Assessment of the Fort Nelson 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 Muskwa River downstream of the Alaska Highway bridge. The pump house is located directly across the river from this view.

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 raw source water,
- 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 City of Fort Nelson's community pump house and directly from its raw potable water source, the Muskwa 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 supply 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.

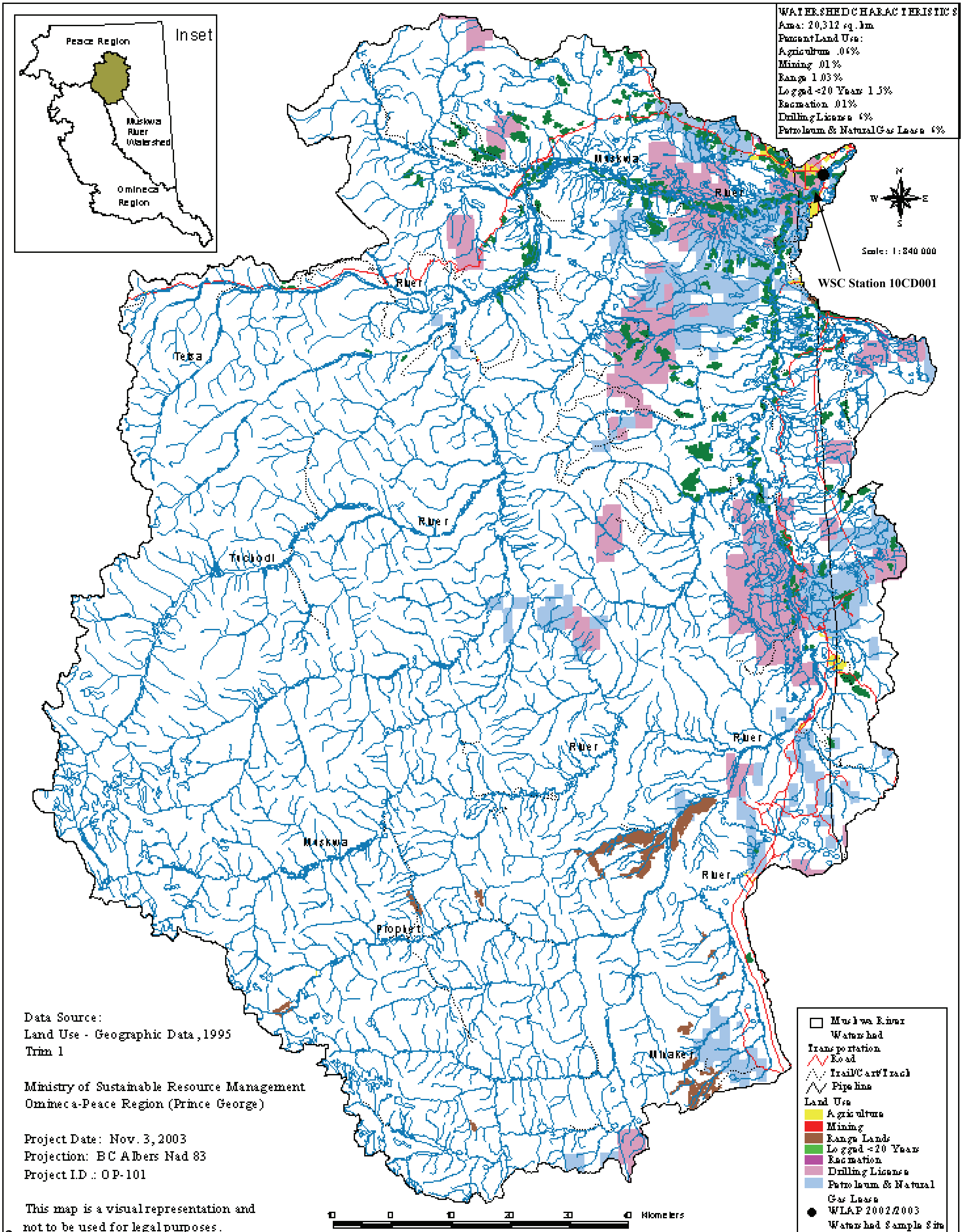

Figure 1. The Muskwa River watershed and associated land-use practices upstream of the City of Fort Nelson.

Site Description

Watershed Overview

The Muskwa River watershed lies within two biogeoclimatic zones including the Boreal White and Black Spruce zone and the Spruce-Willow-Birch zone. The Spruce-Willow-Birch zone experiences long cold winters and brief cool summers. The zone is characterized by white spruce and sub-alpine fir, along with some lodgepole pine and trembling aspen. The Boreal White and Black Spruce zone has 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 (Ministry of Forests, 1998).

As measured at the Fort Nelson Water Survey of Canada station 10CD001 (Figure 1), the Muskwa River drains approximately 20,300 km^2 and has a total length of 400 km. The general trend of the river is northeast, with some minor shifts in other directions. The mainstem of the Muskwa drains into the Fort Nelson River of Fort Nelson, and eventually into the Liard River. There are many tributaries that enter the Muskwa River, with a complete list of the named tributaries being available at fishwizard.com.

Many land use activities exist in the Muskwa drainage, however most are present at low densities (Figure 1). These activities include oil & gas, forestry, mining, urban development, and agriculture (including livestock activities), all of which may affect regional water quality.

There are four major waste disposal permits with relevance to the Muskwa River around the City of Fort Nelson. Three of these are downstream of the drinking water intake, so are not expected to be relevant in this study. The one upstream source is a trailer park that discharges waste to the ground. This discharge site is relatively far from the river itself, so is not expected to have significant impacts on the river water quality.

Two water withdrawal licenses have been permitted on the Muskwa: (1) Tackama Forest Products Ltd. (2.832×10^4 m^3/yr) and (2) City of Fort Nelson (2.574×10^4 m^3/yr). Based on information reported by Lands and Water B.C. and discharge data supplied by Environment Canada, the total annual volume of water licensed to the various users is 5.406×10^4 m^3, which is the equivalent of 8.06×10^{-4} % of the annual flow at the Fort Nelson flow station during average years, according to flow records over the period 1990 to 2000.

Basic Hydrology

Flows in the lower Muskwa River are lowest during the winter months (December through March) and highest during June and July (Figure 2). While we have not had the opportunity to undertake a detailed investigation of hydrological factors that control flows in the Muskwa River, the hydrograph based on the most-recent decade of data shows somewhat normal flow patterns for a large northern B.C. river. If there are land use impacts altering flows within the Muskwa (e.g. agricultural and forestry related land clearings, road building, oil & gas activities, etc.), these small scale impacts are likely buffered to some extent by the large drainage area. Recent hydrometric data indicate that summer flows in the Muskwa River are influenced by precipitation events, with this observation being corroborated by regional water purveyor Mr. Harold DeJong (City of Fort Nelson, Public Works Department, Pers. Comm., March 18th, 2003). Further discussions with Mr. DeJong indicate that there are currently no concerns regarding both source water quality or quantity.

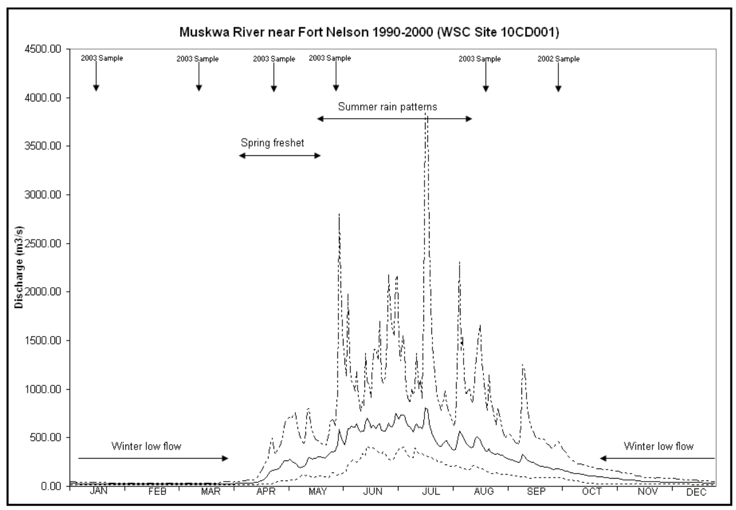

Figure 2. Lowest (bottom line), average (middle line) and maximum (upper line) daily flows observed in the Muskwa River near Fort Nelson

Drinking Water Supply & Treatment

The City of Fort Nelson draws its domestic water from the Muskwa River, downstream of the Alaska Highway bridge crossing, at geographic coordinates 58.7881N/122.6579W. From the pump house, the water is piped approximately 2 km to the water treatment plant where it is coagulated, filtered and chlorinated. During the spring and summer months, the city uses raw water that is stored in three similar sized reservoirs that hold approximately 110 million gallons. During this period, water withdrawal from the Muskwa River is suspended due to high turbidity levels. Based on 2001 statistics, the City of Fort Nelson water supply serves approximately 4,200 people.

The city has no current concerns with the existing water system, as the river is not used directly during periods of high turbidity (spring and summer). Furthermore, Mr. DeJong has indicated there are no concerns with water quantity, treatment and/or distribution.

Materials & Methods

Review of Previous Data

Historic data relevant to the City of Fort Nelson raw water supply assessment have been included in this report. Two data sets, both collected by the Northern Rockies Regional District, are included. The samples were collected directly from the Muskwa River near the Fort Nelson water intake.

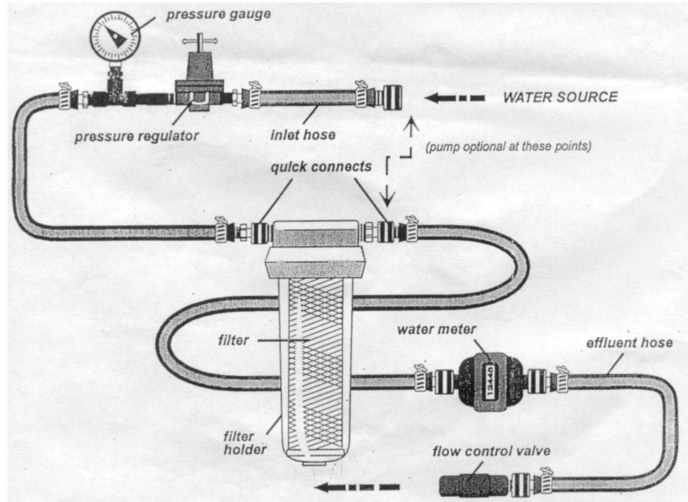

Figure 3. Schematic of the high-volume filtration unit used to sample raw water for Cryptosporidium oocysts and Giardia cysts (from EPA 1995).

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 Muskwa River during the summer months when the raw water tap in the city pump house was not operational, and directly from the raw water tap during pumping periods (site E249351 - Water Source ID Tag 1343). The chemical results, analytical detection levels and drinking water quality guidelines are provided in Table 1, Appendix A.

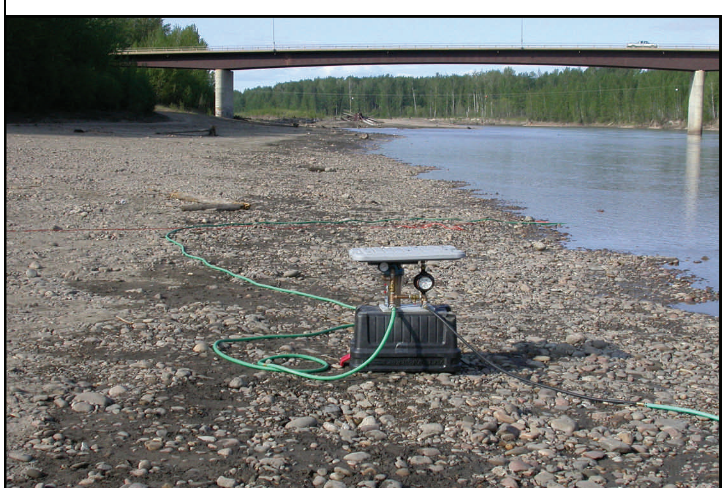
Plate 2. A view of the parasite kit located on the right bank of the Muskwa River.

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. Prior to sampling the raw-water tap, this 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. (September 2002-March 2003) and JR Laboratories Inc. (April 2003-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 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.

Bottom Sediment Quality

Bottom sediments were collected from the Muskwa River during the October, 2002 and August, 2003 low flow's. Stream sediment was analyzed to determine the possible presence of upstream sources of contaminants that were not detected in the water samples. Where follow up is deemed to be necessary, additional monitoring will depend on the type and level of contamination. Samples were collected from several submerged silt/clay areas in the stream using two acetone washed stainless steel spoons for organic analysis, and plastic spoons for metal/grain size analysis. At least one 3-5 cm deep sediment sample was gently scooped from each of a number of these depositional areas with the large spoon. Each of these scoops was sub-divided from the larger spoon into jars for grain size, total organic carbon, hydrocarbons and pesticides, using a second, smaller spoon. Sampling proceeded in an upstream direction with each depositional zone contributing a small amount of fine sediment to each container. Sediment samples were kept cool and shipped to PSC Environmental Laboratories Ltd. for analysis within three days of collection. Samples for metals analysis were dried with heat, disaggregated, sieved at 2 mm and leached with a strong acid. Samples for organic analysis were processed wet and without screening. Results are expressed in dry weight. The sample date and sample parameter concentrations are provided in Table 2, Appendix A.

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

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 number.

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

Results

Review of Previous Data

Bacteriology

The Northern Rockies Regional District sampled the Muskwa River near the Fort Nelson pump house (twice for bacteria) during 2002. Fecal coliforms were detected on both March 5th, 2002 and September 11th, 2002, at concentrations of 1 CFU/100mL and 5 CFU/100mL, respectively. These concentrations are both within the recommended water quality guideline for raw water entering systems with complete water treatment, however, there may be potential for human illness should this treatment system fail.

Water Chemistry

Water chemistry results from the Regional District samples are presented in Table 3, Appendix A.

The data for these two dates did not show significant problems, however the turbidity and colour levels did exceed their recommended drinking water guidelines. The City of Fort Nelson's settling reservoirs as well as their water filters should help deal with the high turbidity levels. Additionally, the complete treatment process would help deal with the colour issue. The high concentration of these two parameters may have been influenced by fall rains (Figure 2) that typically occur in September. While many natural sources can influence these parameters, common anthropogenic sources are agricultural and industrial effluents for colour, and forest harvesting, road building, agriculture and/or urban development for turbidity.

Table 3 also summarizes the metals results from these same samples. All metals were within recommended guidelines except for an exceedance by iron on the Sept. 11th, 2002 sample. The recorded value of 1.1 mg/L was over the aesthetic water quality guideline of 0.3 mg/L.

Tests were also done measuring polychlorinated biphenyls and organochlorine pesticides, however all results were less than their MDL.

Water Monitoring Program (2002/03)

Quality Assessment (QA)

The field blank sample 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 Muskwa River collection 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. Eleven parameters exceeded these acceptance criteria significantly and are listed in Table 4.

Although the levels of some of these results are greater than the concentrations observed in the Muskwa River, they 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.

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	Uranium-T	0.012 µg/L	0.002 µg/L
Jan. 14/03	Cadmium-T	0.11 µg/L	0.01 µg/L
Jan. 14/03	Strontium-T	0.068 µg/L	0.005 µg/L
Jan. 14/03	Tin-T	0.08 µg/L	0.01 µg/L
Jan. 14/03	Tin-D	0.06 µg/L	0.01 µg/L
Mar. 4/03	Sulfate	3.2 mg/L	0.5 mg/L
Mar. 4/03	Strontium-T	0.091 µg/L	0.005 µg/L
Apr. 29/03	Strontium-T	0.034 µg/L	0.005 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

The six water chemistry duplicate samples that were prepared either the same day or within one day of the Muskwa River 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. Most parameters that did have differences greater than 25% between duplicates existed at well below recommended drinking water guidelines. The only parameter to exceed these guidelines was the colour value collected during April, 2003. During this April run, many of the rivers were at bank full capacity and turbid, experiencing the first part of spring runoff. During this period, the river water appeared very heterogeneous.

The duplicate sediment samples indicated that the variations between duplicates were most likely the result of natural in-stream variations rather than collection and/or analytical inconsistencies (Table 6, Appendix A). The lab acceptance criteria for duplicate variation is 35% for metals and other inorganics. All duplicate values, as indicated in Table 6, are within this range.

Bacteriology

The 2002/03 bacterial data are summarised in Table 7. There are no water quality guidelines for raw drinking water receiving complete treatment, however the guideline for raw water receiving no treatment is 0 CFU/100mL for *E. coli*, *Enterococci* and fecal coliforms.

The highest bacterial counts occurred on October 8th, 2002, May 27th, 2003 and August 19th, 2003. The *E. coli*, *Enterococci* and fecal coliform levels were all above 0 CFU/100mL on October 8th with *Enterococci* and fecal coliform levels being greater than 0 CFU/100mL on May 27th. All bacterial levels were greater than 0 CFU/100mL on the August 19th sample. The presence of these fecal coliforms, which originate from the intestines of warm-blooded mammals, indicate that the feces of wildlife, range animals and/or human waste are entering the Muskwa upstream of the water intake. These levels indicate that there is potential for bacterial-related human illness should water treatment become ineffective.

Table 7. Results of bacterial analyses for the City of Fort Nelson's raw water supply (samples from raw water tap in Fort Nelson pump house, water treatment plant, and directly from Muskwa River). Units are CFU/100mL.

Date	Total Coliform	*E. coli*	*Enterococci*	Fecal Coliform
Oct. 8/02	5	**5**	**6**	**5**
Jan. 14/03	1	<1	<1	**1**
Mar. 4/03	2; <1	<1;<1	<1; <1	<1; <1
Apr. 29/03 +	<2	<2	<2	<2
May 27/03 *	70	<2	**12**	**18**
Aug 19/03	340	**23**	**57**	**28**

**- Collected directly from Muskwa River; +- Collected from water treatment plant raw water tap.*

Parasitology

The 2002/03 parasite data are summarised in Table 8. High *Giardia* levels were detected on October 30th, 2002, January 14th, 2003 and March 4th, 2003. By comparison, *Cryptosporidium* oocysts were only detected on Oct. 30th, 2002. High turbidity levels in the Muskwa River increased the detection level on the May 27th/03 sample. Parasites were not collected from the raw water tap on the April 29th and May 27th dates, as the city stopped pumping water during the turbid water conditions. The sample was collected from the raw water tap in the water treatment plant on April 29th, as dangerous ice conditions prevented access to the river. This sample may not be representative, as the water collected was held within large holding reservoirs before feeding the raw water tap. This may have affected the cyst distribution in the water column, which would then decrease the concentration detected in our sample.

Table 8. Parasite densities observed in the City of Fort Nelson's raw water supply over the period October 30th/2002 to May 27th/2003 (samples from raw water tap in Fort Nelson pump house, water treatment plant, and directly from Muskwa River).

Date	Detection Limit (number/100L)	*Cryptosporidium* (oocysts/100L)	*Giardia* (cysts/100L)
Oct. 30/02	-	**30.4**	**758.9**
Jan 14/03	<4.5; <4.3	<4.5; <4.3	**193.9; 142.9**
Mar. 4/03	<4	<4	**188.5**
Apr. 29/03 +	<4.1	<4.1	4.1
May 27/03 *	<85.5	<85.5	<85.5
Aug. 19/03	<52.1	<52.1	<52.1

**- Collected directly from Muskwa River; +- Collected from water treatment plant.*

Data collected in 2002/03 indicate that there is a problem with high *Giardia* cyst densities in the Muskwa River. Human illness resulting from *Giardia* infection is possible should treatment become ineffective.

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 Fort Nelson water treatment system currently uses coagulation, filtration and chlorination as means of treatment.

Water Chemistry

In 2002/03, the Fort Nelson 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, seven were of interest (i.e. they either exceeded or were just below water quality guidelines). A description of these parameters, their concentrations during this study and possible anthropogenic sources are listed below (RIC, 1998).

Colour (TCU) - The mean colour concentration for the year was 28 TCU with a maximum of 120 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. Colour can also originate naturally from organic soils and wetlands.

Specific Conductance (µS/cm) - Specific Conductance measurements were always under the recommended guideline of 700 µS/cm, however, a maximum value of 610 µS/cm was recorded. High specific conductivity values indicate a high ion concentration, which can be related to the dissolved solids content of the water.

Turbidity (NTU) - The mean turbidity was 100 NTU, above the 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).

Some possible sources of increased turbidity are forest harvesting, road building, agriculture and urban development. Natural ground instabilities can also influence high turbidity levels.

Hardness, Total (mg/L $CaCO_3$) - The mean hardness of the raw water was 277 mg/L $CaCO_3$. Waters that exceed 120 mg/L $CaCO_3$ are considered hard. 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 sources that contribute to water hardness are mining and industrial effluents.

Total Organic Carbon (mg/L) - The maximum TOC concentration was 6.6 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. Natural sources are similar to those for colour.

Iron, Total (mg/L) - The mean iron concentration was 4.2 mg/L with a maximum value of 16.8 mg/L, both exceeding the aesthetic guideline of 0.3 mg/L. 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 mean manganese concentration was 64 µg/L with a maximum of 171 µg/L, both exceeding the aesthetic objective of 50 µg/L. Similar to iron, manganese can colour water and form colloidal material that can be difficult to remove.

The remaining parameters generally had low concentrations and are below recommended water quality guidelines. For a complete list of the parameters and their associated concentrations, refer to Table 1 in Appendix A. For a list of the raw data, refer to Table 9, Appendix A.

Bottom Sediment Chemistry

Of the 29 sediment metals analyzed, 27 were detected on both October 30th, 2002 and August 19th, 2003 (Table 2, Appendix A). High concentrations of arsenic, cadmium, copper and nickel were found, however, water samples collected throughout the duration of this project showed very low concentrations of these metals relative to existing drinking water guidelines.

Total oil & grease was not detected on the October 30th, 2002 sample however was detected on the August 19th, 2003 sample at a concentration of 190 µg/g.

Polycyclic aromatic hydrocarbons were detected in trace amounts (Table 10). PAH's were detected in higher concentrations during the 2003 collection, with a total PAH concentration of 0.35 µg/g. This concentration is relatively low, however is more than quadruple the concentration found in 2002. Lower molecular weight PAH's are acutely toxic to aquatic life. Anthropogenic sources of PAH's include fossil fuels, agricultural burning, industrial processes, pest treatment and urban runoff (RIC, 1998).

Table 10. Polycyclic aromatic hydrocarbons detected in Muskwa River sediments in trace amounts.

Compound	Conc. (µg/g) Oct. 02	Conc. (µg/g) Aug. 03	Compound	Conc. (µg/g) Oct. 02	Conc. (µg/g) Aug. 03
Benzo(b)fluoranthene	0.02	<0.02	Phenanthrene	0.04	0.11
Benzo(g,hi)perylene	<0.02	0.06	C1-Phen/Anthracene	0.12	0.17
Chrysene	0.03	0.06	C2-Phen/Anthracene	0.12	0.11
Fluoranthene	<0.01	0.02	Pyrene	0.02	0.04
Fluorene	<0.01	0.02	Total PAHs	0.08	0.35
Napthalene	<0.01	0.04	Total Low MW PAHs	0.04	0.17
C1-Naphthalenes	0.07	0.08	Total High MW PAHs	0.04	0.18
C2-Naphthalenes	0.09	0.22			

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

- Chlorinated phenols
- Phenoxy acid herbicides
- Organochlorine pesticides
- Polychlorinated biphenyls
- Organophosphorus pesticides

Conclusions & Recommendations

Review of the Muskwa River data indicates a raw water quality unsuitable for human consumption without treatment. Bacteria and *Giardia* were detected at high concentrations, suggesting that warm-blooded animals or runoff from animal waste are accessing the Muskwa or tributaries upstream of the water intake. Although wildlife may be the source of most of these organisms, there are range activities in the watershed as indicated on Figure 1.

As shown on the land use map there is an abundance of forestry activities near the banks of the Muskwa River. Forestry activities are known to increase turbidity levels in streams, especially through forest clearing and road building. These forestry activities may be related to the high turbidity levels recorded in the Muskwa River during this study.

Many of the other chemical parameters detected over recommended water quality guidelines naturally occur in many northern streams. The abundance of muskeg in the drainage may influence many of these parameters (e.g. colour, TOC, specific conductance, etc).

PAH's and oil & grease were detected in the Muskwa River sediment, indicating possible contamination from either industrial and/or recreational practices. As indicated on Figure 1, there is an abundance of oil & gas related activities upstream of the water intake. Furthermore, many boats use the Muskwa during summer months that may leak harmful contaminants into the river.

Further water and sediment quality monitoring is recommended for the City of Fort Nelson, as many of the parameters that exceeded guidelines have the potential to cause human illness should treatment become ineffective. Monitoring of treated water for both chemical parameters of interest and parasites may be beneficial. Further sediment monitoring for PAH detection may be useful for identifying possible anthropogenic contamination.

Acknowledgements

We thank Mr. Bruce Hupman (Northern Rockies Regional District) as well as the employees at the Fort Nelson water treatment plant for their help throughout the project. Mr. Todd French is recognized for his help in designing and implementing the project (TDF Watershed Solutions, Research & Management). Mr. Mohamad Khan (Enhanced Water Laboratory, B.C. Centre for Disease Control, Vancouver) provided us with the *Cryptosporidium* and *Giardia* sampling equipment, documentation on parasite collection methodologies and information critical to data interpretation. We are grateful to Water Survey of Canada for making their hydrometric data on the Muskwa River available to us.

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

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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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	7.9	8.2	8.133	0.121	0.1	6.5-8.5	aesthetic objective
Colour (TCU)	6	5	120	28.333	45.350	5	$\leq$ 15	aesthetic objective
Specific Conductance (µS/cm)	6	279	610	458.7	155.28	1	$\leq$ 700	maximum acceptable concentration
Turbidity (NTU)	6	1.25	330	99.7	156.4	0.1	$\leq$ 5	maximum acceptable concentration
Hardness Total (mg/L)	6	211	337	277	58.52			
Hardness Total -Diss. (mg/L)	6	151	341	265.5	81.13		$\leq$ 500 $CaCO_3$	aesthetic objective
Alkalinity (mg/L)	6	98.3	215	169.3	49.97	0.5		
Residue Non-Filterable (mg/L)	6	4	377	91.6	148.62	4		
Total Organic Carbon (mg/L)								
TOC	6	1.4	6.6	3.26	2.175	0.5	$\leq$ 4	maximum, to control THM production
Anions (mg/L)								
Chloride Dissolved	6	0.6	2.3	1.40	0.666	0.5	$\leq$ 250	aesthetic objective
Fluoride Dissolved	6	0.07	0.1	0.083	0.011	0.01		
Bromide Dissolved	6	0.1	0.1	0.10	0.000	0.1		
Nutrients (mg/L)								
Nitrate+Nitrite	6	0.028	0.144	0.085	0.053	0.002	$\leq$45 (Nitrate)	maximum acceptable concentration
Phosphorus Total	6	0.002	0.102	0.032	0.041	0.002	$\leq$ 1.5	maximum acceptable concentration
Phosphorus Total-Diss.	6	0.002	0.009	0.005	0.003	0.002		
Sulphate (mg/L)								
Sulphate	6	45.5	115	88.6	30.10	0.5	$\leq$ 500	aesthetic objective
Metals Total (ug/L)								
Aluminum-T	6	42.75	745	292.01	319.92	0.3		
Aluminum-D	6	2.3	47.4	14.15	17.126	0.3	$\leq$ 200	maximum acceptable concentration
Antimony-T	6	0.065	0.17	0.109	0.039	0.005	$\leq$ 6	interim maximum acceptable concentration
Antimony-D	6	0.077	0.145	0.097	0.026	0.005		
Arsenic-T	6	0.2	1.8	0.667	0.625	0.1	$\leq$ 25	interim maximum acceptable concentration
Arsenic-D	6	0.2	0.4	0.292	0.092	0.1		
Barium-T	6	77.4	196	108.9	43.51	0.02	$\leq$ 1000	maximum acceptable concentration
Barium-D	6	50.5	91.4	76.18	17.87	0.02		
Beryllium-T	6	0.02	0.2	0.062	0.073	0.02		
Beryllium-D	6	0.02	0.02	0.02	0.000	0.02		
Bismuth-T	6	0.02	0.04	0.023	0.008	0.02		
Bismuth-D	6	0.02	0.02	0.02	0.000	0.02		
Cadmium-T	6	0.01	0.46	0.120	0.174	0.01	$\leq$ 5	maximum acceptable concentration
Cadmium-D	6	0.01	0.04	0.022	0.010	0.01		
Calcium-T (mg/L)	6	58.4	92.6	76.550	16.134	0.05		
Calcium-D (mg/L)	6	42.5	94	73.25	22.110	0.05		
Chromium-T	6	0.2	1.1	0.483	0.440	0.2	$\leq$ 50	maximum acceptable concentration
Chromium-D	6	0.2	0.4	0.233	0.082	0.2		
Cobalt-T	6	0.005	3.51	0.847	1.404	0.005		
Cobalt-D	6	0.005	0.151	0.083	0.067	0.005		
Copper-T	6	0.68	8.96	3.789	3.634	0.05	$\leq$ 1000	aesthetic objective
Copper-D	6	0.58	1.86	1.178	0.541	0.05		
Iron-T (mg/L)	6	0.095	16.8	4.188	7.219	0.005	$\leq$ 0.3	aesthetic objective
Iron-D (mg/L)	6	0.005	0.055	0.028	0.019	0.005		
Lead-T	6	0.07	4.79	1.306	1.950	0.01	$\leq$ 10	maximum acceptable concentration
Lead-D	6	0.01	0.2	0.055	0.072	0.01		
Lithium-T	6	9.55	17.05	13.37	3.517	0.05		
Lithium-D	6	8.64	16.8	12.71	4.060	0.05		
Magnesium-T (mg/L)	6	15.9	25.6	20.86	4.430	0.05		
Magnesium-D (mg/L)	6	10.8	25.9	20.04	6.335	0.05	$\leq$ 100	aesthetic objective

Table 1 Continued.

Parameter	# of Values	Min.	Max.	Mean	Std. Dev.	MDL	D.W. Guideline	Guideline Type
Manganese-T	6	26.2	171	64.37	54.541	0.008	≤ 50	aesthetic objective
Manganese-D	6	6.23	54.6	24.617	18.373	0.008		
Molybdenum-T	6	0.94	2.14	1.860	0.457	0.05	≤ 250	maximum acceptable concentration
Molybdenum-D	6	0.93	1.945	1.724	0.395	0.05		
Nickel-T	6	0.05	9.06	2.810	3.872	0.05		
Nickel-D	6	0.05	1.33	0.673	0.462	0.05		
Selenium-T	6	0.6	1.8	1.44	0.445	0.2	≤ 10	maximum acceptable concentration
Selenium-D	6	0.6	1.8	1.33	0.455	0.2		
Silver-T	6	0.02	0.02	0.020	0.000	0.02		
Silver-D	6	0.02	0.02	0.020	0.000	0.02		
Sodium-T (mg/L)	6	2.6	5.68	4.417	1.520	0.05	≤ 200	aesthetic objective
Strontium-T	6	191	330	270.750	57.576	0.005		
Strontium-D	6	153	324	256.667	71.843	0.005		
Thallium-T	6	0.002	0.061	0.019	0.024	0.002	≤ 2	maximum acceptable concentration
Thallium-D	6	0.002	0.009	0.005	0.003	0.002		
Tin-T	6	0.01	0.1	0.029	0.036	0.01		
Tin-D	6	0.01	0.04	0.020	0.015	0.01		
Uranium-T	6	1.11	1.83	1.496	0.277	0.002	≤ 100	maximum acceptable concentration
Uranium-D	6	0.88	1.71	1.347	0.386	0.002		
Vanadium-T	6	0.95	4.99	2.239	1.646	0.06	≤ 100	maximum acceptable concentration
Vanadium-D	6	0.42	1.75	0.930	0.460	0.06		
Zinc-T	6	1.3	30.4	10.250	11.180	0.1	≤ 5000	aesthetic objective
Zinc-D	6	0.2	7.5	2.87	2.682	0.1		

Table 2. Sediment sampling results from both the October 30th/02 and August 19th/03 sampling dates.

Parameter	Unit	Value/02	Value/03	Parameter	Unit	Value/02	Value/03	Parameter	Unit	Value/02	Value/03
% Moisture	(% W/W)	31.4	30.1	Pentachlorophenol	(µg/g)	<0.005	<0.005	Dimethoate	(µg/g)	<0.02	<0.05
Solid Content	(%)			Bromoxynil	(µg/g)	<0.01	<0.01	Ethion	(µg/g)	<0.05	<0.05
>4.00 mm	(% W/W)		0.26	2,4-D	(µg/g)	<0.01	<0.01	Fenitrothion	(µg/g)	<0.02	<0.05
<4.00 >2.0 mm	(% W/W)		0.09	Dicamba	(µg/g)	<0.005	<0.01	Fensulfothion	(µg/g)	<0.01	<0.05
<2.00 >0.063 mm	(% W/W)	46.34	30.8	Dichlorprop	(µg/g)	<0.01	<0.01	Fenthion	(µg/g)	<0.02	<0.05
<0.063 >0.053 mm	(% W/W)	4.59	5.06	Dinoseb	(µg/g)	<0.1	<0.30	Fonofos	(µg/g)	<0.02	<0.05
<0.053 >0.004 mm	(% W/W)	35.07	51.36	MCPA	(µg/g)	<0.01	<0.01	Iodofenphos	(µg/g)	<0.01	<0.05
<0.004 >0.002 mm	(% W/W)	3.08		Picloram	(µg/g)	<0.01	<0.01	Malathion	(µg/g)	<0.01	<0.05
<0.002 mm	(% W/W)	10.93	12.52	2,4,5-T	(µg/g)	<0.005	<0.005	Mevinphos-cis	(µg/g)	<0.05	<0.05
Carbon - Tot. Inorg.	(µg/L)	11000	11000	2,4,5-TP	(µg/g)	<0.005	<0.005	Methamidophos	(µg/g)	<0.05	<0.05
Carbon - Tot. Org.	(µg/L)	10000	11000	Triclopyr	(µg/g)	<0.005	<0.005	Naled	(µg/g)	<0.01	<0.05
Carbon - Tot.	(µg/g)	21000	22000	Aldrin	(µg/g)	<0.002		Omethoate	(µg/g)	<0.02	<0.05
Phosphorus - Tot.	(µg/g)	935	980	BHC, Alpha-	(µg/g)	<0.002		Parathion	(µg/g)	<0.01	<0.05
Aluminum - Tot.	(µg/g)	3420	4100	BHC, Beta-	(µg/g)	<0.002		Parathion Methyl	(µg/g)	<0.02	<0.05
Antimony - Tot.	(µg/g)	0.5	0.6	BHC, Delta-	(µg/g)	<0.002		Phorate	(µg/g)	<0.02	<0.05
Arsenic - Tot.	(µg/g)	7.2	8	Chlordane, Alpha-	(µg/g)	<0.01		Phosalone	(µg/g)	<0.05	<0.1
Barium - Tot.	(µg/g)	218	194	Chlordane, Gamma-	(µg/g)	<0.01		Phosmet	(µg/g)	<0.03	<0.05
Beryllium - Tot.	(µg/g)	0.4	0.2	DDD,p,p'-	(µg/g)	<0.01		Phosphamidon	(µg/g)	<0.05	<0.05
Bismuth - Tot.	(µg/g)	0.1	0.1	DDE-p,p'	(µg/g)	<0.005	113	Sulfotep	(µg/g)	<0.02	<0.05
Cadmium - Tot.	(µg/g)	0.86	0.85	DDT-o,p'-	(µg/g)	<0.01		Tetrachlorvinphos	(µg/g)	<0.02	<0.05
Calcium - Tot.	(µg/g)	33000	34100	DDT-p,p'-	(µg/g)	<0.02		Oil & Grease - Tot.	(µg/g)	<100	190
Chromium - Tot.	(µg/g)	10.1	7.6	Dieldrin	(µg/g)	<0.01		Acenaphthene	(µg/g)	<0.01	<0.01
Cobalt - Tot.	(µg/g)	6.7	7.1	Endosulfan I	(µg/g)	<0.01		Acenaphthylene	(µg/g)	<0.01	<0.01
Copper - Tot.	(µg/g)	37.9	16.6	Endosulfan II	(µg/g)	<0.01		Anthracene	(µg/g)	<0.01	<0.01
Iron - Tot.	(µg/g)	18200	17900	Endosulfan Sulphate	(µg/g)	<0.02		Benzo(a)anthracene	(µg/g)	<0.01	<0.01
Lead - Tot.	(µg/g)	8.9	9.8	Endrin	(µg/g)	<0.02		Benzo(b)fluoranthene	(µg/g)	0.02	<0.02
Magnesium - Tot.	(µg/g)	10400	8970	Hepatachlor	(µg/g)	<0.002		Benzo(k)fluoranthene	(µg/g)	<0.01	<0.01
Manganese - Tot.	(µg/g)	361	331	Hepatachlor epoxide	(µg/g)	<0.004		Benzo(g,hi)perylene	(µg/g)	<0.02	0.06
Molybdenum - Tot.	(µg/g)	2.3	2.9	Lindane, BHC, Gamma-	(µg/g)	<0.002		Benzo(a)pyrene	(µg/g)	<0.01	<0.02
Nickel - Tot.	(µg/g)	20.4	21	Methidathion	(µg/g)	<0.02	<0.05	Chrysene	(µg/g)	0.03	0.06
Potassium - Tot.	(µg/g)	393	655	Methoxychlor	(µg/g)	<0.02		Dibenz(a,h)anthracene	(µg/g)	<0.02	<0.02
Selenium - Tot.	(µg/g)	0.8	0.9	Mirex	(µg/g)	<0.02		Fluoranthene	(µg/g)	<0.01	0.02
Silver - Tot.	(µg/g)	0.18	0.2	Nonchlor, Trans-	(µg/g)	<0.01		Fluorene	(µg/g)	<0.01	0.02
Sodium - Tot.	(µg/g)	<100	<100	Oxychlordane	(µg/g)	<0.01		Indeno(1,2,3-c,d)pyrene	(µg/g)	<0.02	<0.02
Strontium - Tot.	(µg/g)	64.9	63.2	PCBs- Tot.	(µg/g)	<0.05		Naphthalene	(µg/g)	<0.01	0.04
Tellurium - Tot.	(µg/g)	<0.1	<0.1	Acephate	(µg/g)	<0.05	<0.10	C1-Naphthalenes	(µg/g)	0.07	0.08
Thallium - Tot.	(µg/g)	0.21	0.19	Azinphos Methyl	(µg/g)	<0.05	<0.05	C2-Naphthalenes	(µg/g)	0.09	0.22
Tin - Tot.	(µg/g)	0.5	0.3	Bromophos	(µg/g)	<0.01	<0.05	Phenanthrene	(µg/g)	0.04	0.11
Titanium - Tot.	(µg/g)	21	23	Carbophenothion	(µg/g)	<0.01	<0.05	C1-Phen/Anthracene	(µg/g)	0.12	0.17
Vanadium - Tot.	(µg/g)	23	20	Chlorfenvinphos(e)	(µg/g)	<0.01	<0.05	C2-Phen/Anthracene	(µg/g)	0.12	0.11
Zinc - Tot.	(µg/g)	86.3	86.2	Chlorpyrifos	(µg/g)	<0.01	<0.05	Pyrene	(µg/g)	0.02	0.04
Zirconium - Tot.	(µg/g)	2.2	2.6	Demeton	(µg/g)	<0.02	<0.05	Total PAHs	(µg/g)	0.08	0.35
2,3,4,5 - Tetrachlorophenol	(µg/g)	<0.01	<0.01	Diazinon	(µg/g)	<0.02	<0.05	Total Low MW PAHs	(µg/g)	0.04	0.17
2346+2356-TeClPhenol	(µg/g)	<0.01	<0.01	Dichlorvos	(µg/g)	<0.01	<0.05	Total High MW PAHs	(µg/g)	0.04	0.18

Table 3: Historical Muskwa River data collected by the Northern Rockies Regional District.

Parameter	Mar. 5/02 (mg/L)	Sept. 11/02 (mg/L)	Detection Limit (mg/L)	Provincial Guideline (mg/L)	Parameter	Mar. 5/02 (ug/L)	Sept. 11/02 (ug/L)	Detection Limit (mg/L)	Provincial Guideline (mg/L)
pH	7.52	8.27	0.01	6.5-8.5	*Polychlorinated Biphenyls*				
Colour (Co/Pt Units)	10	**35**	5	≤ 15 TCU	Arochlor 1242	<0.1		0.1	N/A
Turbidity (NTU)	**1.5**	**17**	0.2	≤ 1	Arochlor 1248	<0.1		0.1	N/A
Alkalinity Total (pH 4.5)	202	144	1	N/A	Arochlor 1254	<0.1		0.1	N/A
B.O.D.	<10	<10	10	N/A	Arochlor 1260	<0.1		0.1	N/A
Total Dissolved Solids	354	322	1	≤ 500	*Organochlorine Pesticides*				
Chloride	0.8	0.4	0.5	≤ 250	Aldrin	<0.01	<0.01	0.01	N/A
Fluoride	0.2	0.31	0.1	≤ 1.5	Alpha-BHC	<0.02	<0.02	0.02	N/A
Nitrate-N	0.164	0.029	0.003	≤ 10	Beta-BHC	<0.03	<0.03	0.03	N/A
Nitrite-N	0.005	0.003	0.003	≤ 1	Delta-BHC	<0.01	<0.01	0.01	N/A
Total Phosphorus	0.008	0.064	0.003	N/A	Gamma-BHC (Lindane)	<0.01	<0.01	0.01	N/A
Sulphate	73	37	1	≤ 500	Alpha-Chlordane	<0.01	<0.01	0.01	≤ 0.007
Sulphide (as S)	<0.05	<0.05	0.05	≤ 0.05	Gamma-Chlordane	<0.01	<0.01	0.01	≤ 0.007
Phenols	<0.005	<0.005	0.005	≤ 0.3	p,p-DDD	<0.03	<0.03	0.03	N/A
Total Cyanide	<0.005	<0.005	0.005	≤ 0.2	o,p-DDE	<0.01		0.01	N/A
Arsenic	<0.01	<0.01	0.01	≤ 0.025	p,p-DDE	<0.01	<0.01	0.01	N/A
Barium	0.07	0.08	0.01	≤ 1	o,p-DDT	<0.01		0.01	≤ 0.03
Boron	0.01	0.01	0.01	≤ 5	p,p-DDT	<0.01	<0.01	0.01	≤ 0.03
Cadmium	<0.001	<0.001	0.001	≤ 0.005	Dieldrin	<0.02	<0.02	0.02	N/A
Calcium	83.7	64.9	0.1	N/A	Endosulfan I	<0.01	<0.01	0.01	N/A
Chromium	<0.001	<0.001	0.001	≤ 0.05	Endosulfan II	<0.02	<0.02	0.02	N/A
Copper	<0.001	0.003	0.001	≤1	Endosulfan Sulphate	<0.02	<0.02	0.02	N/A
Iron	0.162	1.1	0.005	≤ 0.3	Endrin	<0.02	<0.02	0.02	N/A
Lead	<0.003	<0.003	0.003	≤ 0.01	Endrin Aldehyde	<0.05	<0.05	0.05	N/A
Magnesium	21.2	16.2	0.1	≤ 100	Heptachlor	<0.02	<0.02	0.02	≤ 0.003
Manganese	0.024	0.055	0.005	≤ 0.05	Heptachlor Epoxide	<0.01	<0.01	0.01	≤ 0.003
Mercury (ppb)	<0.05		0.05	≤ 1.0	Methoxychlor	<0.04	<0.04	0.04	0.9
Phosphorus	<0.03	<0.3	0.03	N/A	Toxaphene	<3	<0.08	3	N/A
Selenium	<0.01	<0.01	0.01	≤ 0.01	Total PCB		<1		N/A
Silver	<0.001	<0.001	0.001	≤ 0.003					
Sodium	4.64	2.90	0.02	≤ 200					
Uranium	<0.07	<0.07	0.07	≤ 0.02					
Zinc	0.001	0.006	0.001	≤ 5					

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

Parameter	MDL (µg/L)	Oct./02			Jan./03			Mar./03			Apr./03			Aug./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							3.7	6.5	**55**						
Antimony-T	0.005				0.038	0.029	**27**									
Cobalt-T	0.005							0.062	0.04	**43**				0.036	0.064	**56**
Cobalt-D	0.005													0.027	0.043	**46**
Colour-True (NTU)	5										240	160	**40**			
Fluoride-D (mg/L)	0.01										0.08	0.11	**32**			
Iron-D (mg/L)	0.005							0.026	0.047	**58**						
Manganese-T	0.008	0.707	0.521	**30**												
Nickel-T	0.05							0.35	0.47	**29**						
Phosphorus-T (mg/L)	0.002										0.012	0.084	**150**			
Phosphorus-T-D (mg/L)	0.002										0.002	0.013	**147**			
Vanadium-T	0.06							1.31	0.84	**44**						
Zinc-D	0.1													2.0	4.0	**67**

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

Table 6 . Percent difference in measures taken from duplicate sediment samples.

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

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Table 9. 2002/03 raw water quality data collected from the Fort Nelson drinking water supply.

Date	Cryptosporidium (oocysts/100L)	Giardia (cysts/100L)	Total Coliform (CFU/100mL)	Fecal Coliform (CFU/100mL)	Enterococci (CFU/100mL)
08-Oct-02			5	5	6
30-Oct-02	30.4	758.9			
14-Jan-03	<4.5	193.9	1	1	<1
14-Jan-03	<4.3	142.9			
04-Mar-03	<4	188.5	2	<1	<1
04-Mar-03			<1	<1	<1
29-Apr-03	<4.1	4.1	<2	<2	<2
27-May-03	<85.5	<85.5	70	18	12
19-Aug-03	<52.1	<52.1	340	28	57

E. Coli (CFU/100mL)	pH (pH Units)	True Colour (Col. Unit)	Specific Conductance (µS/cm)	Residues - NonFilt. (mg/L)	Turbidity (NTU)
5	8.2	15	327	27	
<1	8.2	5	610	4	
<1	7.9	5	589	4	2.13
<1	7.9	5	592	<4	2.25
<2	8.2	5	596	<4	1.25
<2	8.1	120	279	377	330
23	8.2	20	350	134	65.4

Hardness - Total (mg/L)	Hardness - Dissolved (mg/L)	Alkalinity - T as CaCO3 (mg/L)	Bromide - Diss. (mg/L)	Chloride - Diss. (mg/L)	Fluoride - Diss. (mg/L)
244	234	155	<0.1	1.1	0.1
337	337	215	<0.1	1.8	0.09
323	329	212	<0.1	1.8	0.08
323	328	213	<0.1	1.8	0.07
328	341	208	<0.1	2.3	0.08
211	151	98.3	<0.1	0.8	0.07
219	202	127	<0.1	0.6	0.08

Carbon - Tot. Org. (mg/L)	NO2 + NO3 (mg/L)	Phosphorus - Tot. Diss. (mg/L)	Phosphorus - Tot. (mg/L)	Sulfate (mg/L)	Aluminum - Tot. (µg/L)
5.4	0.028	0.003	0.012	87.3	215
2	0.144	0.009	0.01	115	50.7
1.4	0.13	<0.002	<0.002	110	39.5
1.4	0.129	<0.002	<0.002	109	46
1.8	0.124	0.002	<0.002	115	54.6
6.6	0.046	0.007	0.102	45.5	745
2.4	0.039	0.008	0.062	59.6	644

Aluminum - Diss. (µg/L)	Antimony - Tot. (µg/L)	Antimony - Diss. (µg/L)	Arsenic - Tot. (µg/L)	Arsenic - Diss. (µg/L)	Barium - Tot. (µg/L)
47.4	0.109	0.086	0.4	0.3	77.4
2.6	0.065	0.09	0.3	0.2	92
3.7	0.077	0.075	0.2	0.2	91.5
6.5	0.078	0.079	0.2	0.3	93.2
2.3	0.096	0.077	0.3	0.2	91.5
15.3	0.17	0.145	1.8	0.4	196
12.2	0.135	0.107	1	0.4	104

Barium - Diss. (µg/L)	Beryllium - Tot. (µg/L)	Beryllium - Diss. (µg/L)	Bismuth - Tot. (µg/L)	Bismuth - Diss. (µg/L)	Cadmium - Tot. (µg/L)
76.1	<0.02	<0.02	<0.02	<0.02	<0.01
89.8	<0.02	<0.02	<0.02	<0.02	0.06
90	<0.02	<0.02	<0.02	<0.02	0.02
91.4	<0.02	<0.02	<0.02	<0.02	0.02
91.4	<0.02	<0.02	0.04	<0.02	0.02
50.5	0.2	<0.02	<0.02	<0.02	0.46
58.6	0.09	<0.02	<0.02	<0.02	0.15

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	67.4	64.5	<0.2	<0.2	0.107
0.04	92.6	92.8	<0.2	<0.2	<0.005
0.02	89.5	90.5	<0.2	<0.2	0.062
0.02	89.9	90.1	<0.2	<0.2	0.04
0.02	90.7	94	<0.2	<0.2	0.061
0.02	58.4	42.5	1	<0.2	3.51
0.02	60.5	55.4	1.1	0.4	1.35

Cobalt - Diss. (µg/L)	Copper - Tot. (µg/L)	Copper - Diss. (µg/L)	Iron - Tot. (mg/L)	Iron - Diss. (mg/L)	Lead - Tot. (µg/L)
0.131	0.68	0.65			0.07
<0.005	2	0.88	0.151	0.015	0.24
0.017	1.67	1.5	0.172	0.026	0.16
0.021	1.78	1.63	0.174	0.047	0.17
0.047	1.48	0.58	0.095	<0.005	0.08
0.147	8.96	1.86	16.8	0.055	4.79
0.151	7.89	1.53	3.72	0.026	2.49

Lead - Diss. (µg/L)	Lithium - Tot. (µg/L)	Lithium - Diss. (µg/L)	Magnesium - Tot. (mg/L)	Magnesium - Diss. (mg/L)	Manganese - Tot. (µg/L)
0.03	9.55	9.49	18.3	17.7	49.7
0.2	16.3	15.9	25.6	25.5	38.2
0.02	16.9	16.5	24.2	25	25.9
0.06	17.2	17.1	24.3	24.9	26.5
<0.01	16.3	16.5	24.6	25.9	31
0.04	10.3	8.64	15.9	10.8	171
<0.01	10.7	8.94	16.5	15.4	70.1

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)
54.6	2.14	1.83	0.34	0.54	1.7	1.3	<0.02
36.6	1.95	1.94	<0.05	<0.05	1.8	1.8	<0.02
18.9	2.15	1.95	0.35	0.33	1.7	1.8	<0.02
20.4	2.11	1.94	0.47	0.39	1.6	1.8	<0.02
22.7	2.02	1.92	0.72	0.73	1.6	1.4	<0.02
6.23	0.94	0.93	9.06	1.33	0.6	0.6	<0.02
7.92	1.98	1.78	6.28	1.03	1.3	1.1	<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		245	242	<0.002	<0.002	0.1	0.04
<0.02	5.41	304	304	0.005	<0.002	0.03	0.04
<0.02	5.46	329	324	0.009	0.007	0.02	<0.01
<0.02	5.49	324	324	0.009	0.007	<0.01	<0.01
<0.02	5.68	330	322	<0.002	<0.002	<0.01	<0.01
<0.02	2.92	191	153	0.061	0.009	<0.01	<0.01
<0.02	2.6	228	195	0.032	0.006	<0.01	<0.01

Uranium - Tot. (µg/L)	Uranium - Diss. (µg/L)	Vanadium - Tot. (µg/L)	Vanadium - Diss. (µg/L)	Zinc - Tot. (µg/L)	Zinc - Diss. (µg/L)
1.27	1.3	3.39	0.65	1.3	7.5
1.83	1.71	0.97	0.75	5.1	1.6
1.61	1.62	1.31	1.05	4	3.3
1.64	1.6	0.84	1.03	4	3.7
1.72	1.69	0.95	0.97	4.3	3.7
1.42	0.893	4.99	0.42	30.4	0.7
1.11	0.88	2.06	1.75	16.4	0.2