Assessment of the Hudson Hope 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 cross view of the Peace River adjacent to the Hudson's Hope 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 Hudson's Hope raw potable water source, the Peace River (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.

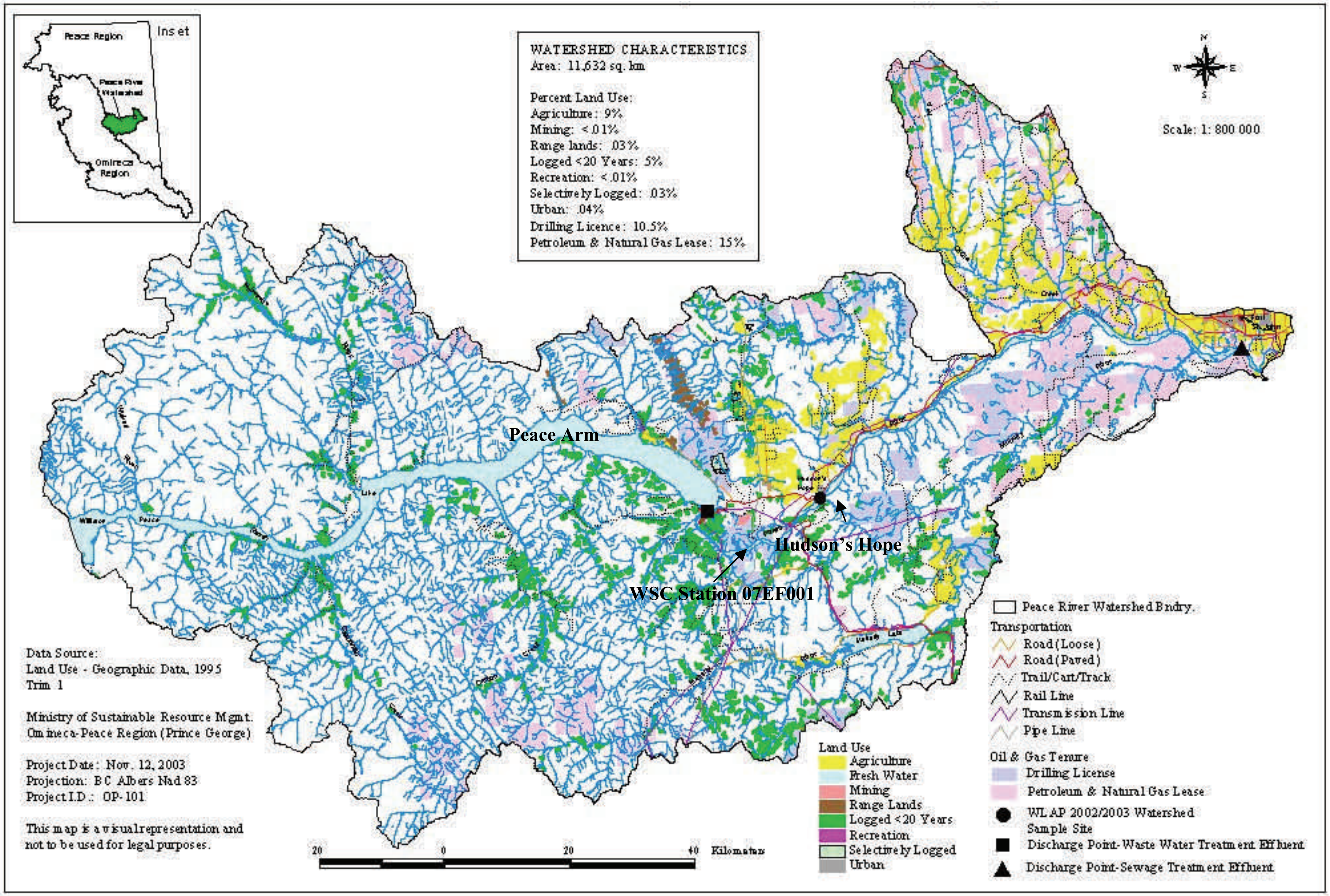

Figure 1. Peace River sub-watershed and associated land-use practices around Hudson's Hope

Site Description

Watershed Overview

The Peace River sub-watershed (Figure 1), surrounding the Village of Hudson's Hope, lies within the Boreal White and Black Spruce biogeoclimatic zone. This zone is characterized by long, extremely cold winters, with a short and cold summer growing season. The terrain has rolling topography, and is dominated by both upland forests and muskeg. Common trees in this zone include white spruce, black spruce, lodgepole pine and trembling aspen (B.C. Ministry of Forests, 1998).

The reach of the Peace River that flows past Hudson's Hope drains through the W.A.C. Bennett Dam. This dam controls flow volume, indicated by the abnormal hydrograph seen in Figure 2. There are many tributaries that enter the Peace River, with most of the named tributaries accessible at fishwizard.com. The river is dominated by a cobble/boulder substrate as seen on the banks of the river. Due to the large volume of water within the river, instream substrate is unknown, however is assumed to be of the cobble/boulder type.

Many land use activities exist in the Peace River watershed surrounding Hudson's Hope, including agriculture, forestry, oil & gas and urban development (Figure 2). The presence of the dam makes it nearly impossible to determine land-use effects related to water quantity because the Peace River hydrograph is abnormal compared to most northern interior British Columbia streams. Issues concerning water quality will be examined later in this report.

There are two waste disposal permits with relevance to the Peace River at Hudson's Hope. The wastewater treatment station located at the Peace Canyon Generating Station with a maximum discharge of 13 m^3/day and the G.M.S. generating station with a maximum discharge of 4.5 m^3/day. Both of these discharges are located upstream of the Hudson's Hope water intake, so although very small, may have limited potential to impact raw water quality.

According to Mr. Marsh Ness (Director of Works & Protective Services, Hudson's Hope), the district withdraws approximately 180,000 gallons/day (~ 818 m^3/day) from the river. This is equivalent to approximately 8.02×10^{-4}% of the Peace River water on a daily basis, which drains at an annual average of 1183 m^3/s (according to the Water Survey of Canada station 07EF001 located at Hudson's Hope).

Basic Hydrology

Flows in the Peace River at Hudson's Hope are lowest during the late spring and summer months (May through August) when they are typically < 1000 m^3/s (Figure 1). Flows in most British Columbia streams are lowest during the winter months, however, the presence of the W.A.C. Bennett dam upstream of the Hudson's Hope water intake regulates flow throughout the year, resulting in abnormal discharge. This dam has helped create the Williston Reservoir (~1659 km^2), which in turn, feeds the Peace River.

Due to the presence of the W.A.C. Bennett dam, it is difficult to determine possible watershed land-use effects on local hydrology or flow variability. Smaller changes that can be seen on the hydrograph may be due to precipitation events, however, due to the water regulation by the dam, assumptions about Peace River hydrology are hard to make.

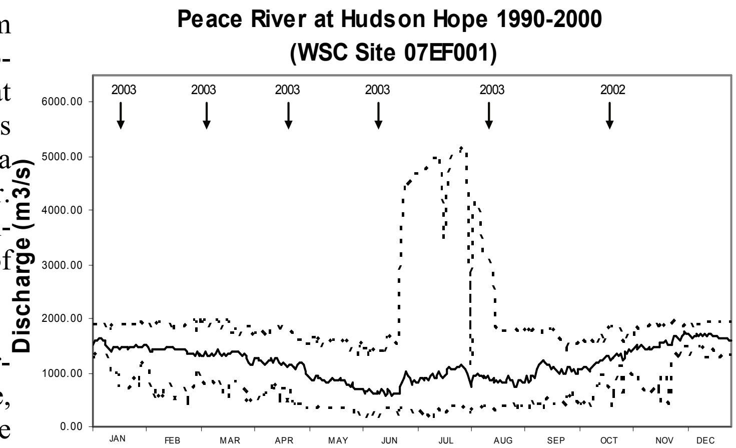

Figure 2. Lowest (bottom line), average (middle line) and maximum (upper line) daily flows observed in the Peace River at Hudson's Hope over the period 1990-2000. The dates indicate when in the hydrological cycle the samples were collected.

Drinking Water Supply & Treatment

The Village of Hudson's Hope draws its domestic water supply from the Peace River, downstream of the W.A.C. Bennett Dam at co-ordinates 56.0239 N/121.9137 W. The water intake is located in the river above a limestone bed. There are ground water springs related to this bed, which are thought to influence water quality to some extent. At the pump house, the water is treated by chlorination and is subsequently transported to approximately 1000-1100 water users.

Current concerns regarding the source water are high algal densities and water hardness (Ness, p.c.). The district is currently studying the benefits of installing a new water filter and of building a new water treatment facility (Ness, p.c.).

Materials & Methods

Review of Previous Data

Historical data relevant to the Hudson's Hope raw water supply assessment have been included in this report. The data were copied from the District of Hudson's Hope water quality files.

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 the Peace River during the October 2002 sample and from the raw water tap in the Hudson's Hope pump house during the remainder of the study (site E249366 - Water source ID Tag 1342). Water was allowed to run for 5 minutes through the raw water tap prior to sample collection to allow sufficient flushing of the pipes. The chemical results, analytical detection levels and drinking water quality guidelines are provided in Table 1, Appendix A.

Although sediment collection occurred at most surface water sites during this program, no sample was collected at Hudson's Hope due to the lack of fine sediment in the Peace River.

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

Plate 2. A view of the parasite kit beside the raw water tap in the Hudson's Hope pump house.

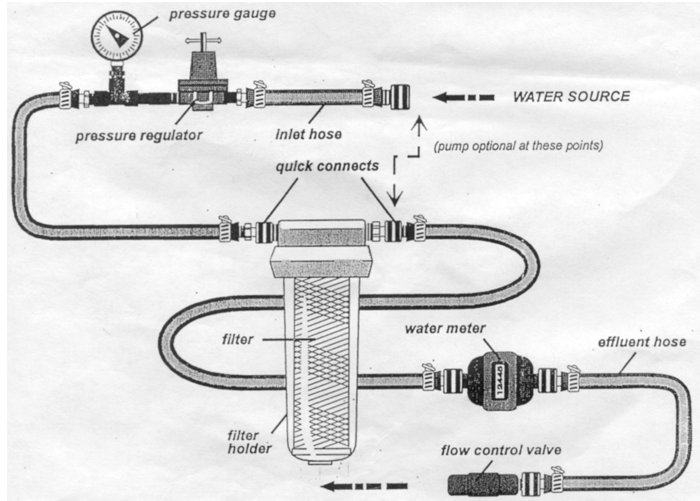

Figure 3. Schematic of the high-volume filtration unit used to sample raw water for Cryptosporidium oocysts and Giardia cysts (from EPA, 1995)

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 3). 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.

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

Parasitology

The District of Hudson's Hope collected parasite samples three times during the summer of 2002. The results of this parasite program are presented in Table 2. As shown, *Cryptosporidium* densities were always below the detection level. By comparison, *Giardia* cysts were detected on all three sample dates ranging between 5.0 and 10 cysts/100L. These samples were collected from a treated water source.

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 Hudson's Hope water treatment system currently uses disinfection as the method of treatment.

Table 2. Historical parasite data for the Village of Hudson's Hope. Samples were collected from two different locations, both of which receive water treatment.

Date	*Cryptosporidium* (oocysts/100L)	*Giardia* (cysts/100L)
District Hall July 9/02	>2	**5.9**
*Municipal Hall June 11/02	>1	**5.0**
+Municipal Hall July 2/02	>1.7	**10**

*River Water and Spring Water
+River Water Only

Water Chemistry

The historical chemistry data (Table 3, Appendix A) collected by the District of Hudson's Hope includes samples collected during 2001 and 2002. As indicated, three parameters were over recommended drinking water quality guidelines. Specific conductivity, measured at 717 µS/cm on July 30th, 2002, was over its respective water quality guideline of 700 µS/cm. Turbidity was measured at 1.5 NTU on July 30th, over its respective water quality guideline of 1 NTU. Hardness was measured at 415 mg/L $CaCO_3$ on July 30th, which is considered to be very hard and approaching the guideline value of 500 mg/L $CaCO_3$.

Elevated hardness and specific conductivity values were also recorded during the MOE 2002/03 monitoring program, so will be discussed later in this report. The turbidity levels in the Peace River at Hudson's Hope are most likely influenced by the W.A.C. Bennett Dam. High turbidity levels can interfere with the disinfection process as well as being aesthetically unpleasant (RIC, 1998).

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 Hudson's Hope 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.

Fourteen parameters exceeded these acceptance criteria and are listed below in Table 4.

Table 4. Blind blank samples that tested strongly positive (≥ 5-fold MDL for chemical contamination.

Date	Parameter	Measured Concentration	MDL
Oct. 8/02	Strontium-T	0.079 µg/L	0.005 µg/L
Oct. 8/02	Strontium-D	0.03 µg/L	0.005 µg/L
Oct. 8/02	Uranium-T	0.012 µg/L	0.002 µg/L
Jan. 13/03	Cadmium-T	0.11 µg/L	0.01 µg/L
Jan. 13/03	Cadmium-D	0.07 µg/L	0.01 µg/L
Jan. 13/03	Strontium-T	0.068 µg/L	0.005 µg/L
Jan. 13/03	Tin-T	0.08 µg/L	0.01 µg/L
Jan. 13/03	Tin-D	0.06 µg/L	0.01 µg/L
Mar. 3/03	Sulphate	3.2 mg/L	0.5 mg/L
Mar. 3/03	Strontium-T	0.091 µg/L	0.005 µg/L
Apr. 29/03	Strontium-T	0.034 µg/L	0.005 µg/L
Apr. 29/03	Uranium-T	0.03 µg/L	0.002 µg/L
May 27/03	Strontium-T	0.048 µg/L	0.005 µg/L
May 27/03	Strontium-D	0.029 µg/L	0.005 µg/L

All of the blank concentrations that exceeded five times the MDL were still well below their respective provincial raw 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 drinking water guidelines.

The six water chemistry duplicate samples that were prepared either the same day or within one day of the Peace River collection did have some values outside the lab acceptance criteria of 25 % relative percent difference (Table 5, 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 and zinc, which both had concentrations well above their respective detection level. All parameters that did have differences greater than 25 % between duplicates existed at well below recommended drinking water guidelines.

Bacteriology

The 2002/03 bacterial data are summarised in Table 6. Drinking 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.

No high bacterial concentrations were detected in any of the samples. Although total coliforms were detected above the detection level on Oct. 8th, 2002, there is currently no recommended guideline for these bacteria. Furthermore, total coliforms are found naturally in many water bodies and do not necessarily indicate harmful land use activities.

Table 6. Results of bacterial analyses of the Village of Hudson's Hope raw water supply. 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.)
Oct. 8/02	5;6	<1; <1	<1;<1	<1; 1
Jan. 13/03	<1	<1	<1	<1
Mar. 3/03	<1	<1	<1	<1
Apr. 28/03	<2; <2	<2; <2	<2; <2	<2; <2
May 26/03	<1; <1	<1; <1	<1;<1	<1; <1
Aug. 18/03	<1;<1	<1;<1	<1;<1	<1;<1

Parasitology

The 2002/03 parasite data are summarised in Table 7. No *Cryptosporidium* oocysts or *Giardia* cysts were detected in any of the samples through the duration of this study. From this dataset, it is apparent that protozoa densities in the Peace River at Hudson's Hope are generally low throughout the year. However, there were *Giardia* cysts detected in the historical dataset as seen in Table 2.

Table 7. Parasite densities observed in the Village of Hudson's Hope raw water supply over the period October 29th/2002 to August 18th/2003.

Date	*Cryptosporidium* (oocysts/100L)	*Giardia* (cysts/100L)
*Oct. 29/02	<4.2	<4.2
Jan. 13/03	<4	<4
Mar. 3/03	<3.9	<3.9
Apr. 28/03	<4.3	<4.3
May 26/03	<3.7	<3.7
Aug. 18/03	<4.5	<4.5

*Sample collected directly from Peace River.

Water Chemistry

In 2002/03, the Hudson's Hope raw water supply 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, two exceeded recommended water quality guidelines and one had concentrations ≥ 75% the guideline value:

Specific Conductance (µS/cm) - Specific Conductance measurements averaged 716 µS/cm with a maximum of 972 µS/cm, both over the recommended water quality 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.

Hardness (mg/L $CaCO_3$) - High values of both total and dissolved hardness were detected. Mean and maximum total hardness values were 438 mg/L and 572 mg/L $CaCO_3$, respectively. Mean and maximum dissolved hardness values were 417 and 586 mg/L $CaCO_3$, respectively. Waters that exceed 120 mg/L $CaCO_3$ are considered hard and the recommended dissolved hardness water quality guideline is ≤ 500 mg/L $CaCO_3$. 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 (RIC, 1998). Hudson's Hope hardness may also be influenced by the spring water that enters the water supply near the pipe intake.

Total Organic Carbon (mg/L) - The maximum TOC concentration was 3.3 mg/L, just below 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 influence the formation of trihalomethanes which are considered carcinogens. Anthropogenic sources of TOC include agricultural, municipal and industrial waste discharges (RIC, 1998). Natural sources of TOC include organic soils, wetlands and organic material in the water column.

The data from this study indicate most chemical parameters in the Peace River are of low concentration throughout the year.

A complete list of the results as well as their corresponding water quality guideline is attached in Table 1, Appendix A. The raw data collected throughout the program is attached in Table 8, Appendix A.

Conclusions & Recommendations

Review of the Peace River data indicates a good overall raw drinking water quality. Most water soluble contaminants were present at concentrations well below drinking water guidelines. Very hard water, high specific conductance and TOC values approaching guideline levels were the only parameters of concern during this study. As indicated by Marsh Ness, both water hardness and high algal densities have been problems in the past. The new filtration system and water treatment plant proposed at Hudson's Hope are intended to help deal with these problems. Additionally, the elevated water hardness concentrations are likely the result of spring water entering the river water system. Using river water alone would probably help decrease these hardness levels.

Future sampling considerations should include the monitoring of trihalomethanes in treated water, which are a known bi-product of high organic concentrations reacting with chlorine. Parasites, which were detected in the historical data, should be monitored in treated water.

Acknowledgements

We thank the District of Hudson's Hope for their useful insight 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. The NHA for their input to program planning. We are grateful to Water Survey of Canada for making their hydrometric data on the Peace River available to us.

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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 1. 2002/03 sample parameters, their Minimum Detectable Limit (MDL), and their associated B.C. water quality guideline.

Parameter	# of Values	Min.	Max.	Mean	Std. Dev.	MDL	D.W. Guideline	Guideline Type
General								
pH	6	7.85	8.2	8.05	0.141	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	162.5	972.5	715.8	283.34	1	≤ 700	maximum acceptable concentration
Turbidity (NTU)	4	0.235	0.8	0.5	0.25	0.1	≤ 5	maximum acceptable concentration
Hardness Total (mg/L)	6	95.45	572.5	437.7	171.30			
Hardness Total -Diss. (mg/L)	6	94.05	585.5	416.6	167.69		≤ 500 $CaCO_3$	aesthetic objective
Alkalinity (mg/L)	6	78.5	268.5	207.8	66.60	0.5		
Residue Non-Filterable (mg/L)	6	4	5	4	0.41	4		
Total Organic Carbon (mg/L)								
TOC	5	1	3.3	1.6	0.87	0.5	≤ 4	maximum, to control THM production
Anions (mg/L)								
Chloride Dissolved	6	0.65	2.55	1.90	0.694	0.5	≤ 250	aesthetic objective
Fluoride Dissolved	6	0.035	0.17	0.132	0.051	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	0.04	0.083	0.063	0.017	0.002	≤ 45 (Nitrate)	maximum acceptable concentration
Phosphorus Total	6	0.002	0.006	0.004	0.001	0.002		
Phosphorus Total-Diss.	6	0.0025	0.008	0.005	0.002	0.002		
Sulphate (mg/L)								
Sulphate	6	18.05	291.5	202.3	94.98	0.5	≤ 500	aesthetic objective
Metals Total (ug/L)								
Aluminum-T	6	8.2	41.3	17.2	12.65	0.3		
Aluminum-D	6	0.9	11.9	3.3	4.23	0.3	≤ 200	maximum acceptable concentration
Antimony-T	6	0.038	0.067	0.055	0.010	0.005	≤ 6	interim maximum acceptable concentration
Antimony-D	6	0.038	0.056	0.048	0.006	0.005		
Arsenic-T	6	0.15	0.3	0.2	0.06	0.1	≤ 25	interim maximum acceptable concentration
Arsenic-D	6	0.15	0.3	0.2	0.07	0.1		
Barium-T	6	25.35	29.75	27.31	1.642	0.02	≤ 1000	maximum acceptable concentration
Barium-D	6	25.2	28.45	27.41	1.176	0.02		
Beryllium-T	6	0.02	0.03	0.02	0.004	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	0.01	0.26	0.06	0.098	0.01	≤ 5	maximum acceptable concentration
Cadmium-D	6	0.01	0.19	0.05	0.070	0.01		
Calcium-T (mg/L)	6	27.7	123	96.4	34.35	0.05		
Calcium-D (mg/L)	6	27.1	126	91.98	33.789	0.05		
Chromium-T	6	0.2	0.35	0.23	0.061	0.2	≤ 50	maximum acceptable concentration
Chromium-D	6	0.2	0.4	0.2	0.08	0.2		
Cobalt-T	6	0.005	0.05	0.02	0.018	0.005		
Cobalt-D	6	0.005	0.035	0.011	0.012	0.005		
Copper-T	6	0.49	0.76	0.58	0.096	0.05	≤ 1000	aesthetic objective
Copper-D	6	0.455	0.985	0.595	0.199	0.05		
Iron-T (mg/L)	5	0.024	0.047	0.031	0.009	0.005	≤ 0.3	aesthetic objective
Iron-D (mg/L)	5	0.005	0.005	0.005	0.000	0.005		
Lead-T	6	0.03	0.33	0.16	0.133	0.01	≤ 10	maximum acceptable concentration
Lead-D	6	0.01	0.22	0.08	0.092	0.01		
Lithium-T	6	0.155	9.265	6.642	3.329	0.05		
Lithium-D	6	0.19	8.98	6.69	3.301	0.05		

Table 1 Continued.

Parameter	# of Values	Min.	Max.	Mean	Std. Dev.	MDL	D.W. Guideline	Guideline Type
Magnesium-T (mg/L)	6	6.38	64.5	47.8	20.78	0.05		
Magnesium-D (mg/L)	6	6.4	65.85	45.39	20.247	0.05	≤ 100	aesthetic objective
Manganese-T	6	0.785	2.74	1.48	0.702	0.008	≤ 50	aesthetic objective
Manganese-D	6	0.546	1.225	0.839	0.248	0.008		
Molybdenum-T	6	0.725	3.855	2.806	1.084	0.05	≤ 250	maximum acceptable concentration
Molybdenum-D	6	0.765	3.56	2.75	1.015	0.05		
Nickel-T	6	0.05	0.05	0.05	0.000	0.05		
Nickel-D	6	0.05	0.05	0.05	0.000	0.05		
Selenium-T	6	0.25	0.5	0.36	0.086	0.2	≤ 10	maximum acceptable concentration
Selenium-D	6	0.2	0.4	0.3	0.08	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	4.91	6.8	5.7	0.69	0.05	≤ 200	aestheic objective
Strontium-T	6	102	478	341	127.2	0.005		
Strontium-D	6	99.25	472	333.38	125.530	0.005		
Thallium-T	6	0.002	0.002	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	0.03	0.02	0.009	0.01		
Tin-D	6	0.01	0.02	0.01	0.004	0.01		
Uranium-T	6	0.433	1.215	0.921	0.261	0.002	≤ 100	maximum acceptable concentration
Uranium-D	6	0.435	1.175	0.905	0.250	0.002		
Vanadium-T	6	0.345	1.38	0.923	0.370	0.06	≤ 100	maximum acceptable concentration
Vanadium-D	6	0.33	1.18	0.748	0.305	0.06		
Zinc-T	6	0.5	6.15	3.78	1.901	0.1	≤ 5000	aesthetic objective
Zinc-D	6	0.2	5.6	3.4	1.87	0.1		

Table 3. Historical chemistry data for the Village of Hudson's Hope. Samples were collected directly from the Peace River by the district.

Physical	**March 28/01**	**July 30/02**		**March 28/01**	**July 30/02**
pH	7.85	7.67	Arsenic-D	<0.01	<0.0002
Colour (TCU)	7	4	Barium-D	0.0325	0.035
Specific Conductance (µS/cm)	393	**717**	Bismuth-D	<0.007	<0.0005
Turbidity (NTU)	0.8	**1.5**	Cadmium-D	<0.0005	0.00004
Hardness Total (mg/L)	212	**415**	Calcium-D	54.1	99.7
T-Alkalinity (mg/L)	134	180	Chromium-D	<0.0008	0.0012
Total Dissolved Solids	243		Cobolt-D	<0.0007	<0.0001
Trihalomethanes (ug/L)			Copper-D	<0.001	<0.001
Chloroform	8		Iron-D	<0.003	<0.003
Cromodichloromethane	<1		Lead-D	<0.002	<0.0001
Dibromochloromethane	<1		Lithium-D	0.004	0.007
Bromoform	<1		Magnesium-D	20.9	45.6
Total Organic Carbon (mg/L)			Manganese-D	0.0034	0.0041
TOC	2.3	2.2	Molybdenum-D	0.002	0.003
Tannin & Ligin	0.14	0.14	Nickel-D	<0.001	<0.0005
Anions (mg/L)			Selenium-D	<0.004	0.0003
Chloride Dissolved	<0.5	2.9	Silver-D	<0.001	<0.0001
Fluoride Dissolved	0.09	0.15	Sodium-D	2.8	4.6
Nutrients (mg/L)			Strontium-T	0.21	0.402
Nitrate+Nitrite	0.072	0.152	Sulphur-D	30.9	71.7
Sulphate (mg/L)			Thallium-T	<0.004	<0.00005
Sulphate	<5	212	Tin-T	<0.003	<0.001
Metals Total (mg/L)			Vanadium-D	<0.001	0.0001
Aluminum-D	0.011	<0.005	Zinc-D	0.0008	0.006
Antimony-D	<0.005	<0.0002			

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

Parameter	MDL (µg/L)	October/02			January/03			March/03			April/03			May/03			August/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 %	Conc. 1	Conc. 2	RPD %
Aluminum-D	0.3																3	1.1	**92.7**
Antimony-T	0.005										0.05	0.084	**50.7**						
Cadmium-T	0.01				0.23	0.11	**70.6**												
Cobalt-T	0.005										0.021	0.03	**35.3**				0.036	0.064	**56**
Cobalt-D	0.005																0.027	0.043	**45.7**
Copper-T	0.05				11.8	28.3	**82.3**	16.5	6.64	**85.2**	0.62	0.9	**36.8**						
Copper-D	0.05	1.34	0.63	**72.1**				16.9	7.01	**82.7**	0.49	0.72	**38**						
Lithium-D	0.05	0.05 <	0.33	**147.4**															
Lead-T	0.01				0.1	0.22	**75**							0.12	0.09	**28.6**			
Vanadium-T	0.06	0.94	0.61	**42.6**										0.55	0.98	**56.2**			
Vanadium-D	0.06													0.62	0.9	**36.8**			
Zinc-T	0.1				1.3	2.9	**76**	86.6	1.5	**193**	4.9	7.4	**40.7**						
Zinc-D	0.1							90.9	1.6	**193**							2	4	**66.7**

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

Table 8. 2002/03 raw water quality data collected from the Hudson's Hope drinking water supply.

Date	Cryptosporidium (oocysts/100L)	Giardia (cysts/100L)	Total Coliform (CFU/100mL)	Fecal Coliform (CFU/100mL)	Enterococci (CFU/100mL)	E. Coli (CFU/100mL)	pH (pH Units)	True Colour (Col. Unit)	Specific Conductance (µS/cm)	Residues - NonFilt. (mg/L)	Turbidity (NTU)
08-Oct-02			5	<1	<1	<1	7.8	5	159	<4	
08-Oct-02			6	1	<1	<1	7.9	5	166	6	
29-Oct-02	<4.2	4.2									
13-Jan-03	<4	<4	<1	<1	<1	<1	8.2	<5	835	<4	
03-Mar-03	<3.9	<3.9	<1	<1	<1	<1	7.9	5	732	<4	0.8
28-Apr-03			<2	<2	<2	<2	8.1	<5	972	<4	0.41
28-Apr-03	<4.3	<4.3	<2	<2	<2	<2	8.2	<5	973	<4	0.5
26-May-03	<3.7	3.7	<1	<1	<1	<1	8.1	5	767	<4	0.68
26-May-03			<1	<1	<1	<1	8.1	5	763	<4	0.7
18-Aug-03			<1	<1	<1	<1	8.1	<5	828	<4	0.24
18-Aug-03	<4.5	<4.5	<1	<1	<1	<1	8.1	<5	827	<4	0.23

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)
95.2	94.1	78	<0.1	0.7	0.04
95.7	94	79	<0.1	0.6	0.03
501	487	240	<0.1	2.4	0.17
486	441	213	<0.1	1.6	0.12
568	576	268	<0.1	2.5	0.17
577	595	269	<0.1	2.6	0.17
476	433	212	<0.1	2.1	0.15
463	420	213	<0.1	2	0.15
492	468	235	<0.1	2.2	0.14
511	463	233	<0.1	2.1	0.15

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)
3.4	0.053	0.003	0.004	17.1	40.6
3.2	0.046	0.003	0.004	19	42
1.1	0.075	0.008	0.006	240	10.7
1.4	0.056	0.006	0.005	213	9.8
1	0.081	0.005	0.003	289	12
1	0.084	0.005	0.003	294	12.2
1.4	0.041	0.002	0.004	209	19.4
1.4	0.039	0.003	0.003	209	22.7
1.3	0.074	<0.002	<0.002	244	8.2
1	0.076	0.003	<0.002	241	8.2

Aluminum - Diss. (µg/L)	Antimony - Tot. (µg/L)	Antimony - Diss. (µg/L)	Arsenic - Tot. (µg/L)	Arsenic - Diss. (µg/L)	Barium - Tot. (µg/L)
11.3	0.058	0.051	0.2	0.1	29.8
12.5	0.045	0.04	0.2	0.2	29.7
1.7	0.038	0.038	0.3	0.3	27.3
1.7	0.052	0.049	0.2	0.3	25.6
0.9	0.05	0.046	0.1	<0.1	27.8
0.9	0.084	0.058	0.2	0.2	28.2
1.5	0.057	0.049	0.2	0.2	25.3
1.6	0.069	0.052	0.2	0.2	25.4
3	0.056	0.053	0.2	0.1	27.8
1.1	0.058	0.058	0.1	0.2	27.9

Barium - Diss. (µg/L)	Beryllium - Tot. (µg/L)	Beryllium - Diss. (µg/L)	Bismuth - Tot. (µg/L)	Bismuth - Diss. (µg/L)	Cadmium - Tot. (µg/L)
28.5	<0.02	<0.02	<0.02	<0.02	<0.01
28.4	<0.02	<0.02	<0.02	<0.02	<0.01
27.1	<0.02	<0.02	<0.02	<0.02	0.26
28.2	<0.02	<0.02	<0.02	<0.02	0.02
27.8	<0.02	<0.02	<0.02	<0.02	0.03
27.7	<0.02	<0.02	<0.02	<0.02	0.03
25.3	<0.02	<0.02	<0.02	<0.02	0.02
25.1	<0.02	<0.02	<0.02	<0.02	0.02
27.7	<0.02	<0.02	<0.02	<0.02	0.02
27.8	0.04	<0.02	<0.02	<0.02	0.02

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	27.6	27.1	<0.2	<0.2	<0.005
<0.01	27.8	27.1	<0.2	<0.2	<0.005
0.19	110	107	<0.2	<0.2	<0.005
0.02	106	96.8	<0.2	<0.2	0.005
0.03	122	124	<0.2	<0.2	0.021
0.03	124	128	<0.2	<0.2	0.03
0.02	104	94.8	<0.2	<0.2	0.013
0.02	101	92.2	<0.2	<0.2	0.013
0.02	107	102	0.4	0.4	0.036
0.02	111	101	0.3	0.4	0.064

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	0.62	1.34			0.03
<0.005	0.62	0.63			0.03
<0.005	0.49	0.55	0.025	<0.005	0.32
<0.005	0.55	0.47	0.028	<0.005	0.33
0.019	0.62	0.49	0.032	<0.005	0.15
0.005	0.9	0.72	0.034	<0.005	0.16
<0.005	0.54	0.44	0.046	<0.005	0.12
0.005	0.58	0.47	0.048	<0.005	0.09
0.027	0.52	0.52	0.024	<0.005	0.04
0.043	0.53	0.49	0.024	<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	0.11	<0.05	6.38	6.41	2.72
<0.01	0.2	0.33	6.38	6.39	2.76
0.17	7.54	7.9	55	53.3	0.785
0.22	7.04	7.39	53.7	48.4	0.863
0.04	9.43	9.3	64	64.8	1.39
0.03	9.1	8.66	65	66.9	1.46
0.02	6.97	6.75	52.5	47.7	1.57
0.03	6.78	6.78	51.1	46.2	1.59
<0.01	9.1	9.06	54.5	51.7	1.5
<0.01	8.85	8.81	56.9	51.2	1.43

Manganese - Diss. (µg/L)	Molybdenum - Tot. (µg/L)	Molybdenum - Diss. (µg/L)	Nickel - Tot. (µg/L)	Nickel - Diss. (µg/L)	Selenium - Tot. (µg/L)
0.655	0.73	0.78	<0.05	<0.05	0.4
0.817	0.72	0.75	0.05	<0.05	0.3
0.546	3.02	3.04	<0.05	<0.05	0.5
0.653	2.78	2.94	<0.05	<0.05	0.4
0.988	3.78	3.53	<0.05	<0.05	<0.2
1.02	3.93	3.59	<0.05	<0.05	0.4
0.858	3.07	2.83	<0.05	<0.05	0.3
0.886	3.11	2.79	<0.05	<0.05	0.4
1.25	3.36	3.4	<0.05	<0.05	0.3
1.2	3.37	3.41	<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		101	98.5	<0.002	<0.002
<0.2	<0.02	<0.02		103	100	<0.002	<0.002
0.3	<0.02	<0.02	5.66	349	355	<0.002	<0.002
0.4	<0.02	<0.02	5.43	382	340	<0.002	<0.002
0.2	<0.02	<0.02	6.76	482	477	<0.002	<0.002
0.5	<0.02	<0.02	6.84	474	467	<0.002	<0.002
0.2	<0.02	<0.02	4.95	337	340	<0.002	<0.002
0.4	<0.02	<0.02	4.87	333	331	<0.002	<0.002
<0.2	<0.02	<0.02	5.63	399	397	<0.002	<0.002
0.2	<0.02	<0.02	5.9	397	400	<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	0.433	0.44	0.94	0.47	0.6	<0.1
0.02	<0.01	0.432	0.429	0.61	0.53	0.4	0.3
0.02	0.02	1.03	1.03	1.08	0.95	4.7	4.8
0.03	<0.01	0.965	0.925	1.38	0.77	4.3	3.7
<0.01	<0.01	1.23	1.17	1.21	1.27	4.9	4.7
<0.01	<0.01	1.2	1.18	1.17	1.09	7.4	6.5
0.02	<0.01	0.974	0.956	0.55	0.62	3	2.9
0.04	<0.01	0.951	0.923	0.98	0.9	3.1	3
<0.01	<0.01	0.922	0.923	0.34	0.34	4	2
0.01	<0.01	0.917	0.926	0.35	0.32	4	4