Assessment of the Buckhorn Improvement District 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. A view of the Buckhorn pump house where the raw water samples were collected.

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 Buckhorn Improvement District raw potable water source (ground water) (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.

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[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.

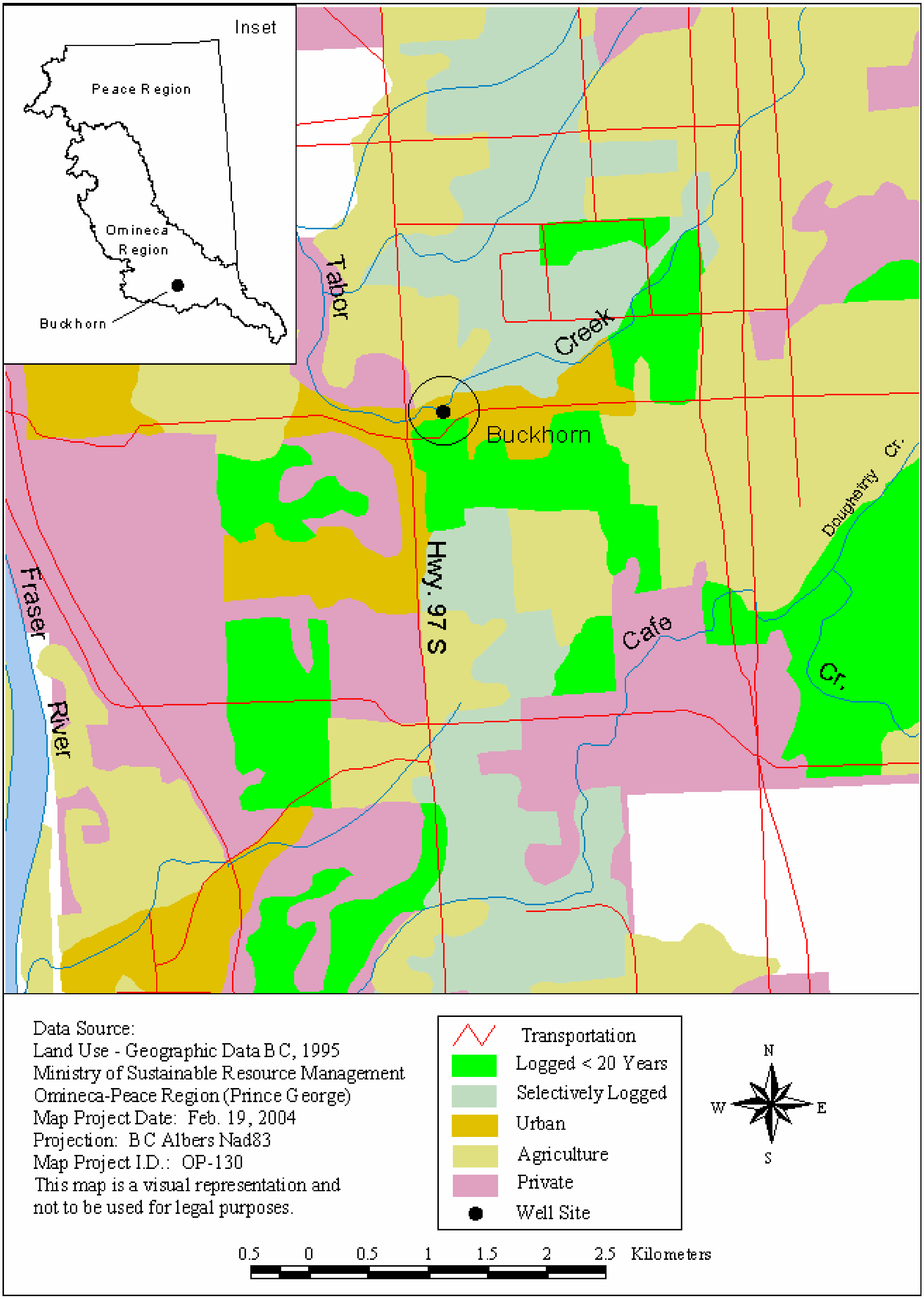

Figure 1. Buckhorn water well and nearby land use practices. A 300 m radius surrounds the well indicating the zone where contamination is most probable to occur.

Site Description

Watershed Overview

The Buckhorn Improvement District is located south of Prince George on Highway 97. The drinking water supply consists of one well, located by the Buckhorn Elementary School. This area lies within the Sub-Boreal Spruce biogeoclimatic zone, which is characterized by gently rolling terrain, dense coniferous forests and extremes in the annual temperature range of -40°C to 30°C (B.C. Ministry of Forests, 1998). However, a large proportion of the land surrounding the Buckhorn well has been developed for either urban, agricultural or forestry use (Figure 1).

According to Rob Verkaik, the water purveyor for the district, the current withdrawal rate for the well is approximately 20-25 gallons/minute (91-114 L/min). The well draws water from a bed composed dominantly of gravels and clays (Table 1). At the time of well construction, the static water level was at 330 ft (101 m). According to this lithology profile, it appears that this well is within a confined aquifer. The abundance of clay layers above the 330 ft static level would help prevent/slow down the transport of materials leached from the surface. This is beneficial compared to an unconfined aquifer, which would be composed dominantly of sands and gravels and would generally be more sensitive to land use activities.

Table 1. Lithology profile from the Buckhorn Improvement District well (well tag number 20061). Data from the aquifer database of

Depth (Ft)	Grain Size
0-28	Brown clay
28-32	Grey silty clay
32-82	Grey silty clay with gravel
82-117	Dry sand and gravel
117-137	Soft silty grey clay
137-348	Dry sand and gravel
348-348	Coarse sand
348-362	Dry sand and gravel
362-402	Sand and gravel (w.b.)
402-406	Fine sand with gravel
406-407	Brown clay with gravel

There is a waste disposal permit in the close proximity to the Buckhorn well, located across the street. This disposal permit, a sewage treatment facility, consists of multiple holding lagoons. Effluent from the facility is subsequently discharged into Tabor Creek. If these holding lagoons, or the discharge pipe entering Tabor Creek were to leak, ground water contamination that may affect the drinking water well is possible.

Drinking Water Supply & Treatment

The Buckhorn Improvement District draws its domestic water from a ground water supply, consisting of one well. The well is situated at the pump house, adjacent to the elementary school. As measured with a GPS unit, the geographic co-ordinates of the pump house are 53.7936N/122.6520W. From the pump house, the water is distributed to the school and throughout the district. According to both Mr. Verkaik and Donna Bush (Northern Health Authority, p.c.), there is currently no community treatment system in place on the source water.

There are some concerns regarding the source water supply. There is an abundance of black silt/sediment in the piping system, probably resulting from the precipitation of manganese. Additionally, hot water tanks have developed scale deposits, attributable to the hardness of the water (Verkaik, p.c.). Furthermore, there has been some concern put forth about the possible leakage of septic tanks, which may have the potential to affect the ground water supply. According to Dave Turvey (a water purveyor for Buckhorn), bleech is put into the raw water once a week to help disinfect the water. Bleech is also put in the water whenever the power shuts down. Again, this is to help prevent contamination by leaking pipes, drainage ditches and/or septic systems.

Materials & Methods

Review of Previous Data

Historical data relevant to the Buckhorn Improvement District source water supply assessment have been included in this report. The data were copied from Northern Health Authority (NHA) computer and paper files and include samples from numerous locations.

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 raw water tap inside the elementary school on the first sampling round (site E249231), with all subsequent samples being collected from the raw water tap (Plate 2) in the Buckhorn pump house (site E249360 - Water Source ID Tag 1317). The chemical results, analytical detection levels and drinking water quality guidelines are provided in Table 2, 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. Prior to sampling the raw water tap, the source was flushed for 5 minutes in order to minimize

Plate 2. A picture of the raw water tap inside the Buckhorn pump house.

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.

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.

Results

Review of Previous Data

Bacteriology

The NHA sampled the Buckhorn Improvement district raw water supply from numerous locations 231 times between March 1990 and August 2002. The results of this raw water bacterial program are presented in Table 3, Appendix A.

All 231 samples were tested for both total and fecal coliforms. Total coliforms were detected on seven occasions, and fecal coliforms were detected on six. There is currently no recommended guideline for total coliforms. Furthermore, total coliforms are found naturally in many water bodies and do not necessarily indicate harmful land use activities. They do however suggest that coliforms may be present in the system and that further testing may be warranted. The recommended guideline for fecal coliforms in a system without water treatment is 0 CFU/100mL. The presence of fecal coliforms usually indicates recent contamination of ground water by human sewage or animal droppings, which could contain other bacteria, viruses, or disease causing micro-organisms (British Columbia Ground Water Association, 2002).

Water Chemistry

The historical chemistry data collected by the NHA between February 1994 and February 2001 (a total of 5 samples) showed some parameters that were either over provincial drinking water guidelines or very high. These parameters include specific conductivity, hardness, magnesium, manganese and lead. There did not appear to be any QA data associated with these samples. 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 minimal field or lab contamination of samples with bacteria occurred and that acceptable precision in bacterial sampling and analysis was observed.

The six water chemistry field blank samples that were prepared either the same day or within one day of the Buckhorn 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. Seven parameters exceeded these acceptance criteria significantly and are listed below in Table 5.

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

Date	Parameter	Measured Concentration	MDL
Sep. 16/02	Strontium-T	0.215 µg/L	0.005 µg/L
Oct. 2/02	Copper-D	0.27 µg/L	0.05 µg/L
Oct. 2/02	Lithium-T	0.36 µg/L	0.05 µg/L
Oct. 2/02	Strontium-D	0.048 µg/L	0.005 µg/L
Jan. 20/03	Copper-D	0.25 µg/L	0.05 µg/L
Jan. 20/03	Sulphate	14.6 mg/L	0.5 mg/L
May 6/03	Copper-T	0.36 µg/L	0.05 µg/L

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

The six water chemistry duplicate samples that were prepared either the same day or within one day of the Buckhorn 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. All of the parameters that did have differences greater than 25% between the duplicates occurred well below recommended drinking water guidelines.

Bacteriology

The 2002/03 bacterial data are summarised in Table 7. Drinking water quality guidelines for *E. coli, Enterococci* and fecal coliforms are all 0 CFU/100mL in drinking water supplies that undergo no treatment.

Most samples collected from this water supply contained no detectable bacteria. The August 13th sample did have positive results for total coliforms, however there are no water quality guidelines for these bacteria. These bacteria do suggest that other bacteria of a more harmful nature may be present, and that further bacterial sampling should occur.

Table 7. Results of bacterial analyses for the Buckhorn Improvement District raw water supply. Units are CFU/100mL.

Date	Total Coliform	*E. coli*	*Enterococci*	Fecal Coliform
Provincial Guideline	No Provincial Guideline	0 CFU/100 mL	0 CFU/100 mL	0 CFU/100 mL
Sep. 16/02*	<1	<1	<1	<1
Oct. 3/02	<1	<1	<1	<1
Jan. 20/03	<1	<1	<1	-
Mar. 13/03	<1	<1	<1	<1
May 6/03	<2; <2	<2; <2	<2; <2	<2; <2
May 27/03	<1	<1	<1	<1
Aug. 13/03	13	<1	<1	<1

*Sample collected from Buckhorn school

Water Chemistry

In 2002/03, ground water samples were collected on seven different dates (six from the pump house and one from the school). The water samples were analysed for 15 general parameters as well as for the ICPMS low level metals package that includes 27 metals in the total form.

Of the chemical parameters tested through the duration of this study, two exceeded the provincial guidelines for raw drinking water and one was of note.

Specific Conductance (µS/cm) - The average specific conductance was 754 µS/cm, over the recommended guideline of 700 µS/cm. High specific conductivity values indicate a high ion concentration, which can be related to the dissolved solids content of the water.

Manganese, Total (µg/L) - The mean manganese concentration was 245 µg/L with a maximum of 308 µg/L, both exceeding the aesthetic objective of 50 µg/L. Manganese can colour water and form colloidal material that can be difficult to remove.

Water hardness, which can often be a problem in ground water supplies, had a mean concentration of 402 mg/L $CaCO_3$. This is considered very hard (>180 mg/L $CaCO_3$), above the optimum range of 60-120 mg/L $CaCO_3$ for a drinking water supply. This hardness is due to the presence of calcium and magnesium in the water. Hard water can reduce the toxicity of some metals, but can also leave scale deposits on piping. Some anthropogenic sources that contribute to water hardness are mining and industrial effluents.

The data from 2002/03, as well as the historical chemistry data, indicate that chemical parameters in the Buckhorn water supply are generally low for drinking water use. There do however appear to be problems regarding both water hardness and manganese levels, both of which probably result from the dissolution of minerals and rocks in the ground.

A complete list of the results as well as their corresponding guideline is attached in Table 2, Appendix A. A complete list of the raw data collected during the program are attached in Table 8, Appendix A.

Conclusions & Recommendations

Review of the Buckhorn Improvement District's ground water data indicates an overall good raw drinking water quality. Most water soluble contaminants were present at concentrations well below drinking water guidelines. The two main parameters of note are hardness and manganese. As previously noted by Rob Verkaik, there is a problem with the scaling of hot water tanks and pipes. Additionally, there may be aesthetic concerns regarding the abundance of calcium and magnesium resulting in the very hard water. Manganese was also a problem mentioned by Mr. Verkaik. An abundance of black particles have been noted to accumulate in the pipes, which is a normal biproduct of high manganese levels. Problems regarding this black precipitate include and unpleasant appearance and taste of the water, as well as allowing an increase in growth of unwanted bacteria that may form slimy layers on system piping (British Columbia Ground Water Association, 2002). High levels of these parameters are normal for many ground water sources, resulting from local geology. There are treatment methods to deal with both water hardness and manganese, however those will not be discussed here.

Based on the lack of information regarding the well, a 300 m radius is arbitrarily assigned as the zone where contamination is most likely (Mike Wei, Senior Hydrogeologist, MOE, p.c.). Since the lithology profile of the well indicates dominantly clay in the upper layers, the aquifer is probably confined and therefore more buffered against land use activities compared to unconfined aquifers (dominantly sands and gravels). Although these clay layers would retard leachates from moving quickly into the sand and gravel where water withdrawal occurs, harmful land use practices in the close vicinity of the well (approximately 300 m) are discouraged. Regardless, a 300 m radius site assessment may still be useful to indicate where there is potential for contamination.

Because the Buckhorn Improvement District currently uses no form of water treatment and some bacteria were detected in the historical data, it is also recommended that periodic bacterial samples are collected to ensure that levels do not exceed recommended drinking water guidelines of 0 CFU/100 mL.

Acknowledgements

We thank Mr. Rob Verkaik and John Bass (Buckhorn Improvement District) for their useful insight and direction around the water supply. Mr. Todd French is recognized for his help in designing and implementing the project (TDF Watershed Solutions, Research & Management). Finally, the insight from Donna Bush (NHA) on the water system was appreciated.

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Contact Information

For more information regarding either this short report, watershed protection and/or drinking water, please contact the Ministry of Environment (Contact: Bruce Carmichael (Prince George), 250-565-6455) or the Northern Health Authority (Contact: Bruce Gaunt (Prince George), 250-565-2150 or Caroline Alexander (Fort St. John), 250-787-3355).

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Appendix A

Table 2. 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	7	8.1	8.2	8.1	0.05	0.1	6.5-8.5	aesthetic objective
Colour (TCU)	7	5	5	5	0.0	5	≤ 15	aesthetic objective
Specific Conductance (µS/cm)	7	687	780.5	753.9	32.26	1	≤ 700	maximum acceptable concentration
Turbidity (NTU)	5	1.33	1.96	1.65	0.224	0.1	≤ 5	maximum acceptable concentration
Hardness Total (mg/L)	7	392	417	402	9.1		≤ 500 $CaCO_3$ -(Diss.)	aesthetic objective
Alkalinity (mg/L)	7	240	275	265	11.6	0.5		
Residue Non-Filterable (mg/L)	7	1	4	3.6	1.13	4		
Total Organic Carbon (mg/L)								
TOC	6	0.5	0.5	0.5	0.00	0.5	≤ 4	maximum, to control THM production
Anions (mg/L)								
Chloride Dissolved	7	0.5	1	0.7	0.16	0.5	≤ 250	aesthetic objective
Fluoride Dissolved	7	0.05	0.1	0.07	0.018	0.01	≤ 1.5	maximum acceptable concentration
Bromide Dissolved	7	0.1	0.1	0.1	0.00	0.1		
Nutrients (mg/L)								
Nitrate+Nitrite	7	0.002	0.022	0.009	0.007	0.002	≤ 45 (Nitrate)	maximum acceptable concentration
Phosphorus Total	1	0.012	0.012	0.012		0.002		
Phosphorus Total-Diss.	1	0.004	0.004	0.004		0.002		
Sulphate (mg/L)								
Sulphate	7	161	178	170	6.0	0.5	≤ 500	aesthetic objective
Metals Total (ug/L)								
Aluminum-T	7	0.3	0.5	0.3	0.08	0.3	≤ 200 (Diss.)	maximum acceptable concentration
Antimony-T	7	0.012	0.028	0.019	0.006	0.005	≤ 6	interim maximum acceptable concentration
Arsenic-T	7	0.5	0.7	0.6	0.08	0.1	≤ 25	interim maximum acceptable concentration
Barium-T	7	21.3	30.5	28.1	3.10	0.02	≤ 1000	maximum acceptable concentration
Beryllium-T	7	0.02	0.02	0.02	0.000	0.02		
Bismuth-T	7	0.02	0.02	0.02	0.000	0.02		
Cadmium-T	7	0.01	0.26	0.047	0.094	0.01	≤ 5	maximum acceptable concentration
Calcium-T (mg/L)	7	99.1	106	101.9	2.40	0.05		
Chromium-T	7	0.2	8.6	1.7	3.14	0.2	≤ 50	maximum acceptable concentration
Cobalt-T	7	0.005	0.036	0.009	0.012	0.005		
Copper-T	7	0.07	8.76	2.12	2.970	0.05	≤ 1000	aesthetic objective
Iron-T (mg/L)	5	0.056	0.228	0.148	0.062	0.005	≤ 0.3	aesthetic objective
Lead-T	7	0.01	0.94	0.227	0.321	0.01	≤ 10	maximum acceptable concentration
Lithium-T	7	0.05	1.35	1.00	0.472	0.05		
Magnesium-T (mg/L)	7	34.7	36.9	35.8	0.77	0.05	≤ 100 (Diss.)	aesthetic objective
Manganese-T	7	23.4	308	245.3	103.64	0.008	≤ 50	aesthetic objective
Molybdenum-T	7	2.09	2.39	2.25	0.126	0.05	≤ 250	maximum acceptable concentration
Nickel-T	7	0.05	0.78	0.20	0.279	0.05		
Selenium-T	7	0.2	0.3	0.2	0.04	0.2	≤ 10	maximum acceptable concentration
Silver-T	7	0.02	0.02	0.02	0.000	0.02		
Sodium-T (mg/L)	5	20.9	21.7	21.1	0.34	0.05	≤ 200	aesthetic objective
Strontium-T	7	572	655	619	30.9	0.005		
Thallium-T	7	0.002	0.003	0.002	0.000	0.002	≤ 2	maximum acceptable concentration
Tin-T	7	0.01	0.08	0.03	0.026	0.01		
Uranium-T	7	2.95	4.97	4.47	0.693	0.002	≤ 100	maximum acceptable concentration
Vanadium-T	7	0.425	2.62	1.34	0.748	0.06	≤ 100	maximum acceptable concentration
Zinc-T	7	0.7	24	14.8	9.68	0.1	≤ 5000	aesthetic objective

Table 3. Historical bacteriological data from the Buckhorn Improvement District. The samples were collected from numerous locations, all of which have no water treatment. Bacterial units are CFU/100mL.

Location	Parameter	*n*	Concentration Range	# Samples >1	Average Concentration	Provincial Guideline
4235 Damms Rd.	Total Coliforms	14	<1	0	<1	None
	Fecal Coliforms		<1	0	<1	0
4720 Danning Rd.	Total Coliforms	23	<1	0	<1	None
	Fecal Coliforms		<1	0	<1	0
4880 Damms Rd.	Total Coliforms	52	<1-92	2	2.8	None
	Fecal Coliforms		<1-78	1	**2.5**	0
5190 Buckhorn Lake Rd.	Total Coliforms	3	<1	0	<1	None
	Fecal Coliforms		<1	0	<1	0
6700 Buckhorn Lake Rd.	Total Coliforms	78	<1	0	<1	None
	Fecal Coliforms		<1	0	<1	0
Buckhorn School	Total Coliforms	29	<1-58	2	4.4	None
	Fecal Coliforms		<1-13	2	**1.5**	0
Prest Residence	Total Coliforms	21	<1-115	4	8.8	None
	Fecal Coliforms		<1-3	3	**1.3**	0
Pumphouse	Total Coliforms	2	<1	0	<1	None
	Fecal Coliforms		<1	0	<1	0
Unspecified Site	Total Coliforms	1	<1	0	<1	None
	Fecal Coliforms		<1	0	<1	0

Table 4. Historic chemical data collected from the Buckhorn school as well as unspecified locations. All concentrations are in µg/L unless otherwise specified.

Parameter	March 1/90	February 21/94	November 14/96	February 16/99	February 21/01
pH	7.9	8.2	7.92	7.94	8.31
True Colour	<5	<5			
Specific Conductivity (µS/cm)	**820**	**735**	**850**	**790**	**925**
Turbidity (NTU)	2	0.2	0.13	1.34	0.11
Hardness-T (mg/L)	**404**	90.1	153	**389**	
Bromide-D (mg/L)			<0.05	<0.05	<0.05
Chloride-D (mg/L)	1	0.6	0.63	<4.4	0.8
Fluoride-D (mg/L)	<0.1	<0.01	0.08	<0.01	0.1
Nitrate+Nitrite (mg/L)		0.03			
Phosphorus-T (mg/L)	0.014	<0.04	<0.1	<0.1	<0.05
Sulphate (mg/L)	165	166	145	167	165
Aluminium-T	<100	<20	<50	<50	<0.2
Antimony-T	<5	<15	<0.1	<1	0.043
Arsenic-T	<1	<1	<0.5	1	0.7
Barium-T	30	4	6	29	0.56
Beryllium-T		<1	<1	2	<0.002
Bismuth-T	<20			0.03	
Boron-T		8	10	10	7
Cadmium-T	<0.5	<0.1	<0.2	<0.2	<0.01
Calcium-T (mg/L)	109	23.5	22.5	98.9	
Chromium-T	<10	<2	<5	<5	<0.2
Cobalt-T	<100	<3	<5	<9	<0.005
Copper-T	<30	9	39	<0.5	11.5
Iron-T (mg/L)	0.24	0.004	0.008	0.13	
Lead-T	6	<1	**22**	0.8	0.13
Lithium-T					0.12
Magnesium-T (mg/L)	32.1	7.62	23.5	34.1	**115**
Manganese-T	**160**	24	13	**305**	1.24
Molybdenum-T	<10	<4	<10	10	2.38
Nickel-T	<50	<8	<20	<20	0.1
Potassium-T		0.6	14.1	2.8	
Selenium-T		<2	<1	<1	<0.2
Silver-T		<10	<10	<10	<0.02

Table 4 Continued.

Parameter	March 1/90	February 21/94	November 14/96	February 16/99	February 21/01
Sodium-T (mg/L)	20.4	152	122	21.4	
Strontium-T		125	144	643	2.69
Tellurium-T		<0.02			
Thallium-T	<0.02			0.003	
Tin-T		<20	<50	<50	0.06
Titanium-T		<0.003	<0.002	<0.002	
Uranium-T	6.4	3.7			4.5
Vanadium-T	30	3	<10	<0.01	0.36
Zinc-T	10	40	118	38	3.8
Zirconium-T				<3	

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

Parameter	MDL (µg/L)	September/02			October 2/02			January 20/03			May/03			August 13/03		
		Conc. 1	Conc. 2	RPD %	Conc. 1	Conc. 2	RPD %	Conc. 1	Conc. 2	RPD %	Conc. 1	Conc. 2	RPD %	Conc. 1	Conc. 2	RPD %
Aluminum-D	0.3				31.2	13.5	**79**									
Antimony-T	0.005							0.03	0.042	**33**						
Chromium-T	0.2				2.1	4.3	**69**									
Copper-T	0.05	11.2	8.44	**28**										0.315	0.065	**132**
Manganese-T	0.008													1.68	6.03	**113**
Phosphorus-T (mg/L)	0.002													0.014	0.019	**30**
Nitrate + Nitrite (mg/L)	0.002	<0.002	0.015	**153**												
Vanadium-T	0.06				1.94	3.35	**53**				0.28	0.57	**68**			
Zinc-T	0.1				2.8	1.1	**87**							0.8	1.4	**55**

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

Table 8. 2002/03 raw drinking water data collected from the Buckhorn well.

Date	Total Coliform (Col./100mL)	Fecal Coliform (Col./100mL)	Enterococci (Col./100mL)	E. Coli (Col./100mL)	pH (pH Units)
16-Sep-02	<1	<1	<1	<1	8.2
03-Oct-02	<1	<1	<1	<1	8.1
20-Jan-03	<1	<1	<1		8.1
13-Mar-03	<1	<1	<1	<1	8.1
06-May-03	<2	<2	<2	<2	8.1
06-May-03	<2	<2	<2	<2	8.1
27-May-03	<1	<1	<1	<1	8.2
13-Aug-03	13	<1	<1	<1	8.2

True Colour (Col. Unit)	Specific Conductance (µS/cm)	Residues - NonFilt. (mg/L)	Turbidity (NTU)	Hardness - Total (mg/L)	Alkalinity - T as CaCO3 (mg/L)
<5	687	<4		392	240
<5	741	<1		396	269
5	756	<4	1.7	394	272
5	768	<4	1.65	410	275
5	781	<4	1.97	400	265
<5	780	<4	1.94	399	266
5	772	<4	1.6	402	269
<5	773	<4	1.33	417	267

Bromide - Diss. (mg/L)	Chloride - Diss. (mg/L)	Fluoride - Diss. (mg/L)	Carbon - Tot. Org. (mg/L)	NO2 + NO3 (mg/L)	Phosphorus - Tot. Diss. (mg/L)
<0.1	0.7	0.09	<0.5	0.006	
<0.1	<0.5	0.07	<0.5	0.004	
<0.1	0.9	0.07		0.007	
<0.1	0.7	0.05	<0.5	0.012	
<0.1	1	0.05	<0.5	0.008	
<0.1	1	0.07	<0.5	0.008	
<0.1	0.7	0.06	<0.5	<0.002	
<0.1	0.7	0.1	<0.5	0.022	0.004

Phosphorus - Tot. (mg/L)	Sulfate (mg/L)	Aluminum - Tot. (µg/L)	Antimony - Tot. (µg/L)	Arsenic - Tot. (µg/L)	Barium - Tot. (µg/L)
	164	<0.3	0.012	0.6	29.5
	178	<0.3	0.016	0.5	28.5
	170	<0.3	0.018	0.6	29.3
	170	0.5	0.015	0.7	29.5
	169	<0.3	0.027	0.7	27.7
	171	<0.3	0.025	0.7	27.9
	161	0.3	0.019	0.6	30.5
0.012	176	<0.3	0.028	0.5	21.3

Beryllium - Tot. (µg/L)	Bismuth - Tot. (µg/L)	Cadmium - Tot. (µg/L)	Calcium - Tot. (mg/L)	Chromium - Tot. (µg/L)	Cobalt - Tot. (µg/L)
<0.02	<0.02	<0.01	99.9	<0.2	<0.005
<0.02	<0.02	<0.01	101	2.2	<0.005
<0.02	<0.02	0.26	99.1	<0.2	<0.005
<0.02	<0.02	0.02	104	<0.2	0.036
<0.02	<0.02	0.01	101	<0.2	<0.005
	<0.02	0.01	101	<0.2	<0.005
<0.02	<0.02	0.01	102	<0.2	<0.005
<0.02	<0.02	<0.01	106	8.6	<0.005

Copper - Tot. (µg/L)	Iron - Tot. (mg/L)	Lead - Tot. (µg/L)	Lithium - Tot. (µg/L)	Magnesium - Tot. (mg/L)	Manganese - Tot. (µg/L)
8.76		0.94	<0.05	34.7	219
1.13		0.09	1.35	35	305
1.68	0.228	0.23	0.93	35.7	253
1.23	0.142	0.14	0.8	36.5	308
0.79	0.163	0.09	1.3	35.9	303
0.77	0.165	0.09	1.33	35.7	310
1.18	0.148	0.09	1.3	35.7	302
0.07	0.056	<0.01	1.28	36.9	23.4

Molybdenum - Tot. (µg/L)	Nickel - Tot. (µg/L)	Selenium - Tot. (µg/L)	Silver - Tot. (µg/L)	Sodium - Tot. (mg/L)	Strontium - Tot. (µg/L)
2.25	<0.05	<0.2	<0.02		648
2.09	0.78	<0.2	<0.02		590
2.12	<0.05	<0.2	<0.02	20.9	605
2.16	0.34	0.2	<0.02	21.2	655
2.33	<0.05	<0.2	<0.02	21	624
2.35	<0.05	<0.2	0.02	20.8	631
2.39	<0.05	<0.2	<0.02	21	635
2.38	<0.05	0.3	<0.02	21.7	572

Thallium - Tot. (µg/L)	Tin - Tot. (µg/L)	Uranium - Tot. (µg/L)	Vanadium - Tot. (µg/L)	Zinc - Tot. (µg/L)
<0.002	<0.01	4.79	1.45	3.4
<0.002	0.02	4.51	1.56	23
0.002	0.08	4.97	1.22	13.6
0.003	0.04	4.51	1.6	24
<0.002	<0.01	4.74	0.28	15.6
<0.002	0.02	4.82	0.57	15.4
<0.002	<0.01	4.81	0.48	23.7
<0.002	<0.01	2.95	2.62	0.7