Assessment of the City of Dawson Creek's Drinking Water Supply (Kiskatinaw River): Source Water Characteristics

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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 BC, 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 BC Ministry of Health and local water purveyors. However, through the BC Environmental Management Act, the British Columbia Ministry of Water, Land and Air Protection (WLAP) is responsible for managing and regulating activities in watersheds that have a potential to affect water quality. Accordingly, the Ministry plans to take an active role in protecting drinking water quality at its source.

Plate 1. An upstream view of the Kiskatinaw River (from the cross-channel weir) and the Dawson Creek pump house.

WLAP 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 City of Dawson's Creek's raw potable water source, the Kiskatinaw 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.

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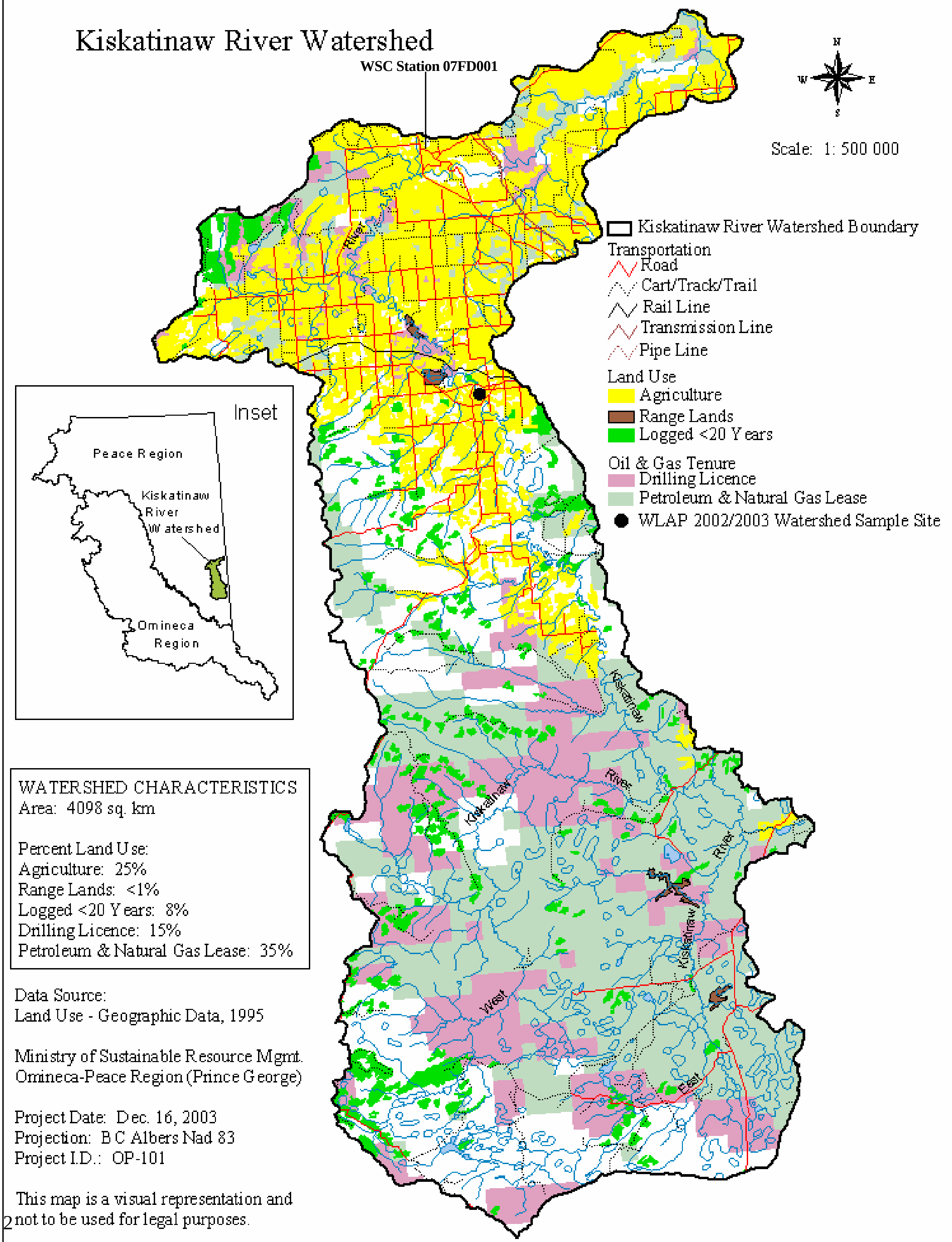

Figure 1. The Kiskatinaw River watershed and associated land-use practices.

Site Description

Watershed Overview

The Kiskatinaw River watershed (Figure 1) lies within the Boreal White and Black Spruce biogeoclimatic zone. The zone has rolling topography, long and cold winters and a landscape composed of black spruce bogs intermixed with stands of white spruce and trembling aspen at higher elevations (Ministry of Forests, 1998). While the watershed topography is generally low-gradient, the Kiskatinaw River channel can be deeply entrenched into a highly-erodable landscape. Exposed sloughing banks are common, suggesting that landscape characteristics have the potential to affect water quality.

As measured at the Farmington Water Survey of Canada (WSC) station 07FD001 (Figure 1), the Kiskatinaw River drains 3,600 km^2 and has a total length of about 200 km. The river flows from south to north, with the mainstem being formed from the convergence of two southern branches: the West Kiskatinaw River that starts flowing along the eastern foothills of the Rocky Mountains near the community of Tumbler Ridge, and the somewhat longer East Kiskatinaw River. From this convergence, the mainstem flows northeastwardly for about 120 km to where it joins the Peace River, east of the community of Taylor. Major tributaries to the Kiskatinaw River include Hourglass, Jackpine, Sundown and Burial creeks which flow into the West Kiskatinaw River; Sunderman, Borden and Ministik creeks which flow into the East Kiskatinaw River; and Oetata, Brassey, Tremblay, Norrie and Coal creeks which flow into the mainstem.

The predominant land use in the watershed is agriculture (e.g. grains, livestock and mixed farming), with oil & gas development, mineral exploration and forestry also existing. Range activity/grazing is included with agriculture in many locations on Figure 1. Because the data used to create the map is from 1995, current grazing activities initiated after this date may not be included.

At present, no major waste disposal permits with relevance to the Kiskatinaw River watershed have been issued; however, 12 water withdrawal licenses have been permitted. Based on information reported in BC MoWLAP (2002 DRAFT), the total annual volume of water licensed to various users is 8.4 x 10^6 m^3, equivalent to 2.3% of the annual flow at Farmington during average-flow years, 0.6% during extreme-high flow years and 36.4% during extreme-low flow years according to flow records for the 1990 to 2000 period.

Basic Hydrology

Flows in the lower Kiskatinaw River are lowest during the winter months and highest during spring melt (late April) and summer wet periods, particularly in mid-June (Figure 2). Data collected over the period 1990 to 2000 suggest that much of the spring and summer inflow enters he river via direct channel and overland flow, suggesting that water quality in the lower Kiskatinaw River is particularly sensitive to land use activities. Thus, in terms of hydrologic processes, particular care should be taken when managing livestock access to streams in the riparian habitats of the Kiskatinaw watershed.

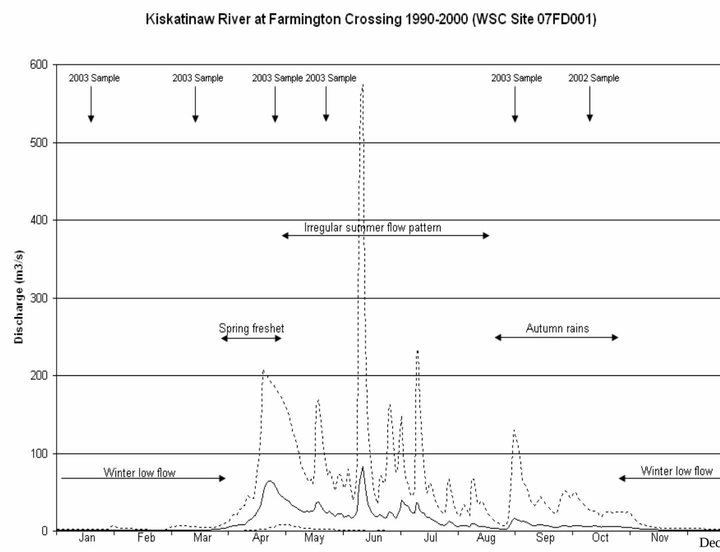

Figure 2. Lowest (bottom line), average (middle line) and maximum (upper line) daily flows observed in the Kiskatinaw River near Farmington over the period 1990-2000.

Plate 2. Cross-stream weir located immediately downstream of the Arras pump house. The weir raises water levels to ensure that there is sufficient water to support domestic users (October, 2002).

Drinking Water Supply & Treatment

The City of Dawson Creek draws its domestic water supply from the Kiskatinaw River mainstem near Arras, immediately upstream of the cross-stream weir (Plate 2) at co-ordinates 55°45.174'N/120°33.168'W. From the pump house, water is piped approximately 14 km to a raw-water settling reservoir, and an additional 2 km to a treatment facility where it is coagulated, filtered and chlorinated (Mr. Rod Harmon, City of Dawson Creek, Public Works

Dept., Pers. Comm.). Based on 2002 statistics, the City of Dawson Creek water supply serves approximately 12,000 people and 5000 private dwellings. Drinking water is also trucked from the City of Dawson Creek and stored at several rural schools and one community (1) Devereaux Elementary School (population served +/- 111), (2) Kelly Lake School (recently closed), (3) McLeod Elementary School (+/- 63), (4) Parkland Elementary School (+/- 105), (5) Rolla Elementary School (+/- 56), (6) Tate Creek Elementary School (+/- 70) and the Community of Pouce Coupe (+/- 981).

The primary concerns with use of the Kiskatinaw River as a domestic water supply are supply volume, the very high suspended sediment loads, and the fact that livestock have periodic access to river and stream channels upstream of the water intake. The City is currently upgrading their system to replace chlorine gas with sodium hypochlorite, the addition of GAC filters for organic removal and the installation of UV disinfection.

Materials & Methods

Review of Previous Data

Historic data relevant to the City of Dawson Creek raw water supply assessment have been included in this report. The following data were copied from Northern Health Authority and WLAP computer and paper files: Kiskatinaw River water quality data collected at WLAP sites 0400545 (Kiskatinaw River at Hart Highway Bridge) and E216170 (Kiskatinaw River near Arras pumphouse – mid stream), given their proximity to the Dawson Creek pumphouse; Kiskatinaw River flow data, collected downstream near Farmington (WSC station 07FD001); and City of Dawson Creek long-term turbidity monitoring program data.

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

Water Quality

An experienced consultant and/or WLAP 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 Kiskatinaw River immediately upstream from the Arras weir during the October, 2002 collection. All subsequent samples were collected from the raw water tap inside the Arras pump house (site E249356 - Water Source ID Tag 1345). The chemical sample parameters/results, analytical detection levels and drinking water quality guidelines are provided in Table 1, Appendix A.

Bottles used for general ion analyses were rinsed three times with source water prior to sample collection. Metal and bacterial bottles were not field rinsed and metal samples were lab preserved. Prior to sampling the raw water tap, the source was flushed for 5 minutes in order to minimize contamination by system piping.

Water samples were shipped by overnight courier in coolers with ice packs to CanTest Ltd. (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) (Figure 3). Filters were shipped by overnight courier in a cooler with ice packs to the BC Centre for Disease Control's Enhanced Water Laboratory for analysis.

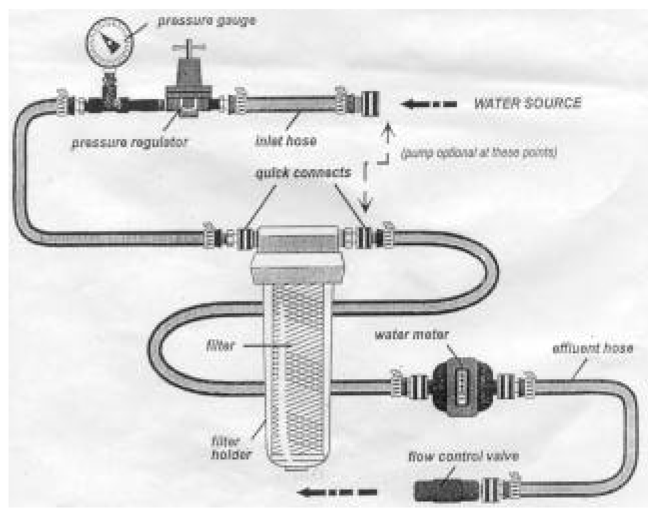

Figure 3. Schematic of the high-volume filtration unit used to sample raw water for Cryptosporidium oocysts and Giardia cysts (from EPA, 1995).

Bottom Sediment Quality

Bottom sediments were collected from the Kiskatinaw River during low flow periods in October, 2002 and August, 2003. Two samples were collected during 2003, one from either side of the river. 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 Tables 2 and 3, 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 (which were collected from one stream in the drinking water program) 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 Health Authority (NHA) sampled the City of Dawson Creek's raw water supply near the Arras pump house 13 times for total and/or fecal coliforms over the period November 1988 to March 1997. The Ministry of Environment sampled the same supply for fecal coliforms and/or *E. coli* on 17 sampling dates over the period August 1991 to November 1997. The results of these raw water bacterial programs are presented in Table 4.

Of the samples collected for *E. coli* analysis over the period September through November 1997, three dates produced colonies exceeding the maximum guideline for untreated drinking waters (0 CFU/100mL). The highest *E. coli* densities were detected on September 18th (10 and 60 CFU/100mL) and November 6th (< 1 and 26 CFU/100mL). Fecal coliforms were detected at concentrations greater than 0 CFU/100mL on 18 of the 27 sample dates. The samples producing the greatest numbers of fecal coliform colonies were generally collected during late summer and fall.

These historical bacterial data indicate that water from the Kiskatinaw River was not suitable for human consumption when in an untreated state, as is the case for most surface waters. As previously noted, Dawson Creek has full treatment consisting of coagulation, filtration and chlorination. There are currently no upper limits with regards to microorganisms in the B.C. water quality guidelines for systems undergoing complete water treatment.

Table 4. Historical bacterial data for the City of Dawson Creek raw water supply near Arras.

*Provincial Guidelines	0 CFU/100 mL	0 CFU/100 mL	No Provincial Guideline
Date	*E. Coli* (CFU/100mL)	Fecal Coliforms (CFU/100mL)	Total Coliforms (CFU/100mL)
Nov 2/1988	-	< 1.8	2400
Feb 16/1989	-	< 2	< 2
Oct 9/1990	-	**2**	2
Mar 5/1991	-	< 2	33
Aug 7/1991	-	**1; 5**	-
Aug 8/1991	-	**2**	-
Aug 28/1991	-	**22**	-
Aug 29/1991	-	**22**	-
Sep 10/1991	-	< 2	-
Sep 18/1991	-	**3**	-
Sep 18/1991	-	**3**; <2	-
Sep 25/1991	-	**3**	-
Feb 6/1992	-	< 2	-
Feb 17/1992	-	**3; 1**; < 2	-
Feb 24/1992	-	< 2	-
May 13/1992	-	< 2; **3; 8; 2**	-
May 20/1992	-	**14**	-
May 27/1992	-	**10**	-
Jun 2/1992	-	**10**	-
Jan 21/1997	-	< 1	-
Mar 4/1997	-	< 1	-
Sep 18/1997	**10; 60**	**40; 90**	-
Sep 25/1997	< 1	< 1	-
Oct 2/1997	**7**	**21**	-
Oct 9/1997	**1; 4**	**4; 12**	-
Oct 30/1997	< 1	**6**	-
Nov 6/1997	< 1; **26**	**32; 40**	-

*Guidelines for raw water in an untreated state.

Parasitology

One single parasite filter was collected December 10th, 2001 from unfinished water at the city water treatment plant. It contained *Cryptosporidium* and *Giardia* densities of 10 oocysts/100L and 25 cysts/100L, respectively. These data show that potential existed for human illness to result from infection by *Cryptosporidium* and/or *Giardia* if treatment systems were not fully effective.

Water Chemistry

The City of Dawson Creek has been taking daily turbidity measurements of raw water directly from the Kiskatinaw River (open-water seasons) and from the tap in the Arras pump house (winter months) continuously since 1995. According to the data, the raw water supply had extremely high turbidity levels. Turbidity was relatively low during winter months (9 to 45 NTU) when stream flows and erosion also tended to be low. Turbidity was highly variable during the spring and summer months (5 to 2000+ NTU) when it was likely influenced by snow melt, precipitation and active erosion. Given that the Canadian aesthetic guideline for drinking water entering at the point of consumption is 5 NTU and that the untreated waters were typically much greater than 500 NTU, substantial efforts will be required to remove sediment from the raw water.

The BC government undertook various water quality monitoring programs of the raw water supply at Arras over the periods December, 1986 to September, 2001 (Matscha et al., 2003).

Complex organic compounds were analysed in only 1 to 4 samples and were always detected at concentrations less than or equal to the analytical detection limit (Table 5, Appendix A). Given these small sample sizes, it is not possible to make strong conclusions regarding contaminant presence in the system; however the data do suggest that their concentrations were generally very low when tested.

Of the 29 analysed chemical parameters, 20 were detected in the water samples. However, the concentrations of 15 of these parameters were well below their respective British Columbia drinking water guideline, with their maximum detected value less than 75% the guideline value (Table 6).

Specific conductance was measured at values between 321 and 568 µS/cm in 44 samples, with an average of 416 µS/cm. The maximum measured value was approaching the provincial guideline of 700 µS/cm. The high conductivities likely reflected high concentrations of major ions, such as calcium and magnesium, which are more relevant to aesthetics rather than health-related properties of water.

Table 6. Fifteen of the twenty detected parameters that were less than 75% the guideline value; n (sample size) based on combined number of samples collected by the Province and NHA.

Parameter	Concentration Range	Average Concentration	*n*	Provincial Criteria
Antimony-T	0.1-1.4 µg/L	0.1 µg/L	4	6 µg/L
Arsenic-T	0.5-0.6 µg/L	0.5 µg/L	4	25 µg/L
Barium-T	1-287 µg/L	178 µg/L	48	1000 µg/L
Cadmium-T	0.46-0.84 µg/L	0.5 µg/L	6	5 µg/L
Chromium-T	1.1-9.0 µg/L	4 µg/L	6	50 µg/L
Copper-T	1-100 µg/L	9 µg/L	49	1000 µg/L
Fluoride	all 0.07 mg/L	0.07 mg/L	3	1.5 mg/L
Lithium-T	3-4 µg/L	3 µg/L	4	5000 µg/L
Lead-T	0.6-2 µg/L	0.9 µg/L	6	10 µg/L
Molybdenum-T	0.3-0.4 µg/L	0.4 µg/L	4	250 ug/L
Nitrate	<0.2-1.2 mg/L	<0.14 mg/L	24	10 mg/L
Sodium-T	0.22-13 mg/L	8 mg/L	43	200 mg/L
Uranium-T	0.005-0.4 µg/L	0.27 µg/L	6	100 µg/L
Vanadium-T	2.2-3.5 µg/L	3.3 µg/L	4	100 µg/L
Zinc-T	<1-80 µg/L	<17 µg/L	49	5000 µg/L

Aluminum (total), true colour, iron and manganese had maximum concentrations that exceeded their provincial drinking water guidelines (Table 7). The provincial drinking water guidelines are defined as threshold values, below which water quality problems are expected to be nonexistent. Parameter concentrations exceeding these guidelines are not automatically problematic, but indicate that further assessment is required to determine possible impact. The maximum detected concentrations of all four parameters exceeded their respective guideline by at least three times. The exceeded guideline for iron, manganese and colour true are aesthetic guidelines. The provincial guideline for dissolved aluminum (200 ug/L) is based on aesthetic thresholds; however, the Canadian guideline (100/200 ug/L) are operational values for water treatment facilities. There is no provincial guideline for total aluminium.

Table 7. Parameters of high concern based on pre-existing data (maximum observed "totals" concentration > Provincial criteria ; n based on combined number of samples collected by the Province and NHA).

Parameter (totals)	Concentration Range	Average Concentration	*n*	Provincial Guideline
Aluminum-T	20-8030 µg/L	810 µg/L	45	200 µg/L (Diss.)
Colour-True	<5-250 NTU	30 NTU	40	5 TCU
Iron	10-6100 µg/L	916 µg/L	49	300 µg/L
Manganese	2-183 µg/L	27 µg/L	45	50 µg/L

Bottom Sediment Chemistry

A review of the Provincial Environmental Monitoring System (EMS) database indicated that bottom sediments from the Kiskatinaw River were sampled once on August 3rd, 1995 (EMS Site E222079, Kiskatinaw River 200 m upstream of Peace River confluence). The samples were analysed in duplicate for total metals, with total inorganic carbon, and the herbicides glyphosate, AMPA (glyphosate by-product) and diallate not being duplicated.

Of the 18 analyzed metals, 15 were detected in the sediment. Table 8, Appendix A summarises the average (of duplicate measures) concentrations of metals that were detectable in Kiskatinaw River bottom sediments.

The grain size distribution of the sampled bottom sediments were not provided in the EMS database; however the carbon content of the sediments was determined and can also be found in Table 8, Appendix A.

Neither the herbicide glyphosate nor the glyphosate degradation by-product AMPA were detected in the August 3rd, 1995 bottom sediment sample. However, the herbicide diallate was detected at a concentration of 89 µg/g. No provincial or federal drinking water guidelines exist for diallate.

Water Monitoring Program (2002/03)

Quality Assessment (QA)

The field blank results indicate that no field or lab contamination of samples with bacteria occurred. There were some large differences between the bacterial duplicates during both the April and May collections; however, these difference were probably due to natural variation rather than sampling error. Both of these samples were collected during bankfull conditions, when the water within the Kiskatinaw River was very heterogeneous in appearance. Regardless, when there were large variations in bacterial densities, the concentrations of both duplicates were well over recommended guidelines for raw water receiving no treatment (0 CFU/100 mL). 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 Dawson Creek 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. Seven parameters exceeded these acceptance criteria significantly and are listed in Table 9.

Although the levels of some of these results are greater than the concentrations observed in the Kiskatinaw River, the values are usually well below provincial raw drinking water guidelines by greater than two orders of magnitude.

Table 9. Blind blank samples that tested strongly positive (≥ 5-fold MDL) for chemical contamination.

Date	Parameter	Measured	MDL
Oct. 2/02	Copper-D	0.27 µg/L	0.05 µg/L
Oct. 2/03	Lithium-T	0.36 µg/L	0.05 µg/L
Oct. 2/03	Strontium-D	0.048 µg/L	0.005 µg/L
Jan. 15/03	Chloride-D	18.5 µg/L	0.5 µg/L
Jan. 15/03	Sulfate-T	3.1 mg/L	0.5 mg/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

The contamination that did occur may have resulted during the deionization process in the lab or during the transfer of the deionized water between bottles in the field. Regardless, these levels of blank contamination should not limit the comparison of data to water quality guidelines.

The five water chemistry duplicate samples that were prepared either the same day or within one day of the Kiskatinaw River did have some values outside the lab acceptance criteria of 25% relative percent difference (Table 10, 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 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 11, Appendix A). The lab acceptance criteria for duplicate variation is 35% for metals and other inorganics. All duplicate values, as indicated in Table 11, are within this range.

Bacteriology

The 2002/03 bacterial data are summarised in Table 12. There are no water quality guidelines for raw drinking water receiving complete treatment (as in Dawson Creek), however the guideline for raw water receiving no treatment is 0 CFU/100mL for *E. coli*, *Enterococci* and fecal coliforms.

Table 12. Results of bacterial analyses for the City of Dawson Creek's 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
Oct. 2/02	4;3	**2**;<1	**18;10**	**2**;<1
Jan. 15/03	<1	<1	<1	<1
Mar. 5/03	<1	<1	<1	<1
Apr. 30/03	330;200	**20;10**	**10;10**	**30;30**
May 28/03	270;140	<2;<2	**210;370**	<2;<2
Aug. 20/03	35	**13**	**55**	**57**

*Provincial Guideline for raw, untreated water.

The highest bacterial counts occurred during October 2002, April 2003, May 2003 and August 2003. As shown in Table 12, bacterial counts were notable during all of these sample periods. The presence of the 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 Kiskatinaw or tributaries upstream of the water intake. These levels indicate that there is potential for bacterial-related human illness should water treatment become ineffective.

As previously mentioned, there are no bacterial provincial guidelines for raw drinking water receiving complete treatment, as is the case for Dawson Creek; however, these data suggest upstream activities are degrading the Kiskatinaw River water quality.

Parasitology

The 2002/03 parasite data are summarised in Table 13. While *Cryptosporidium* oocysts were detected in the sample collected by the NHA on December 10th, 2001, none were observed in any of the seven samples (including a duplicate) collected in 2002/03. By comparison, *Giardia* densities ranged from 76.7 to 961.7 cysts/100L and were detected in every sample.

The large detection level variations were due to changes in river turbidity. High turbidity levels interfere during the lab analysis process, and consequently increase the detection level.

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

Table 13. Parasite densities observed in the City of Dawson Creek's raw water supply over the period October 31st, 2002 to August 20th, 2003.

Date	*Cryptosporidium* (oocysts/100L)	*Giardia* (cysts/100L)
Oct. 31/02	<11.7	**338.6**
Jan. 15/03	<4.8	**76.7**
Mar. 5/03	<4.6	**961.7**
Apr. 30/03	<129.4	**906.4**
May 28/03	<29.7; <27.6	**178.1;165.4**
Aug. 20/03	<12.7	**190.6**

The BC 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 Dawson Creek water treatment system currently uses coagulation, filtration and disinfection.

Water Chemistry

In 2002/03, the Dawson Creek raw water supply was sampled on six different dates. The water samples were analysed for 15 general parameters as well as the ICPMS low level metals package that includes 27 metals in both the total and dissolved form (Table 1, Appendix A).

Of the chemical parameters tested through the duration of this study, nine 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 (RIC, 1998) are listed below.

Colour (TCU) - The mean colour concentration for the year was 57.5 TCU with a maximum of 200 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) - There were specific conductance exceedances on two occasions: Jan. 15th, 2003 (797µS/cm) and Mar. 5th, 2003 (876µS/cm). The provincial guideline is 700µS/cm. 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 689 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. The Kiskatinaw River does have naturally sloughing banks that input sediment to the water, however, other possible sources are forest harvesting, road building, agriculture, livestock and urban development.

Hardness (mg/L $CaCO_3$) - The maximum total and dissolved hardness values were both greater than 500 mg/L $CaCO_3$, the recommended guideline limit. 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.

Residue, Non-Filterable (mg/L) - The mean level of non-filterable residue collected during the study was 244 mg/L with a maximum of 1165 mg/L. This is a measure of the particulate matter suspended within the water column. High levels can increase turbidity as well as damage aquatic habitats. Sources are forest harvesting, road building, industrial effluents, livestock and urban development.

Total Organic Carbon (mg/L) - The mean TOC concentration was 10.5 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 for the year was 10.5 mg/L, a median of 1.25 mg/L and a maximum value of 38.6 mg/L, all 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.

Lead, Total (µg/L) - The values for lead were generally quite low, however the April 30th, 2003 sample produced a maximum value of 8.82 µg/L which is approaching the guideline of 10 µg/L. Lead generally accumulates in skeletal structures and can be toxic when the concentrations are high enough. Anthropogenic sources are urban development, industrial effluents and mining.

Manganese, Total (µg/L) - The mean manganese concentration was 131 µg/L with a maximum of 517 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 (Table 14, Appendix A for the raw data set).

Bottom Sediment Chemistry

A total of three sediment samples were collected from the Kiskatinaw River during the 2002/03 program, with two samples collected at the Arras pump house and one sample collected approximately 1 km upstream of the pump house (this sample was collected on the opposite side of the river). Of the 29 sediment metals analyzed, the number detected at the Arras site were 26 and 27, with 25 being collected at the upstream site (Tables 2 and 3, Appendix A). High concentrations of arsenic, cadmium, copper and nickel were found in both samples at the pump house site relative to the other sites in the program, 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 31st, 2002 sample however was detected on the August 20th, 2003 upstream sample at a concentration of 290 µg/g.

Polycyclic aromatic hydrocarbons were detected in trace amounts (Table 15). The one 2002 sample had a total PAH concentration of 0.11 µg/g. PAH's were detected in higher concentrations during the 2003 collection at both sites, with total PAH concentrations of 0.58 and 0.39 µg/g. Anthropogenic sources of PAH's include fossil fuels, agricultural burning, industrial processes, pest treatment and urban runoff (RIC, 1998).

Table 15. Polycyclic aromatic hydrocarbons detected in Kiskatinaw River sediments in trace amounts. All values in µg/g.

Compound	Oct, 2002 @ pump house	Aug. 2003 @ pump house	Aug. 2003 1km U/S of pump house
Benzo(a)anthracene	<0.01	0.01	<0.01
Benzo(b)fluoranthene	0.02	0.05	0.03
Benzo(g,hi)perylene	<0.02	0.05	0.03
Benzo(a)pyrene	<0.01	0.01	<0.01
Chrysene	0.03	0.1	0.07
Fluoranthene	<0.01	0.03	0.02
Fluorene	<0.01	<0.02	<0.02
Naphthalene	<0.01	0.07	0.06
C1-Naphthalenes	0.06	-	-
C2-Naphthalenes	0.13	0.4	0.29
Phenanthrene	0.05	0.22	0.15
C1-Phen/Anthracene	0.12	0.34	0.24
C2-Phen/Anthracene	0.15	0.2	0.13
Pyrene	0.01	0.04	0.03
Total PAHs	0.11	0.58	0.39
Total Low MW PAHs	0.05	0.29	0.21
Total High MW PAHs	0.06	0.29	0.18

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

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

Conclusions & Recommendations

Review of the Kiskatinaw River data indicates a raw water quality unsuitable for human consumption without treatment. Bacteria and *Giardia* were detected at moderate to high concentrations on many of the sample dates, suggesting that warm-blooded animals or runoff from animal waste are accessing the Kiskatinaw or tributaries upstream of the water intake. Although wildlife may be the source of some of these organisms, livestock have been observed in stream channels upstream of the water intake. One recommendation based on our water quality observations would be to undertake a livestock monitoring program to determine where and when livestock have access to upstream channels. Furthermore, as per the EPA recommendation on high parasite densities, a watershed management program appears necessary in the Kiskatinaw River basin.

High-frequency data collected by the City of Dawson Creek show that turbidity levels are excessive in the Kiskatinaw River. Observations indicate that most, if not all, of this turbidity is the result of suspended sediment. It is recommended that watershed surveys be undertaken to map sediment sources caused by human activities (e.g., roads and road crossings, oil and gas well-head sites, agricultural fields with poor riparian function, grazing leases, forestry activities). Once such sediment sources are identified, previously-developed sediment control techniques can be implemented. It would also be useful to purchase the 1995 to present precipitation and climatic data available for the region from Environment Canada. These data could be overlaid on the turbidity plots to better describe how turbidity changes in relation to precipitation events. Understanding the relationship between rain events and turbidity may assist with any sediment-source surveys.

PAH's and oil & grease were detected in the Kiskatinaw River sediment, indicating possible contamination from either industrial and/or recreational practices. As indicated on Figure 1, there is an abundance of land use activities (oil & gas, agriculture, etc.) upstream of the water intake. Further sediment sampling needs to be taken to help identify whether the previous PAH detection was a result of anthropogenic sources (mainly petroleum hydrocarbons), or from the natural breakdown of organic material (EPH's). Furthermore, new oil & gas development that will be undertaken by Encana in the Dawson Creek area in the near future suggests that monitoring needs to be continued to insure a further degradation of water quality does not occur.

The herbicide diallate was detected in the historical sediment sample collected on August 3rd, 1995. Because of the severe health issues related to this product, it may be useful to analyze for this parameter in the future. Furthermore, the presence of this chemical indicates that pesticide runoff from some land use source was previously accessing the Kiskatinaw River. Future sampling may help indicate whether this detrimental runoff is still occurring.

Monitoring of treated water for bacteria, parasites and specific chemical parameters may be beneficial. Because parasites were found at such high concentrations in the raw water, tests should be done to ensure water treatment is effective. More specifically for chemistry, tests on treated water for trihalomethanes may be useful. High concentrations of TOC were found in every sample during the 2002/03 program, which have the potential to form carcinogenic bi-products when reacted with chlorine. Aditionally, metals such as lead and aluminium, both found at moderately high concentrations during this study, have the potential to cause human related illness.

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Appendix A

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

Parameter	# of Values	Min.	Max.	Mean	Std. Dev.	MDL	D.W. Guideline	Guideline Type
Physical								
pH	6	7.95	8.5	8.23	0.199	0.1	6.5-8.5	aesthetic objective
Colour (TCU)	6	10	200	57.5	74.68	5	= 15	aesthetic objective
Specific Conductance (µS/cm)	6	200.5	876	474.8	287.42	1	= 700	maximum acceptable concentration
Turbidity (NTU)	4	7.14	1585	521.7	739.13	0.1	= 5	maximum acceptable concentration
Hardness Total (mg/L)	6	194	502	334	132.1			
Hardness Total -Diss. (mg/L)	6	99.5	510	271.3	168.83		= 500 $CaCO_3$	aesthetic objective
Alkalinity (mg/L)	6	111.5	509	274.1	165.19	0.5		
Residue Non-Filterable (mg/L)	6	4	1165	244	463.1	4		
Total Organic Carbon (mg/L)								
TOC	6	5.5	16.85	10.5	3.94	0.5	= 4	maximum, to control THM production
Anions (mg/L)								
Chloride Dissolved	6	0.5	1.6	0.92	0.458	0.5	= 250	aesthetic objective
Fluoride Dissolved	6	0.05	0.12	0.09	0.023	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	0.002	0.3505	0.074	0.137	0.002	≤ 45 (Nitrate)	maximum acceptable concentration
Phosphorus Total	6	0.006	0.2505	0.058	0.095	0.002		
Phosphorus Total-Diss.	6	0.002	0.0075	0.005	0.002	0.002		
Sulphate (mg/L)								
Sulphate	6	4.4	24.7	11.8	7.78	0.5	= 500	aesthetic objective
Metals Total (ug/L)								
Aluminum-T	6	54.9	814.5	323.9	351.41	0.3		
Aluminum-D	6	0.8	65.8	20.9	25.01	0.3	= 200	maximum acceptable concentration
Antimony -T	6	0.0925	0.1735	0.129	0.027	0.005	= 6	interim maximum acceptable concentration
Antimony -D	6	0.0915	0.1355	0.119	0.016	0.005		
Arsenic-T	6	0.4	1.55	0.767	0.451	0.1	= 25	interim maximum acceptable concentration
Arsenic-D	6	0.4	0.5	0.433	0.041	0.1		
Barium-T	6	175	368	273	90.2	0.02	= 1000	maximum acceptable concentration
Barium-D	6	71.05	364	199	120.6	0.02		
Beryllium-T	6	0.02	0.32	0.10	0.128	0.02		
Beryllium-D	6	0.02	0.03	0.02	0.004	0.02		
Bismuth-T	6	0.02	0.02	0.02	0.000	0.02		
Bismuth-D	6	0.02	0.03	0.02	0.004	0.02		
Cadmium-T	6	0.01	1.065	0.26	0.420	0.01	= 5	maximum acceptable concentration
Cadmium-D	6	0.01	0.03	0.02	0.008	0.01		
Calcium-T (mg/L)	6	56	143	95	37.372	0.05		
Calcium-D (mg/L)	6	28.5	145	77.5	47.994	0.05		
Chromium-T	6	0.2	3.2	0.97	1.168	0.2	= 50	maximum acceptable concentration
Chromium-D	6	0.2	3.5	0.9	1.32	0.2		
Cobalt-T	6	0.005	3.33	0.99	1.389	0.005		
Cobalt-D	6	0.005	0.1965	0.086	0.073	0.005		
Copper-T	6	1.11	15.4	5.3	5.605	0.05	= 1000	aesthetic objective
Copper-D	6	0.945	4.04	2.30	1.079	0.05		
Iron-T (mg/L)	5	0.057	38.55	10.48	16.502	0.005	= 0.3	aesthetic objective
Iron-D (mg/L)	5	0.007	0.117	0.044	0.043	0.005		
Lead-T	6	0.05	8.75	2.28	3.508	0.01	= 10	maximum acceptable concentration
Lead-D	6	0.01	0.12	0.04	0.042	0.01		
Lithium-T	6	2.66	6.22	3.65	1.336	0.05		
Lithium-D	6	1.685	6.35	3.30	1.754	0.05		
Magnesium-T (mg/L)	6	13.1	35.1	23.4	9.39	0.05		
Magnesium-D (mg/L)	6	6.85	36	18	11.9	0.05	= 100	aesthetic objective

Table 1 Continued.

Parameter	# of Values	Min.	Max.	Mean	Std. Dev.	MDL	D.W. Guideline	Guideline Type
Manganese-T	6	18.35	517.5	131.1	193.96	0.008	= 50	aesthetic objective
Manganese-D	6	1	63	24	26.5	0.008		
Molybdenum-T	6	0.285	0.99	0.65	0.255	0.05	= 250	maximum acceptable concentration
Molybdenum-D	6	0.27	1.04	0.67	0.274	0.05		
Nickel-T	6	0.05	9.81	3.38	3.710	0.05		
Nickel-D	6	0.05	3.305	1.26	1.093	0.05		
Selenium-T	6	0.2	0.5	0.3	0.11	0.2	= 10	maximum acceptable concentration
Selenium-D	6	0.2	0.4	0.3	0.07	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	3.53	21.3	10.4	7.90	0.05	= 200	aesthetic objective
Strontium-T	6	187.5	562	308	151.7	0.005		
Strontium-D	6	101.5	567	286	179.3	0.005		
Thallium-T	6	0.002	0.063	0.022	0.025	0.002	= 2	maximum acceptable concentration
Thallium-D	6	0.002	0.0105	0.006	0.003	0.002		
Tin-T	6	0.01	0.03	0.02	0.008	0.01		
Tin-D	6	0.01	0.03	0.02	0.010	0.01		
Uranium-T	6	0.335	1.43	0.85	0.391	0.002	= 100	maximum acceptable concentration
Uranium-D	6	0.297	1.12	0.63	0.354	0.002		
Vanadium-T	6	1.07	5.975	3.44	1.709	0.06	= 100	maximum acceptable concentration
Vanadium-D	6	0.54	2.86	1.52	1.112	0.06		
Zinc-T	6	1.6	30	10	11.9	0.1	= 5000	aesthetic objective
Zinc-D	6	0.1	1.4	0.7	0.58	0.1		

Table 2. Results from the October 31st, 2002 and the August 20th, 2003 sediment samples collected from the Kiskatinaw River at the Arras pump house.

Parameter	Unit	Value/02	Value/03	Parameter	Unit	Value/02	Value/03	Parameter	Unit	Value/02	Value/03
% Moisture	(% W/W)	29	28.5	Bromoxynil	(µg/g)	<0.01	<0.05	Fenitrothion	(µg/g)	<0.02	<0.05
Solid Content	(%)	71		2,4-D	(µg/g)	<0.01	<0.05	Fensulfothion	(µg/g)	<0.01	<0.05
>2.00 mm	(% W/W)	0	0	Dicamba	(µg/g)	<0.005	<0.025	Fenthion	(µg/g)	<0.02	<0.05
0.063-2.00 mm	(% W/W)	16.23	11.91	Dichlorprop	(µg/g)	<0.01	<0.05	Fonofos	(µg/g)	<0.02	<0.05
0.053-0.063 mm	(% W/W)	4.64	4.75	Dinoseb	(µg/g)	<0.1	<1.5	Iodofenphos	(µg/g)	<0.01	<0.05
0.004-0.053 mm	(% W/W)	62.63		MCPA	(µg/g)	<0.01	<0.05	Malathion	(µg/g)	<0.01	<0.05
0.002-0.053 mm	(% W/W)		66.05	Picloram	(µg/g)	<0.01	<0.05	Mevinphos-cis	(µg/g)	<0.05	<0.05
0.002-0.004 mm	(% W/W)	4.33		2,4,5-T	(µg/g)	<0.005	<0.025	Methamidophos	(µg/g)	<0.05	<0.05
<0.002 mm	(% W/W)	12.17	17.28	2,4,5-TP	(µg/g)	<0.005	<0.025	Naled	(µg/g)	<0.01	<0.05
Carbon - Tot. Inorg.	(µg/L)	14000	14000	Triclopyr	(µg/g)	<0.005	<0.025	Omethoate	(µg/g)	<0.02	<0.1
Carbon - Tot. Org.	(µg/L)	12000	10000	Aldrin	(µg/g)	<0.002	<0.002	Parathion	(µg/g)	<0.01	<0.05
Carbon - Tot.	(µg/g)	26000	24000	BHC, Alpha-	(µg/g)	<0.002	<0.002	Parathion Methyl	(µg/g)	<0.02	<0.05
Phosphorus - Tot.	(µg/g)	803	778	BHC, Beta-	(µg/g)	<0.002	<0.002	Phorate	(µg/g)	<0.02	<0.05
Aluminum - Tot.	(µg/g)	4530	5870	BHC, Delta-	(µg/g)	<0.002	<0.002	Phosalone	(µg/g)	<0.05	<0.1
Antimony - Tot.	(µg/g)	0.4	0.6	Chlordane, Alpha-	(µg/g)	<0.01	<0.002	Phosmet	(µg/g)	<0.03	<0.05
Arsenic - Tot.	(µg/g)	4.8	5.6	Chlordane, Gamma-	(µg/g)	<0.01	<0.002	Phosphamidon	(µg/g)	<0.05	<0.05
Barium - Tot.	(µg/g)	282	325	DDD,p,p'-	(µg/g)	<0.01	<0.004	Sulfotep	(µg/g)	<0.02	<0.05
Beryllium - Tot.	(µg/g)	3	0.3	DDE-p,p'	(µg/g)	<0.005	<0.004	Tetrachlorvinphos	(µg/g)	<0.02	<0.05
Bismuth - Tot.	(µg/g)	<0.1	0.1	DDT-o,p'-	(µg/g)	<0.01	<0.004	Oil & Grease - Tot.	(µg/g)	<100	
Cadmium - Tot.	(µg/g)	0.58	0.72	DDT-p,p'-	(µg/g)	<0.02	<0.004	Acenaphthene	(µg/g)	<0.01	<0.01
Calcium - Tot.	(µg/g)	42300	42700	Dieldrin	(µg/g)	<0.01	<0.002	Acenaphthylene	(µg/g)	<0.01	<0.01
Chromium - Tot.	(µg/g)	15.5	10.1	Endosulfan I	(µg/g)	<0.01	<0.004	Anthracene	(µg/g)	<0.01	<0.01
Cobalt - Tot.	(µg/g)	6.4	7.6	Endosulfan II	(µg/g)	<0.01	<0.004	Benzo(a)anthracene	(µg/g)	<0.01	0.01
Copper - Tot.	(µg/g)	36.5	17	Endosulfan Sulphate	(µg/g)	<0.02	<0.01	Benzo(b)fluoranthene	(µg/g)	0.02	0.05
Iron - Tot.	(µg/g)	16200	17700	Endrin	(µg/g)	<0.02	<0.004	Benzo(k)fluoranthene	(µg/g)	<0.01	<0.01
Lead - Tot.	(µg/g)	8	9.9	Hepatachlor	(µg/g)	<0.002	<0.002	Benzo(g,hi)perylene	(µg/g)	<0.02	0.05
Magnesium - Tot.	(µg/g)	12500	11100	Hepatachlor epoxide	(µg/g)	<0.004	<0.002	Benzo(a)pyrene	(µg/g)	<0.01	0.01
Manganese - Tot.	(µg/g)	284	336	Lindane, BHC, Gamma-	(µg/g)	<0.002	<0.002	Chrysene	(µg/g)	0.03	0.1
Molybdenum - Tot.	(µg/g)	0.8	1	Methidathion	(µg/g)	<0.02	<0.05	Dibenz(a,h)anthracene	(µg/g)	<0.02	<0.02
Nickel - Tot.	(µg/g)	22.9	23.7	Methoxychlor	(µg/g)	<0.02	<0.02	Fluoranthene	(µg/g)	<0.01	0.03
Potassium - Tot.	(µg/g)	412	775	Mirex	(µg/g)	<0.02	<0.004	Fluorene	(µg/g)	<0.01	<0.02
Selenium - Tot.	(µg/g)	<0.5	0.7	Nonchlor, Trans-	(µg/g)	<0.01	<0.01	Indeno(1,2,3-c,d)pyrene	(µg/g)	<0.02	<0.02
Silver - Tot.	(µg/g)	0.15	0.2	Oxychlordane	(µg/g)	<0.01	<0.004	Naphthalene	(µg/g)	<0.01	0.07
Sodium - Tot.	(µg/g)	<100	<100	PCBs- Tot.	(µg/g)	<0.05	<0.02	C1-Naphthalenes	(µg/g)	0.06	
Strontium - Tot.	(µg/g)	56.8	62.2	Acephate	(µg/g)	<0.05	<0.1	C2-Naphthalenes	(µg/g)	0.13	0.4
Tellurium - Tot.	(µg/g)	<0.1	<0.1	Azinphos Methyl	(µg/g)	<0.05	<0.05	Phenanthrene	(µg/g)	0.05	0.22
Thallium - Tot.	(µg/g)	0.13	0.15	Bromophos	(µg/g)	<0.01	<0.05	C1-Phen/Anthracene	(µg/g)	0.12	0.34
Tin - Tot.	(µg/g)	0.4	0.5	Carbophenothion	(µg/g)	<0.01	<0.05	C2-Phen/Anthracene	(µg/g)	0.15	0.2
Titanium - Tot.	(µg/g)	29	31	Chlorfenvinphos(e)	(µg/g)	<0.01	<0.05	Pyrene	(µg/g)	0.01	0.04
Vanadium - Tot.	(µg/g)	21	23	Chlorpyrifos	(µg/g)	<0.01	<0.05	Total PAHs	(µg/g)	0.11	0.58
Zinc - Tot.	(µg/g)	70.2	79.1	Demeton	(µg/g)	<0.02	<0.05	Total Low MW PAHs	(µg/g)	0.05	0.29
Zirconium - Tot.	(µg/g)	1.5	1.8	Diazinon	(µg/g)	<0.02	<0.05	Total High MW PAHs	(µg/g)	0.06	0.29
2,3,4,5 - Tetrachlorophenol	(µg/g)	<0.01	<0.05	Dichlorvos	(µg/g)	<0.01	<0.05	1-methylnaphthalene	(µg/g)		0.14
2346+2356-TeClPhenol	(µg/g)	<0.01	<0.05	Dimethoate	(µg/g)	<0.02	<0.05	HCB	(µg/g)		<0.01
Pentachlorophenol	(µg/g)	<0.005	<0.025	Ethion	(µg/g)	<0.05	<0.05	Toxaphene	(µg/g)		<0.3

Table 3. Results from the August 20th, 2003 sediment sample collected from the Kiskatinaw River 1 km upstream of the Arras pump house.

Parameter	Unit	Value/03	Parameter	Unit	Value/03	Parameter	Unit	Value/03
% Moisture	(% W/W)		2346+2356-TeClPhenol	(µg/g)	<0.01	Fenitrothion	(µg/g)	<0.05
Solid Content	(%)		Pentachlorophenol	(µg/g)	<0.005	Fensulfothion	(µg/g)	<0.05
>2.00 mm	(% W/W)		Bromoxynil	(µg/g)	<0.01	Fenthion	(µg/g)	<0.05
0.063-2.00 mm	(% W/W)	50.69	2,4,5-T	(µg/g)	<0.01	Omethoate	(µg/g)	<0.1
0.053-0.063 mm	(% W/W)	14.06	2,4,5-TP	(µg/g)	<0.005	Parathion	(µg/g)	<0.05
0.002-0.053 mm	(% W/W)	38.15	Triclopyr	(µg/g)	<0.01	Parathion Methyl	(µg/g)	<0.05
<0.002 mm	(% W/W)	10.93	Aldrin	(µg/g)	<0.1	Phorate	(µg/g)	<0.05
Carbon - Tot. Inorg.	(µg/L)	5400	BHC, Alpha-	(µg/g)	<0.01	Phosalone	(µg/g)	<0.1
Carbon - Tot. Org.	(µg/L)	8600	BHC, Beta-	(µg/g)	<0.01	Phosmet	(µg/g)	<0.05
Carbon - Tot.	(µg/g)	14000	BHC, Delta-	(µg/g)	<0.005	Phosphamidon	(µg/g)	<0.05
Phosphorus - Tot.	(µg/g)	629	Chlordane, Alpha-	(µg/g)	<0.005	Sulfotep	(µg/g)	<0.05
Aluminum - Tot.	(µg/g)	2970	Chlordane, Gamma-	(µg/g)	<0.005	Tetrachlorvinphos	(µg/g)	<0.05
Antimony - Tot.	(µg/g)	0.3	DDD,p,p'-	(µg/g)	<0.002	Oil & Grease - Tot.	(µg/g)	290
Arsenic - Tot.	(µg/g)	3.6	DDE-p,p'	(µg/g)	<0.002	Acenaphthene	(µg/g)	<0.01
Barium - Tot.	(µg/g)	156	DDT-o,p'-	(µg/g)	<0.002	Acenaphthylene	(µg/g)	<0.01
Beryllium - Tot.	(µg/g)	0.1	DDT-p,p'-	(µg/g)	<0.002	Anthracene	(µg/g)	<0.01
Bismuth - Tot.	(µg/g)	<0.1	Dieldrin	(µg/g)	<0.01	Benzo(a)anthracene	(µg/g)	<0.01
Cadmium - Tot.	(µg/g)	0.33	Endosulfan I	(µg/g)	<0.01	Benzo(b)fluoranthene	(µg/g)	0.03
Calcium - Tot.	(µg/g)	20900	Endosulfan II	(µg/g)	<0.01	Benzo(k)fluoranthene	(µg/g)	<0.01
Chromium - Tot.	(µg/g)	4.2	Endosulfan Sulphate	(µg/g)	<0.005	Benzo(g,hi)perylene	(µg/g)	0.03
Cobalt - Tot.	(µg/g)	4.9	Endrin	(µg/g)	<0.01	Benzo(a)pyrene	(µg/g)	<0.01
Copper - Tot.	(µg/g)	7.9	Hepatachlor	(µg/g)	<0.02	Chrysene	(µg/g)	0.07
Iron - Tot.	(µg/g)	10200	Hepatachlor epoxide	(µg/g)	<0.01	Dibenz(a,h)anthracene	(µg/g)	<0.02
Lead - Tot.	(µg/g)	5.7	Lindane, BHC, Gamma-	(µg/g)	<0.01	Fluoranthene	(µg/g)	0.02
Magnesium - Tot.	(µg/g)	5430	Methidathion	(µg/g)	<0.01	Fluorene	(µg/g)	<0.02
Manganese - Tot.	(µg/g)	225	Methoxychlor	(µg/g)	0.02	Indeno(1,2,3-c,d)pyrene	(µg/g)	<0.02
Molybdenum - Tot.	(µg/g)	0.5	Mirex	(µg/g)	<0.02	Naphthalene	(µg/g)	0.06
Nickel - Tot.	(µg/g)	13.5	Nonchlor, Trans-	(µg/g)		C1-Naphthalenes	(µg/g)	
Potassium - Tot.	(µg/g)	374	Oxychlordane	(µg/g)	<0.004	C2-Naphthalenes	(µg/g)	0.29
Selenium - Tot.	(µg/g)	<0.5	PCBs- Tot.	(µg/g)	<0.002	Phenanthrene	(µg/g)	0.15
Silver - Tot.	(µg/g)	0.09	Acephate	(µg/g)	<0.02	C1-Phen/Anthracene	(µg/g)	0.24
Sodium - Tot.	(µg/g)	<100	Azinphos Methyl	(µg/g)	<0.02	C2-Phen/Anthracene	(µg/g)	0.13
Strontium - Tot.	(µg/g)	30.6	Bromophos	(µg/g)	<0.02	Pyrene	(µg/g)	0.03
Tellurium - Tot.	(µg/g)	<0.1	Carbophenothion	(µg/g)	<0.01	Total PAHs	(µg/g)	0.39
Thallium - Tot.	(µg/g)	0.08	Chlorfenvinphos(e)	(µg/g)	<0.01	Total Low MW PAHs	(µg/g)	0.21
Tin - Tot.	(µg/g)	0.2	Chlorpyrifos	(µg/g)	<0.05	Total High MW PAHs	(µg/g)	0.18
Titanium - Tot.	(µg/g)	16	Demeton	(µg/g)	<0.05	1-methylnaphthalene	(µg/g)	0.1
Vanadium - Tot.	(µg/g)	12	Diazinon	(µg/g)	<0.05	HCB	(µg/g)	<0.01
Zinc - Tot.	(µg/g)	43.9	Dichlorvos	(µg/g)	<0.01	Toxaphene	(µg/g)	<0.3
Zirconium - Tot.	(µg/g)	0.9	Dimethoate	(µg/g)	<0.01			
2,3,4,5 - Tetrachlorophenol	(µg/g)	<0.01	Ethion	(µg/g)	<0.01			

Table 5. Complex organic molecules that were always present in concentrations less that the analytical detection limit (MDL). Note that samples sizes (n) are very small.

Parameter	MDL (mg/L)	*n*	Parameter	MDL	*n*
2-4-Dichlorophenol	0.005	4	1-4-Dichlorobenzene	0.0002	1
2-Chlorophenol	0.005	4	1-1-Dichloroethene	0.0005	1
2-Methyl-4-6-Dinitrophenol	0.02	4	Trans 1-2 Dichloroethene	0.0004	1
4-Chloro-3-Methylphenol	0.005	4	Dinoseb	0.0002	3
2-4-Dimethylphenol	0.005	4	Diuron	0.002	1
2-4-Dinitrophenol	0.2	4	Ethylbenzene	0.0005	1
2-Nitrophenol	0.005	4	Ethylene Dibromide	0.0005	1
4-Nitrophenol	0.02	4	Total Hydrocarbon	0.1	1
Pentachlorophenol	0.005	4	Linuron	0.0005	1
2-4-6-Trichlorophenol	0.005	4	Methyl-4-Chlorophenoxyacetic Acid	0.002	1
Chloroform	0.0003	1	Methyl & Butyl Ether	0.0007	1
Bromodichloromethane	0.0005	1	PCB	0.0004	1
Bromoform	0.0003	1	Pentachlorophenol	0.0001	3
2-4-5-Trichlorophenoxyacetic acid	0.0001	2	Picloram	0.0002	3
Atrazine	0.0002	1	Simazine	0.0002	1
Bromocil	0.0005	1	Styrene	0.0004	1
Bromochloromethane	0.0005	1	Tebuthiuron	0.0002	1
Bromomethane	0.002	1	Tetrachloroethene	0.0004	1
Bromooxynil	0.0002	1	Tetrachloroethylene	0.0002	1
Carbon Tetrachloride	0.0007	1	Tetrachlorophenol	0.0002	1
Chlorobenzene	0.0005	1	Toluene	0.0005	1
Chloroethane	0.002	1	Triclopyr	0.0001	3
Tetrachlorophenol	0.002	1	1-1-1-Trichloroethane	0.005	1
Cis 1-2-Dichloroethane	0.003	1	1-1-2 Trichloroethane	0.0005	1
Cis 1-3-Dichloropropene	0.0005	1	Trichloroethylene	0.0003	1
Trans 1-3-Dichloropropene	0.0005	1	Trichlorofluoromethane	0.0006	1
Dibromochloromethane	0.0003	1	Total Trihalomethanes	0.0005	1
Dicamba	0.0001	1	Vinyl Chloride	0.001	1
1-2-Dichlorobenzene	0.0004	1	Total Xylene	0.0005	1
1-3-Dichlorobenzene	0.0003	1			

Table 8. Total metals and carbon concentrations (µg/g, dw) in Kiskatinaw River sediments 200 m upstream of Peace River confluence (only detectable metals shown) (August 3rd,1995 sample).

Parameter	Conc. (µg/g)	Parameter	Conc. (µg/g)	Parameter	Conc. (µg/g)
Aluminum	35550	Copper	26	Strontium	82
Arsenic	29	Iron	24700	Vanadium	103
Barium	633	Magnesium	8170	Zinc	118
Calcium	16150	Manganese	286	Inorganic Carbon	7000
Cobalt	11	Nickel	35	Organic Carbon	9900
Chromium	15	Lead	12	Carbon	16900

Table 10. Duplicate samples that exceeded precision acceptability criteria (≤25% difference when > 5-fold MDL). All concentrations in µg/L except bacteria which are CFU/100mL. There is no lab acceptability criteria for bacteria.

Parameter	MDL (µg/L)	October 2002			January 2003			March 2003			April 2003			May 2003		
		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	**79.19**				3.7	6.5	**54.9**						
Antimony-T	0.005				0.038	0.029	**26.87**									
Cobalt -T	0.005							0.062	0.04	**43.14**						
Chromium -T	0.2	2.1	4.3	**68.75**												
Iron-D	0.005							0.026	0.047	**57.53**						
Nickel-T	0.05							0.35	0.47	**29.27**						
Phosphorus-T (mg/L)	0.002										0.084	0.012	**150**			
Phosphorus-T-D (mg/L)	0.002										0.013	0.002	**146.67**			
Vanadium-T	0.06	1.94	3.35	**53.31**				1.31	0.84	**43.72**						
Zinc-T	0.1	2.8	1.1	**87.18**												

RPD %= Relative Percent Difference

**Data are presented for the purpose of batch specific QA assessment. Most QA samples were not collected at Dawson Creek.*

Table 11. 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 14. 2002/03 raw drinking water data collected from the Kiskatinaw River.

Date	Cryptosporidium (oocysts/100L)	Giardia (cysts/100L)	Total Coliform (Col./100mL)	Fecal Coliform (Col./100mL)	Enterococci (Col./100mL)
02-Oct-02			4	2	18
02-Oct-02			3	<1	10
31-Oct-02	<11.7	338.6			
15-Jan-03	<4.8	76.7	<1	<1	<1
05-Mar-03	<4.6	961.7	<1	<1	<1
30-Apr-03	<129.4	906.4	330	30	10
30-Apr-03			200	30	<10
28-May-03	<29.7	178.1	270	<2	210
28-May-03	<27.6	165.4	140	<2	370
20-Aug-03	<12.7	190.6	35	57	55

E. Coli (Col./100mL)	pH (pH Units)	True Colour (Col. Unit)	Specific Conductance (µS/cm)	Residues - NonFilt. (mg/L)	Turbidity (NTU)
2	8.2	10	369	9	
<1	8.3	10	361	10	
<1	8.4	10	797	<4	
<1	8.1	15	876	4	7.14
20	8	240	201	1130	1570
10	7.9	160	200	1200	1600
<2	8.2	80	263	260	431
<2	8.2	80	264	280	495
13	8.5	30	347	13	31.7

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)
243	241	234	<0.1	0.5	0.09
241	244	235	<0.1	0.9	0.09
446	447	450	<0.1	0.9	0.12
502	510	509	<0.1	1.6	0.1
425	102	112	<0.1	1.4	0.08
380	97	111	<0.1	1.3	0.11
223	138	154	<0.1	<0.5	0.05
211	136	153	<0.1	<0.5	0.05
194	192	186	<0.1	<0.5	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)
5.5	0.002	0.002	0.014	11.3	118
5.5	0.002	0.002	0.014	12.5	99
8.4	0.029	0.006	0.006	16.7	58.6
8.7	0.057	0.006	0.01	24.7	54.9
16.5	0.363	0.013	0.084	6.7	814
17.2	0.338	0.002	0.012	6.8	815
12.6	<0.002	0.003	0.258	6	756
12.6	<0.002	0.005	0.243	6.3	706
11.1	<0.002	0.003	0.022	4.4	176

Aluminum - Diss. (µg/L)	Antimony - Tot. (µg/L)	Antimony - Diss. (µg/L)	Arsenic - Tot. (µg/L)	Arsenic - Diss. (µg/L)	Barium - Tot. (µg/L)
31.2	0.091	0.093	0.4	0.5	187
13.5	0.094	0.09	0.4	0.4	186
2	0.122	0.117	0.4	0.4	327
0.8	0.129	0.126	0.6	0.4	366
62.8	0.173	0.131	1.6	0.5	373
68.8	0.174	0.129	1.5	0.4	363
29.2	0.148	0.135	1.1	0.4	223
30.4	0.131	0.136	1	0.4	213
4.5	0.116	0.113	0.6	0.5	175

Barium - Diss. (µg/L)	Beryllium - Tot. (µg/L)	Beryllium - Diss. (µg/L)	Bismuth - Tot. (µg/L)	Bismuth - Diss. (µg/L)	Cadmium - Tot. (µg/L)
179	0.02	<0.02	<0.02	<0.02	0.02
179	<0.02	<0.02	<0.02	<0.02	0.02
329	<0.02	<0.02	0.02	<0.02	<0.01
364	<0.02	<0.02	<0.02	<0.02	0.02
73.8	0.32	<0.02	<0.02	<0.02	1.08
68.3	0.32	<0.02	<0.02	0.04	1.05
99.5	0.2	<0.02	<0.02	<0.02	0.42
101	0.19	<0.02	<0.02	<0.02	0.37
153	0.03	0.03	<0.02	<0.02	0.06

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	69.1	68.3	2.1	3.3	<0.005
<0.01	68.5	69.3	4.3	3.7	<0.005
<0.01	127	128	<0.2	<0.2	<0.005
0.02	143	145	<0.2	<0.2	0.144
0.03	120	29.2	<0.2	<0.2	3.46
0.03	107	27.8	<0.2	<0.2	3.2
0.01	63.3	39.5	1	<0.2	2.15
0.01	60.2	39	0.7	<0.2	2
<0.01	56	55.8	1.2	0.9	0.404

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	1.03	0.98			0.2
<0.005	1.19	0.91			0.19
<0.005	1.63	1.72	0.057	0.007	0.05
0.105	2.56	2.14	0.266	0.018	0.15
0.194	15.5	4.19	39.8	0.112	8.82
0.199	15.3	3.89	37.3	0.122	8.68
0.087	8.89	3	13.8	0.05	4.17
0.088	8.12	2.99	10.7	0.044	3.74
0.117	2.8	1.96	1.25	0.031	0.55

Lead - Diss. (µg/L)	Lithium - Tot. (µg/L)	Lithium - Diss. (µg/L)	Magnesium - Tot. (mg/L)	Magnesium - Diss. (mg/L)	Manganese - Tot. (µg/L)	Manganese - Diss. (µg/L)
0.02	2.95	2.95	17.2	17	18.3	4.24
<0.01	2.96	2.6	17.1	17.3	18.4	3.4
0.03	3.89	4.35	31.2	31	33.1	26.2
<0.01	6.22	6.35	35.1	36	54.7	49.2
0.12	2.68	1.74	30.5	7.01	538	58.4
0.12	2.64	1.63	27.5	6.69	497	67.6
0.05	3.47	1.96	15.7	9.46	142	3.87
0.04	3.29	2.08	14.7	9.37	128	3.38
<0.01	2.8	2.63	13.1	12.9	28	1

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)
0.56	0.69	1.15	0.99	0.2	0.4	<0.02
0.56	0.7	1.35	1.07	<0.2	0.3	<0.02
0.87	0.89	<0.05	<0.05	0.4	0.3	0.02
0.99	1.04	1.38	1.31	0.5	0.4	<0.02
0.55	0.55	10.1	3.43	<0.2	0.3	<0.02
0.49	0.49	9.52	3.18	0.3	0.2	<0.02
0.28	0.28	6.02	0.75	0.5	0.3	0.02
0.29	0.26	5.6	0.8	0.2	0.4	<0.02
0.7	0.59	1.98	1.08	0.3	<0.2	<0.02

Silver - Diss. (µg/L)	Sodium - Tot. (mg/L)	Strontium - Tot. (µg/L)	Strontium - Diss. (µg/L)	Thallium - Tot. (µg/L)	Thallium - Diss. (µg/L)	Tin - Tot. (µg/L)
<0.02		261	259	<0.002	<0.002	0.02
<0.02		266	260	<0.002	<0.002	<0.01
<0.02	16.3	423	435	<0.002	<0.002	0.03
<0.02	21.3	562	567	0.009	0.006	0.02
<0.02	3.65	205	100	0.061	0.012	0.02
<0.02	3.41	199	103	0.065	0.009	0.02
<0.02	4.53	189	153	0.044	0.007	<0.01
<0.02	4.5	186	154	0.041	0.006	<0.01
<0.02	6.6	210	201	0.013	0.006	<0.01

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)
0.04	0.616	0.6	1.94	2.47	2.8	0.2
0.02	0.611	0.603	3.35	2.74	1.1	<0.1
0.03	1.04	1.12	4.27	2.86	1.6	1.4
<0.01	1.43	1	2.55		4.1	
0.01	1.03	0.357	6.03	0.73	30.2	1
0.01	1.04	0.322	5.92	0.81	29.8	1.2
<0.01	0.68	0.402	4.26	0.56	20.5	0.5
<0.01	0.641	0.398	3.95	0.52	18.5	0.6
<0.01	0.335	0.297	1.07	0.85	2.9	<0.1