocysts/100L)	Giardia (cysts/100L)	Total Coliform (CFU/100mL)	Fecal Coliform (CFU/100mL)	Enterococci (CFU/100mL)
25-Sep-02			2	2	<1
25-Sep-02			1	1	1
15-Oct-02	<4.6	<4.6			
20-Jan-03	<4.9	9.7	<1	<1	<1
20-Jan-03			2	<1	<1
10-Mar-03	<3.3	19.8	<1	<1	<1
23-Apr-03	<4.3	59.9	<2	<2	<2
22-May-03	4.9	82.7	1	<1	<1
13-Aug-03	<4.4	13.1	<1	<1	<2

E. Coli (CFU/100mL)	pH (pH Units)	True Colour (Col. Unit)	Specific Conductance (µS/cm)	Residues - NonFilt. (mg/L)	Turbidity (NTU)
<1	7.7	10	104	<4	
<1	7.8	10	104	<4	
<1	7.8	15	112	<4	
<1	7.7	15	112	<4	
<1	7.7	5	116	<4	0.5
<2	7.8	15	128	4	4.07
<1	7.9	20	109	5	2.25
<1	7.9	15	106	<4	1.27

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)
44.5	43.3	43	<0.1	0.8	0.07
43.2	43.7	44	<0.1	0.7	0.07
49.4	50.5	49	<0.1	1.2	0.07
48.6	50.9	49	<0.1	0.8	0.07
50.6	51.5	46	<0.1	2	0.07
55.9	60.1	50	<0.1	3	0.07
52.2	49.6	47.3	<0.1	1.1	0.08
48.4	47.7	46.6	<0.1	0.9	0.07

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)
7	0.006	0.008	0.016	6.6	9.9
6.7	0.004	0.006	0.015	6	12.1
7.8	0.061	0.012	0.014	7.7	7.8
8.1	0.061	0.013	0.013	7.9	9.5
6.4	0.062	0.014	0.014	7.3	6.1
5.8	0.02	0.012	0.025	9.4	50.3
8	<0.002	0.008	0.027	7	38.9
6.6	0.928	0.006	0.018	6	9.3

Aluminum - Diss. (µg/L)	Antimony - Tot. (µg/L)	Antimony - Diss. (µg/L)	Arsenic - Tot. (µg/L)	Arsenic - Diss. (µg/L)	Barium - Tot. (µg/L)
0.5	0.034	0.032	0.4	0.4	15.2
<0.3	0.057	0.04	0.5	0.5	15
1.2	0.03	0.016	0.3	0.4	16.4
1.3	0.042	0.02	0.5	0.4	16.1
<0.3	0.048	0.045	0.5	0.4	16.4
2.7	0.054	0.038	0.6	0.4	20.1
4.8	0.049	0.042	0.5	0.4	19.1
0.5	0.056	0.047	0.5	0.5	17.1

Barium - Diss. (µg/L)	Beryllium - Tot. (µg/L)	Beryllium - Diss. (µg/L)	Bismuth - Tot. (µg/L)	Bismuth - Diss. (µg/L)	Cadmium - Tot. (µg/L)
14.4	<0.02	<0.02	<0.02	<0.02	0.02
14.5	<0.02	<0.02	<0.02	<0.02	0.02
15.9	<0.02	<0.02	<0.02	<0.02	0.04
16.3	<0.02	<0.02	<0.02	<0.02	0.03
16.5	<0.02	<0.02	<0.02	<0.02	0.03
19	<0.02	<0.02	<0.02	<0.02	0.06
15.8	<0.02	<0.02	0.02	<0.02	0.03
15.6	<0.02	<0.02	<0.02	<0.02	0.03

Cadmium - Diss. (µg/L)	Calcium - Tot. (mg/L)	Calcium - Diss. (mg/L)	Chromium - Tot. (µg/L)	Chromium - Diss. (µg/L)	Cobalt - Tot. (µg/L)
0.02	12.8	12.4	<0.2	<0.2	<0.005
0.02	12.4	12.5	<0.2	<0.2	<0.005
0.06	14	14.4	<0.2	<0.2	<0.005
<0.01	13.8	14.5	<0.2	<0.2	<0.005
0.03	14.5	14.7	<0.2	<0.2	0.021
0.05	16.1	17.3	<0.2	<0.2	0.077
0.03	14.7	14.1	<0.2	<0.2	0.053
0.03	13.8	13.6	<0.2	<0.2	0.026

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	4.85	6.19			0.38
<0.005	8.97	3.49			0.69
<0.005	0.86	0.78	0.085	0.031	0.02
<0.005	0.89	0.83	0.071	0.03	0.01
0.006	1.89	1.73	0.08	0.023	0.12
0.02	3.57	1.79	0.493	0.114	0.43
0.006	1.15	1.17	0.226	0.032	0.08
0.005	39.1	25.8	0.065	0.006	1.73

Lead - Diss. (µg/L)	Lithium - Tot. (µg/L)	Lithium - Diss. (µg/L)	Magnesium - Tot. (mg/L)	Magnesium - Diss. (mg/L)	Manganese - Tot. (µg/L)
0.07	0.28	0.14	3.04	3	19.6
0.04	<0.05	<0.05	2.97	3.04	19.9
0.01	0.52	0.7	3.5	3.54	7.02
0.01	0.52	0.56	3.44	3.56	6.86
0.06	0.95	0.79	3.49	3.6	6.68
0.06	0.74	0.67	3.82	4.11	35
0.03	0.67	0.59	3.76	3.5	26.6
0.03	0.61	0.66	3.38	3.33	62.8

Manganese - Diss. (µg/L)	Molybdenum - Tot. (µg/L)	Molybdenum - Diss. (µg/L)	Nickel - Tot. (µg/L)	Nickel - Diss. (µg/L)	Selenium - Tot. (µg/L)	Selenium - Diss. (µg/L)	Silver - Tot. (µg/L)
1.89	9.65	9.31	0.05	0.11	<0.2	<0.2	<0.02
1.7	9.43	9.47	0.09	0.05	<0.2	<0.2	<0.02
3.6	9.39	9.57	0.09	<0.05	<0.2	<0.2	<0.02
3.5	9.27	9.76	0.05	<0.05	<0.2	<0.2	<0.02
3.22	9.73	9.94	0.22	0.24	<0.2	<0.2	<0.02
12.8	17.3	16.2	0.38	0.35	<0.2	<0.2	<0.02
0.436	15.3	13.4	0.4	0.39	<0.2	<0.2	<0.02
10.4	11.2	10.5	0.37	0.29	<0.2	<0.2	<0.02

Silver - Diss. (µg/L)	Sodium - Tot. (mg/L)	Strontium - Tot. (µg/L)	Strontium - Diss. (µg/L)	Thallium - Tot. (µg/L)	Thallium - Diss. (µg/L)	Tin - Tot. (µg/L)	Tin - Diss. (µg/L)
<0.02		108	106	<0.002	<0.002	0.04	0.02
<0.02		108	107	<0.002	<0.002	0.09	0.04
<0.02	4.12	116	121	<0.002	<0.002	<0.01	0.01
<0.02	4.03	118	121	<0.002	<0.002	0.03	<0.01
<0.02	4.09	119	119	0.005	<0.002	<0.01	<0.01
<0.02	4.31	145	145	0.002	<0.002	0.03	<0.01
<0.02	4.29	110	97.2	<0.002	<0.002	<0.01	<0.01
<0.02	3.94	105	105	<0.002	<0.002	0.33	0.02

Uranium - Tot. (µg/L)	Uranium - Diss. (µg/L)	Vanadium - Tot. (µg/L)	Vanadium - Diss. (µg/L)	Zinc - Tot. (µg/L)	Zinc - Diss. (µg/L)
0.122	0.116	0.63	0.64	21.7	21.6
0.118	0.119	0.59	0.61	24.7	19.5
0.162	0.159	0.35	0.26	9.7	10.5
0.158	0.165	0.3	0.28	11.6	11.3
0.159	0.162	0.45	0.36	42	32.8
0.354	0.334	0.37	0.16	73.1	64.2
0.212	0.168	0.55	0.38	12.4	7.7
0.119	0.099	0.25	0.19	34.6	28.3