REPORT

Alberta Environment and Parks

Upper Athabasca
Effluent Characterization

May 2019

ISO 9001 and 14001 Certified | An Associated Engineering Company

Executive Summary

1 INTRODUCTION AND APPROACH

Alberta Environment and Parks (AEP) is collecting information required to develop a Surface Water Quality Management Framework (SWQMF) in the Upper Athabasca Region that will allow the management of cumulative effects on surface water quality. AEP retained Associated Environmental to conduct an initial study to characterize effluents and inform effluent monitoring programs in the Upper Athabasca Region based on existing information.

The principal goals of this study were to:

- identify variables of concern (VOCs) for the Upper Athabasca River,
- develop recommendations for future effluent monitoring programs, and
- develop a prototype effluent quality database that can provide readily available information on effluent quality.

Effluent is discharged to the Upper Athabasca River from municipal wastewater treatment facilities, coal mines, and pulp mills. For this report, effluent data were available from two coal mines, two municipal dischargers, and six pulp and paper mills. Receiving waters data were available for the coal mines and pulp and paper mills. The data were compiled, analyzed and used in the identification of VOCs. A literature review was completed to provide additional information on VOCs for the three sectors in the Upper Athabasca Region.

2 VARIABLES OF CONCERN

Out of about 250 variables with effluent data, 58 potential VOCs were identified based on meeting at least one of the following three criteria:

- exceeded a guideline at least once in available effluent data,
- identified as a concern or potential concern in the literature review, or
- presented potential to impact surface water quality, indicated by median effluent concentrations exceeding upstream river concentrations by a factor of > 10.

A prioritization matrix was developed based on these criteria and then used to identify 24 VOCs for the Upper Athabasca Region. The leading VOCs were total phosphorus, total nitrogen, total suspended solids, and biochemical oxygen demand, due to their prominence in all effluent types and their observed impact on the river. Dissolved oxygen is an important VOC as an indicator of impacts of oxygen-consuming substances to the river. Selenium is of large importance due to coal mining but also pulp and paper. Other metals (e.g., zinc, cadmium, and cobalt) feature on the list, as well as conductivity, fecal coliforms, sulphate and sulphide, phenolic compounds, and chloride.

3 EFFLUENT MONITORING PROGRAM REVIEW AND RECOMMENDATIONS

The study included a review of effluent monitoring programs that are currently in place for municipal, coal mining, and pulp and paper dischargers in the Upper Athabasca Region. We summarized current monitoring requirements, identified gaps, and provided recommendations for idealized monitoring programs for each sector.

Existing monitoring programs include at least monthly monitoring for key parameters TSS (all sectors) and cBOD (pulp and paper and municipal). Some sector-specific parameters are monitored at least monthly as well, such as ammonia and TP for some municipalities, nitrate for coal mines, and colour and nutrients in pulp and paper mill effluent. Many additional parameters are monitored less frequently in coal mine and pulp and paper effluents. Toxicity testing is conducted at coal mines and pulp and paper effluent.

The following recommendations were provided for additions and changes to sector-specific monitoring programs:

- Always monitor ammonia, temperature, and pH together for municipalities to allow assessing un-ionized ammonia,
- Include TP in municipal effluent monitoring programs,
- Add selenium, variables associated with calcite deposition potential (e.g., calcium, carbonate, magnesium, hardness), and sublethal toxicity testing to coal mining monitoring, and
- Add sulphide and hardness to pulp and paper monitoring, consistently monitor major ions, and increase heavy metal monitoring frequency from annually to at least quarterly or monthly.

The following recommendations were provided for additions and changes to monitoring programs for all sectors:

- Complete a one-time effluent characterization of an extended dataset to confirm list of VOCs,
- Complete one-time receiving water impact study to identify site-specific constraints on effluent quality,
- Include effluent volumes and loadings in monitoring and reporting to better support cumulative effects management efforts, and
- Homogenize and improve reporting requirements, which includes the submission of spreadsheet-format duplicates of data with annual and monthly reporting in pdf format, including relevant metadata.

This study was based on a limited amount of effluent quality and river data, in particular for coal mines and municipalities. More effluent and river data should be collected for these sectors to increase our confidence in the results of identification and prioritization of VOCs. Coal mine and municipal effluent data are available in pdf format from annual reports and can be extracted. Obtaining original data from the facilities themselves may be an alternative approach. Additional river data from upstream locations of municipal discharges may be obtained from the AEP ambient water quality database. This would help improve the river impact analysis and thereby increase confidence in the VOC prioritization.

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List of Abbreviations

AEP	Alberta Environment and Parks
Ag T	total silver
ALPAC	Alberta-Pacific Forest Industries
Al D	dissolved aluminum
ANC	Alberta Newsprint Company
As T	total arsenic
BOD_5	biochemical oxygen demand measured at 20˚C over a period of 5 days
B T	total boron
BTEX	benzene, toluene, ethylbenzene, xylene
cBOD	carbonaceous BOD_5
CCME	Canadian Council of Ministers of the Environment
Cd T	total cadmium
COD	chemical oxygen demand
Co T	total cobalt
CTMP	chemi-thermomechanical pulp
DO	dissolved oxygen
DOC	dissolved organic carbon
EEM	Environmental Effects Monitoring
EPEA	Environmental Protection and Enhancement Act
Fe D	dissolved iron
Hg T	total mercury
K	potassium
Mb T	total molybdenum
Na	sodium
NA	not applicable / not available
Ortho-P	ortho phosphorous
PAH	polycyclic aromatic hydrocarbon
QA/QC	quality assurance / quality control
Se	selenium
SO_4	sulphate
SWQMF	Surface Water Quality Management Framework
TDP	total dissolved phosphorus
Tl T	total thallium
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TSS	total suspended solids
VOC	variables of concern

WQBEL	Water Quality Based Effluent Limit
WW	wastewater
U T	total uranium
Zn T	total zinc

1 Introduction

Surface Water Quality Management Frameworks are a key component of Alberta's cumulative effects management system that is being advanced under regional planning and the Land-use Framework. Alberta Environment and Parks is collecting information required to develop a Surface Water Quality Management Framework (SWQMF) in the Upper Athabasca Region that will be prepared to allow the management of cumulative effects on surface water quality. One example of cumulative effects are additive effects of multiple dischargers. Even if all dischargers meet their individual approval standards, their combined (i.e., cumulative) effects on the river can be significant. It is therefore important to have a good understanding of the nature of effluent discharges to be able to assess their combined effect on the mainstem Upper Athabasca River system and major tributaries and to develop management strategies.

Alberta Environment and Parks (AEP) retained Associated Environmental (Associated) to conduct an initial study to characterize effluents and inform effluent monitoring programs in the Upper Athabasca Region based on existing information. The principal goals of this project are to:

- identify variables of concern for the Upper Athabasca River,
- develop recommendations for future effluent monitoring programs, and
- develop a prototype effluent quality database that can provide readily available information on effluent quality.

This report presents the analysis of available data and literature at time of reporting to gain an understanding of effluent quality in the Upper Athabasca River. Based on these data, variables of concern were identified and recommendations on future effluent monitoring programs were developed.

2 Study Area

The Upper Athabasca Region stretches from the headwaters of the Athabasca River at Columbia Icefield in the Rocky Mountains to several kilometers downstream of the town of Athabasca, covering approximately 800 km of river. Major tributaries of the Athabasca River in the Upper Athabasca Region are:

- Lesser Slave River (draining Lesser Slave Lake);
- Pembina River (joining the Athabasca upstream of the Lesser Slave junction); and
- McLeod River (joining the Athabasca further upstream, near the town of Whitecourt).

The Athabasca watershed is home to many small to medium sized communities, but no major urban centres. An abundance of natural resource extraction, such as forestry and coal mining, have led to extensive anthropogenic development of the land. As a result, multiple sources of point discharge (e.g. effluent outfalls from pulp and paper mills, coal mines and municipalities, Figure 3-1) and non-point discharge (e.g. surface water runoff) impact the Athabasca River. This report focuses on point source discharges from municipal wastewater treatment facilities, coal mines and pulp and paper mills in the Upper Athabasca Region.

3 Data Analysis

3.1 DATASET OVERVIEW

Effluent is discharged to the Upper Athabasca River from the following sectors:

- municipal wastewater treatment facilities;
- coal mines; and
- pulp mills.

Each sector and data used for this project are described in detail below. For this report, effluent data was available from a subset of point-source dischargers in the Upper Athabasca Region (Table 3-1, Appendix A). In addition to data from individual sectors, AEP provided data from a synoptic survey of the Athabasca River and point-source discharges conducted in winter 2015. AEP also provided copies of *Environmental Protection and Enhancement Act* Approval documents for all coal mines and pulp mills, and selected municipalities; these were mainly used to summarize existing monitoring programs (section 5.1).

3.1.1 Municipal Wastewater Treatment Facilities

There are several small to medium-sized municipal effluent discharges in the region. These include the Town of Whitecourt (pop. approx. 10,000, continuous discharge), Edson (pop. approx. 8,500, continuous discharge), Slave Lake (pop. approx. 6,500, continuous discharge), Barrhead (pop. approx. 4,500, seasonal discharge) and Athabasca (pop. approx. 3,000, continuous discharge). Also, the Hinton Pulp Mill has a combined outflow, meaning that the mill collects municipal wastewater from a surrounding population of approximately 10,000). In addition, many smaller communities discharge effluent seasonally to surface water across the watershed (Figure 3-1).

Effluent data for municipalities in spreadsheet format were provided by the towns of Barrhead and Slave Lake. These data originated from *Environmental Protection and Enhancement Act* (EPEA) approval compliance reporting, effluent characterization studies and water quality based effluent limits studies. No data in spreadsheet format were available from other municipalities at time of reporting.

3.1.2 Pulp and Paper Mills

Five pulp and paper mills are located in the Upper Athabasca Region. These include

- two bleached kraft pulp mills (West Fraser Mills in Hinton and Alberta-Pacific Forest Industries (ALPAC) in Athabasca);
- three chemi-thermomechanical pulp (CTMP) mills (Millar Western and Alberta Newsprint Company (ANC) in Whitecourt, Slave Lake Pulp Corporation).

Four mills discharge directly to the Athabasca River (Hinton, ANC, Millar, ALPAC), and one discharges to a tributary (Slave Lake Pulp to the Lesser Slave River; Figure 3-1). Effluent and receiving water quality data sets were provided by AEP for all five pulp and paper mills.

3.1.3 Coal Mines

Coal mining is another important resource industry that contributes point source discharges to receiving waters. Six coal mines discharge into the headwaters of the Athabasca River (Obed) and to tributaries of the McLeod River (all other mines), in the Rocky Mountains or their foothills:

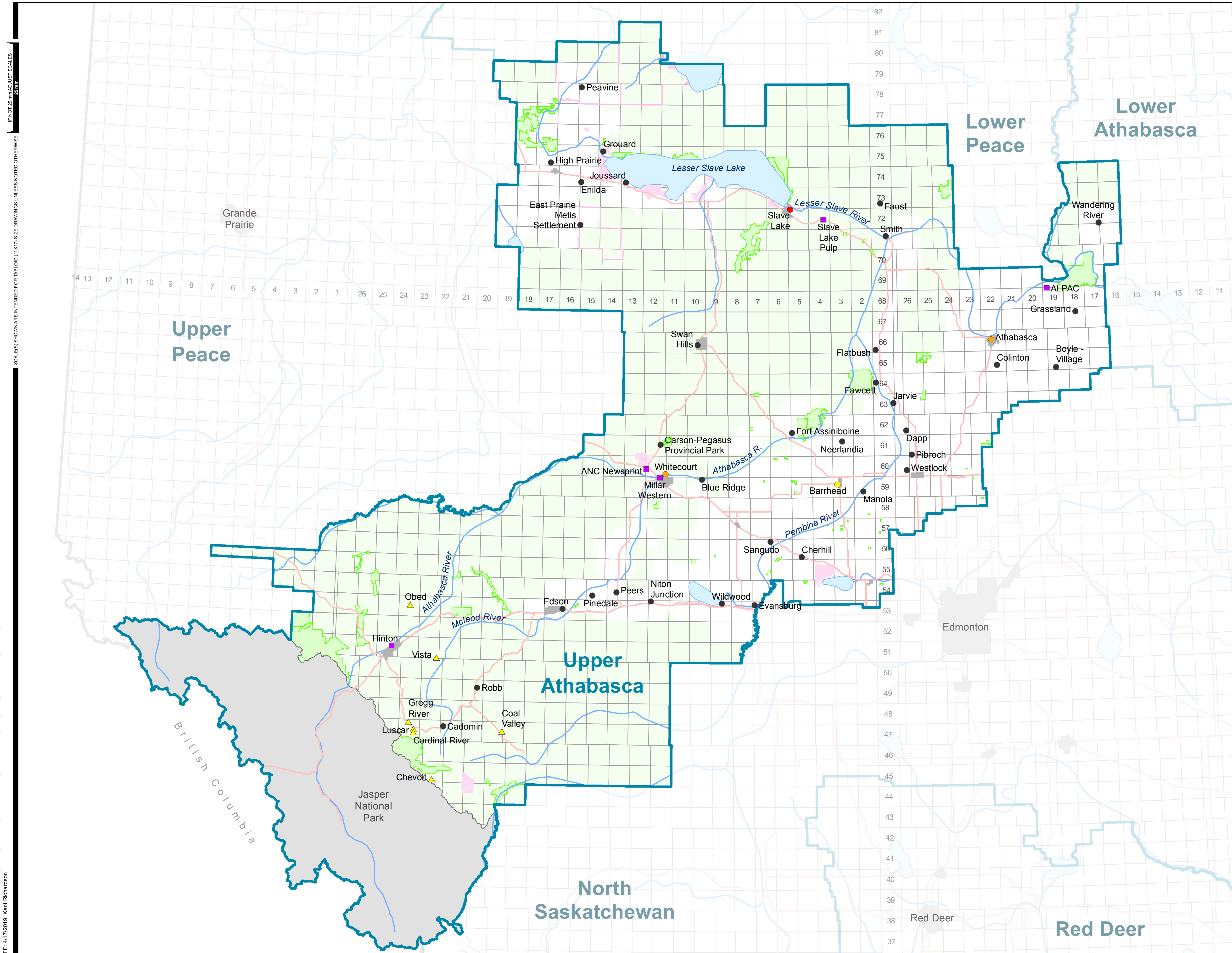
- Vista, operated by Coalspur Mines;
- Coal Valley operated by Coal Valley Resources (Westmoreland);
- Cheviot, part of Cardinal River operations by Teck;
- Luscar, part of Cardinal River operations by Teck, currently in reclamation;
- Obed operated by Westmoreland, currently in reclamation; and
- Gregg River operated by Coal Valley Resources (Westmoreland), currently in reclamation.

For coal mines, the only readily available data in spreadsheet format were monthly reports from Coal Valley Mine; all other coal-mine related data were available as part of annual reports in pdf format. Some additional data were extracted from the annual report of Vista coal mine (in pdf) because individual measurements were available. All other mines were reviewed for the scope of their monitoring program, but effluent data were only available in synthesized form (e.g., as summary statistics) and was therefore not included. The data for coal mines were from major and minor wastewater ponds. These are defined as follows in the Alberta Coal Mining Wastewater Guidelines (AER 2014):

> "*major pond"* means a mine wastewater handling facility that receives mine wastewater from active mining areas, dumping locations, the plant or maintenance shop areas and discharges to the environment.
> "*minor pond*" means a mine wastewater handling facility which has met all approval limits in the recent past or receives mine wastewater from a reclaimed area and discharges to the environment.

Table 3-1
Municipal, coal and pulp & paper dischargers in the Upper Athabasca Region included in effluent quality analysis.

Sector	Site	Monitoring Programs	Types of Data	Date Range of Data
Municipal	Barrhead	EPEA, WQBEL, effluent characterization	effluent	2014 - 2017
	Slave Lake	EPEA, WQBEL, effluent characterization, synoptic	effluent	2009 – 2014, 2016 - 2017
	Whitecourt, Athabasca	Synoptic	effluent	2015
Coal	Coal Valley, Vista	EPEA	effluent and receiving waters	2018
Pulp & Paper	Alberta Newsprint Company (ANC), Alberta-Pacific (ALPAC), Hinton Pulp, Slave Lake Pulp (SLP), Millar Western FP	EPEA, EEM, Synoptic	effluent and receiving waters	2000 - 2016



Associated Environmental

FIGURE No. 1

UPPER ATHABASCA REGION

EFFLUENT SUMMARY LOCATIONS

AE PROJECT No.	2018-8254
SCALE	1:1,700,000
COORD. SYSTEM	NAD 1983 10TM FOREST
DATE	2019 APRIL
REV	
DESCRIPTION	ISSUED FOR DRAFT

3.2 DATA PROCESSING

The two goals for data processing were to compile all available data into a master spreadsheet for AEP (Goal #1) and to organize data by sector for analysis (Goal #2).

Data compilation and homogenization included:

- Compiling data from different sources (e.g., PDF extracts, monthly reporting spreadsheets, data tables from municipalities, spreadsheet data from AEP);
- Extracting data from PDF files where desired and converting them to excel files,
- Aligning variables, checking units, homogenizing date format, removing letters from cells with numeric values, replacing "NA"s with blank cells;
- Distinguishing between dissolved and total forms of arsenic and titanium in pulp and paper dataset by inspecting concentrations, reporting order and non-detect summaries;
- Counting censored data (values below detection limit) and including them in summary statistics summary (Appendix B); and
- Setting all censored data as the value of the reported detection limit (i.e., removing all "<" symbols). This allowed maximizing the sample size.

Data were first processed manually in Excel and then transferred into the R environment R Core Team, 2018) to allow processing of larger datasets simultaneously.

For Goal 1, data were organized into a master spreadsheet for electronic delivery to AEP. One master spreadsheet was created for each sector (municipal, coal mines, pulp and paper mills). All samples were categorized as reference / background, effluent, or downstream effluent. Variables were grouped according to the following categories:

- General;
- Nutrients;
- Metals; and
- Organics & Other variables.

For Goal 2, data for each sector were organized for data analysis by:

- Determining what data were available for each sector (e.g. monthly averages, daily samples, weekly samples, etc.);
- Extracting effluent data into one data set for each sector; and
- Extracting background / upstream data into one data set each for coal and pulp and paper[1].

Data manipulation, summary statistics, and boxplots were completed using the statistical software R. Boxplots were produced by month to allow examining seasonal trends in effluent quality.

[1] There was not enough municipal background data to extract a set to compare to effluent.

3.3 SUMMARY STATISTICS

The number of measurements (n) in variables and sectors ranged from 1 (e.g., cBOD in coal data) to over 13,000 (BOD and COD in pulp and paper, Table 3-2). The most common sample size was approximately 12 data points.

Table 3-2
Range of sample size per sector and variable class

Sector	General (TSS, cBOD, DO, turbidity etc.)	Nutrients (TP, Ammonia-N, Nitrate-N)	Metals	Organics
Municipal	10 (COD) to 262 (TSS)	16 (nitrate-N) to 236 (ammonia-N)	4	4
Coal	1 (cBOD) to 3717 (turbidity)	12 (nitrate-nitrite-N) to 335 (nitrate-N)	11 (dissolved) to 32 (total)	39 (BTEX)
Pulp and Paper	1 (Na, K) to >13,000 for BOD and COD	4 (Ortho-P) to 12	8 (dissolved) to 12 (total)	0

Summary statistics, including number of observations, minimum, maximum, median, mean, and 90th percentiles, were calculated separately for municipal, coal mine and pulp and paper mill data (Appendix B). Summary statistics may not be representative for the entire range of dischargers for the studies sectors, due to limited data availability. The largest uncertainties are related to municipal discharge, where only data from two out of dozens facilities were available. Coal mine data were available from two out of three active coal mines and pulp mill data were available for all facilities, providing more confidence in these summary statistics.

Sector-wide median background concentrations were calculated for use in the river impact analysis (section 4.4). Variables with available river data included coal and pulp and paper. For pulp and paper mills, all available reference data from locations upstream of the discharges (i.e., in the Athabasca River or Lesser Slave River) were pooled and used to represent background concentrations. For coal mines, all data from locations identified as “upstream” in the dataset (i.e., local creeks and McLeod River) were pooled and analyzed to represent background concentrations. This approach was chosen to maximize sample size for this analysis while allowing a general characterization of the receiving waters compared to overall effluent quality. Site-specific investigations were beyond the scope of this study.

3.4 CENSORED DATA

The datasets were not accompanied by information on method detection limits. We therefore identified all reporting limits, i.e., the values that were indicated were below detection in the dataset itself. This reporting limit is the limit of detection after any adjustments have been made for dilutions to bring the sample into equipment range of detection. The number and percent of non-detects in each dataset was reported as part of the summary statistics.

Reporting limits for some variables were above their chronic Environmental Quality Guidelines for Alberta Surface Waters (AEP 2018, Table 3-3). These datasets were not flagged as guideline exceedances and may represent a data gap with respect to guideline exceedances. Four were observed in a municipal dataset and one in the pulp and paper dataset, representing a very small sample size. Only toluene was included in the list of potential variables of concern. In cases where guidelines were below detection limit, any identified exceedances were not counted in the prioritization table.

Table 3-3
Variables with reporting limits above guidelines

Variable	Dataset	Guideline (µg/L)	Reporting Limit (µg/L)
Endosulfan	Municipal	0.003	0.05
Methoxychlor	Municipal	0.03	0.05
Mirex	Municipal	0.001	0.05
Toluene	Municipal	0.5	1.0
Total Mercury	Pulp and Paper	0.005	0.005-0.5

Substituting reported detection limits for non-detects as done in this study did not affect guideline comparison, since most reported detection limits were below guidelines. It may, however, have influenced some data analysis results. For example, some summary statistic results for municipal and coal data may be biased to a higher value, because of a large proportion (>50%) of censored data. A scan of the river impact analysis results showed that the results of VOCs with high number of non-detects were not affected because river data were missing (e.g., mercury and nitrate for coal). In addition, the non-detect summary showed that VOCs identified in this report were generally detected in the majority of the analyzed effluent data (>50%), except nitrate and nitrite. Some seasonality analysis results, however, may be unreliable because of censored data (see notes on Table 3 4).

3.5 SEASONALITY

Municipal effluent quality of the two reviewed lagoon treatment systems was lowest in spring, when ice cover reduces treatment effectiveness (e.g., Figure 3-2, Appendix C). Most effluent variable concentrations decrease in summer, reflecting better treatment effectiveness (Table 3-4). Nitrate showed a tendency for increased concentrations in summer, possibly due to better nitrification of ammonia, but more data are needed to support this pattern. All parameters or parameter groups with statistically significant differences among months are listed in Table 3-4 below. Results of Kruskall Wallis Test for seasonality (i.e., test for differences between months) are presented in Appendix B-4 to B-6.

Discharges from coal mining ponds were more elevated in TSS and associated metals in spring compared to late summer, likely due to the influence of the wet season and possibly ongoing snow melt. Pulp and paper effluent was relatively stable throughout the year for cBOD and TSS, but effluent samples taken in fall indicate large variations in metals between individual months. More data are needed to confirm this trend.

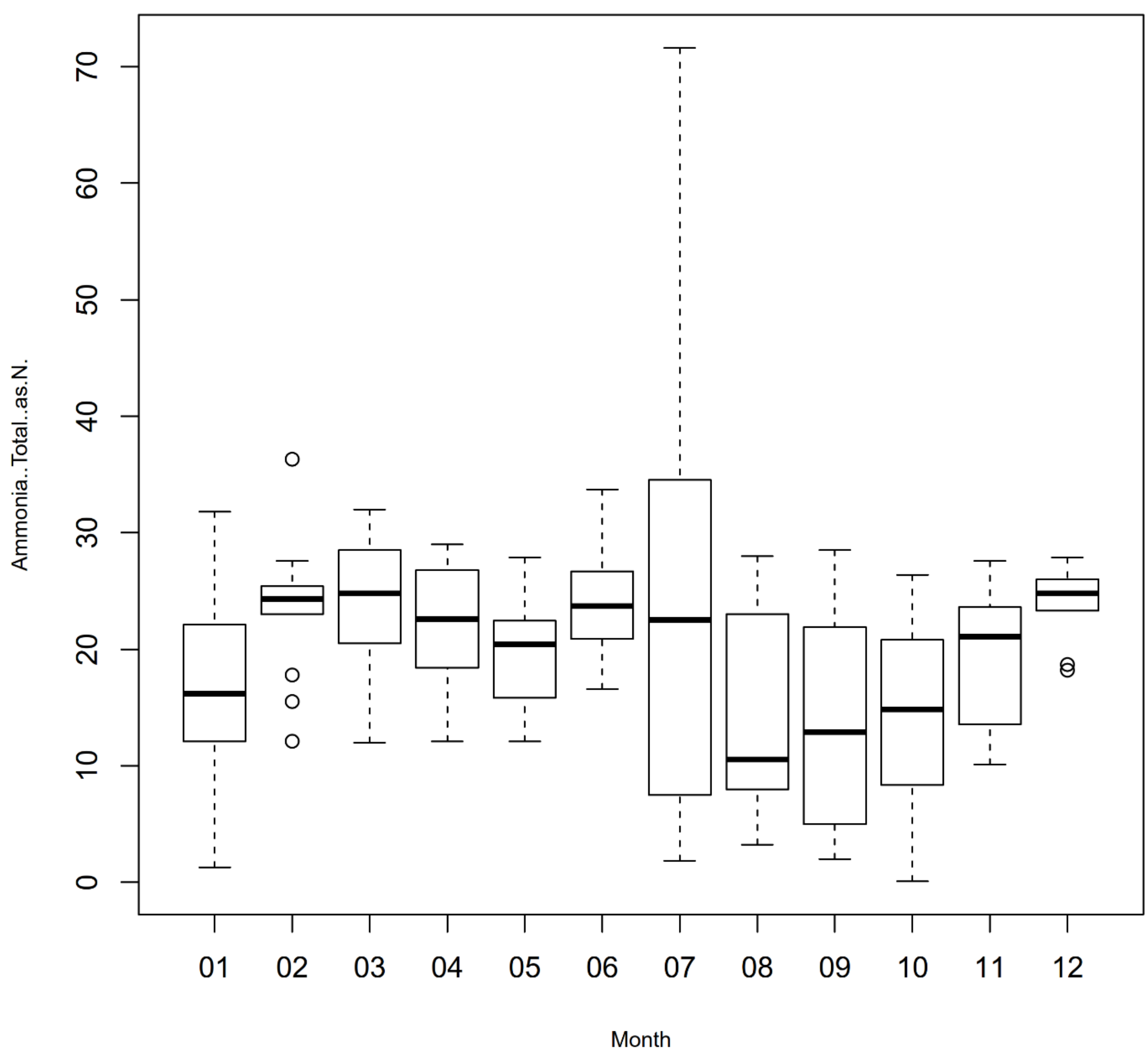


Figure 3-2
Boxplot of total ammonia nitrogen in municipal effluent

Table 3-4
Seasonal patterns recorded in Upper Athabasca municipal and industrial effluents

Sector	Variables	Seasonal Patterns[1]	Monitoring Frequency to address Seasonality
Municipal	Ammonia-N, TP, TDP, cBOD	Elevated in spring, low in summer	Monthly; Weekly for ammonia
	TSS	Elevated in May and late summer	Monthly
	Nitrate-N	Elevated Jul-Nov[2]	Monthly
	Fecal coliforms	Elevated Dec-Mar, low Apr-Nov	Monthly
Coal	Metals, cBOD*	Elevated in spring (Apr-Jun)	Monthly
	TSS, turbidity	Elevated in spring, early summer (Apr-Jul)	Daily
	Se T, U T, Na, K, TDS, SO_4	Elevated in Jan-Apr, lower May-Aug	Monthly
	Ammonia-N*	Elevated Jan-Mar, low Apr-Aug	Monthly
	Nitrite-N*	Elevated Jan-May, lower Jun-Aug	Monthly
	Nitrate-N	Elevated in winter, decreasing throughout spring and summer	Monthly
Pulp and Paper	Metals	Large difference between Oct and Nov.[2]	Monthly
	BOD, colour, COD	Slightly elevated in Mar, Apr[3]	Monthly
	Conductivity	Elevated in winter, lower in summer	Monthly
All	Temperature, pH	Low in winter, high in summer, very large differences for temperature	Weekly
	Dissolved Oxygen	Elevated in winter and fall, lower in spring and summer	Weekly

Notes: [1]Based on visual inspection of Monthly boxplots; [2]Based on small datasets (<5 data points per month) and most not statistically significant using Kruskal Wallis test; more data are required to verify statistical significance. [3]Patterns require post-hoc tests, as they are not visible on boxplots. *Results may be unreliable, due to majority of values (>50%) below detection.

4 Variables of Concern

Variables of concern (VOCs) for point-source discharges to surface waters in the Upper Athabasca Region are presented in this section. The two main reasons for identifying VOCs are:

1) for consideration of indicator selection for the Surface Water Management Framework (SWQMF) for the Upper Athabasca Region, which will determine variables to be assessed by AEP on regular basis in the future, and
2) for inclusion in idealized effluent monitoring programs for point source dischargers in the region (see section 5.2).

4.1 APPROACH TO IDENTIFYING VARIABLES OF CONCERN

Potential variables of concern were identified if they met one of the following three criteria:

- exceeded a guideline at least once in available effluent data (section 4.2),
- were identified as a concern or potential concern in the literature review (section 4.3), or
- had the potential to impact surface water quality, indicated by median effluent concentrations exceeding upstream river concentrations by a factor of > 10 (section 4.4).

4.2 GUIDELINE EXCEEDANCES

Since there are no consistent effluent quality standards for all sectors, the compiled effluent quality datasets for each sector were compared to the provincial surface water quality guidelines (AEP 2018) where available. Effluent discharges are not required to meet these guidelines, but these guidelines serve as a useful screening tool to identify variables that have the potential to exceed instream guidelines downstream of the discharge where an exceedance occurs.

For variables where guidelines were not available, other standards were used (e.g., for the key variables cBOD and TSS). Federal regulatory standards for municipal discharges were applied to TSS and cBOD (*Wastewater Systems Effluent Regulations*, SOR/2012-139). While these regulations only apply to municipal discharges, they were considered useful for effluent quality comparison between sectors. The proportion of samples that exceeded guidelines relative to the total number of measurements for each variable was used as a measure of frequency of exceedance.

The variables with the largest frequency of exceedance, which was defined herein as >50% of values exceeded, varied among sectors (Table 4-1). Ammonia and fecal coliforms exceeded surface water quality guidelines in more than half of the municipal effluent data and selenium in the majority of coal effluent data (Table 4-1, Appendix B). Several total metals and sulphur compounds frequently exceeded guidelines in pulp and paper discharge. Several other metals, nitrate and nitrite, TSS and cBOD exceeded guidelines in effluents between 20% and 50% of the time.

Table 4-1
Variables exceeding surface water quality guidelines in discharges in the Upper Athabasca Region

Sector	Exceeded guidelines* in >50% of samples	Exceeded guidelines* in 20-50% of samples	Exceeded guidelines* in <20% of samples
Municipal	Ammonia-N, fecal coliform	Nitrite-N, Cyanide, Zn T	Hg T, nitrate-N, TSS, cBOD**
Coal Mining	Se T	Al D, Fe D, TSS**, pH>9.5,	Nitrate-N, nitrite-N, Cd T, Co T, cyanide, DO, sulphide, Hg T, Mb T, and U T
Pulp & Paper	Co T, Cd T, sulphate, sulphide, and Zn T.	Al D, B T, chloride, nitrite-N, Se T, Ag T, BOD**	As T, Tl T

*Environmental Quality Guidelines for Alberta Surface Waters for the protection of aquatic life (except fecal coliforms, which are compared to the guidelines for recreation and aesthetics).
**TSS and cBOD were compared to the federal WSER standard of 25 mg/L.

4.3 LITERATURE REVIEW OF VARIABLES OF CONCERN IN EFFLUENTS

A high-level, non-exhaustive literature review was conducted to identify VOCs for point source discharges from municipalities, coal mines and pulp and paper mills in Upper Athabasca Region. The documented and potential impacts from point source discharges to water quality in the Upper Athabasca discussed in the literature are summarized in the following sections. The literature sources were technical reports, State-of-the-Watershed reports, guidance documents and peer-reviewed publications on water quality in the Upper Athabasca Region and impacts of the main three sectors (i.e., municipal, coal and pulp and paper, see Appendix D). Variables associated with effluents from these sectors were included in the list of potential variables of concern (Appendix F).

Studies indicate that the main impacts of effluent discharges to the Athabasca River were on dissolved oxygen and nutrients. Enrichment in nutrients, such as total nitrogen and phosphorus, from municipal and pulp mill effluent has caused increased periphyton productivity in reaches downstream of the discharges (Chambers et al. 2000). Dissolved oxygen levels decrease over the river flow path in response to cumulative impacts of oxygen-consuming substances as well as increased nutrient levels and resulting increased aquatic productivity and night-time oxygen consumption (NREI 2004). On the other hand, DO periodically increases throughout the Athabasca River flow path due to natural reaeration caused by river morphology (i.e. aeration at Grand Rapids downstream of Athabasca).

The 2015 monitoring program of the Athabasca River[2] showed that treated wastewater discharges from various sources caused increases in the following substances (Tondu 2017):

- Bacteria;
- Major ions (bicarbonate, chloride, potassium, sodium, sulphate, sulphide, total dissolved solids);
- Nutrients (ammonia, dissolved phosphorus, ortho-phosphate, total phosphorus, and total nitrogen);
- Adsorbable organic halides;
- Metals (dissolved aluminum, total barium, total and dissolved boron, total and dissolved cadmium, dissolved cobalt, dissolved manganese, dissolved tin, dissolved vanadium, and dissolved zinc);
- Hydrocarbons (F2-F4);
- Colour; and
- Temperature.

4.3.1 Municipalities

All municipalities in Alberta are required to treat wastewater before discharge (NREI 2004). Most municipalities in the Upper Athabasca Region use lagoon-based systems, which typically provide a combination of primary (solids reduction) and secondary (organics reduction) treatments to mitigate effects of effluent on surface water.

The Canada-wide strategy for the management of municipal wastewater effluents (the Strategy, CCME 2008) provides detailed guidance on variables of concern in municipal discharges. The Strategy proposes a set of national performance standards that all municipal wastewater treatment facilities above a minimal size must meet; these include standards for TSS, cBOD, unionized ammonia and chlorine. These were subsequently enacted in the federal *Wastewater Systems Effluent Regulations* (2012) that apply to most wastewater systems across Canada with effluent rates of 100 m^3/d or more.

Variables of concern for nitrogen in municipal discharge include Total Kjeldahl nitrogen, ammonia, nitrate and nitrite. Soluble reactive phosphorus (or orthophosphate), total and dissolved phosphorus, are directly linked to eutrophication of the Upper Athabasca surface waters (Chambers et al. 2000), although high spring and summer flows often mask increases in nutrients of receiving waters.

4.3.2 Coal Mines

The metallurgical and thermal coal mining of the Upper Athabasca area is concentrated in the McLeod sub-watershed near Hinton. One exception is the Obed Mine, which is in the Upper Athabasca sub-watershed. Selenium released from coal mines to surface waters in the upper McLeod watershed has been associated with impacts to fish health in the watershed. Selenium loading and deposition has been associated with high concentrations of selenium in fish tissue and teratogenic deformities, potentially via fish eggs located on the contaminated substrate (Casey 2005).

[2] Synoptic survey conducted along the length of the river and at major outfalls to the river.

Selenium is a naturally occurring element within the regional geology, and is an essential nutrient for organism function, but is also toxic at only slightly higher concentrations. It may also be present as water-bourne inorganic (e.g. selenite and selenate) and organic selenium compounds. It is mobilized into surface waters either by natural processes (e.g. weathering and runoff) or by anthropogenic causes (coal extraction processes used in west-central Albertan mines). For example, elevated selenium concentrations were observed downstream of three mountain mines in the upper McLeod and upper Smoky river system. Dissolved selenium concentrations in coal mine effluents ranged from concentrations equal to the guidelines for the protection of freshwater aquatic life, to those exceeding the guidelines by an order of magnitude. Discharge points known to cause elevated selenium concentrations within surface waters initially show increased levels but gradually decline further downstream. Of 28 metals tested, selenium was the only one that exceeded the applicable guidelines for six streams sampled. In addition to surface water concentrations, bioaccumulation of selenium in the aquatic food web (e.g. sediment, biofilm, and aquatic insects) was also present, however, biomagnification was less pronounced (Casey 2005).

In 2013, coal process water was spilled into the Athabasca River from Obed Mine and the turbidity plume was traced. In-river results were as follows: high concentrations of nutrients (nitrogen and phosphorus), metals, and polycyclic hydrocarbons; elevated concentrations of metals (arsenic, lead, mercury, selenium, and zinc) and PAHs (acenaphthene, fluorene, naphthalene, phenanthrene, and pyrene). Toxicity analysis of the released substance showed a short-lived acute risk to the aquatic environment, but known carcinogens were detected in sediment and water quality, which may lead to negative long-term impacts. (Cooke et al. 2016).

4.3.3 Pulp and Paper

One of the most significant impacts of pulp mill discharges on the aquatic ecosystem is caused by biochemical oxygen-demand (BOD). To reduce discharge of oxygen-demanding substances, nutrients (e.g. phosphorus) are often added to treatment lagoons to accelerate bacterial degradation of organic compounds prior to its release into the environment (Alberta Environmental Protection 1996), resulting in nutrient enrichment downstream. Nutrient and BOD loading of a river system cause both an immediate sag of DO and linear decay of DO concentrations downstream of the discharge point in response to degradation of organic matter over time. The latter condition is most prominent under frozen conditions, because aeration is limited due to ice cover (Chambers et al. 1997). Another impact of pulp and paper effluent is that it causes sediments to settle faster under low flow conditions due to increased flocculation.

Effluent quality from pulp and paper mills has improved significantly over the past two decades due to updates in the *Pulp and Paper Effluent Regulations SOR/92-269*. In 1990, oxygen delignification and chlorine dioxide substitution were introduced to eliminate the use of elemental chlorine. In addition, upgrades to treatment systems were completed, such as using aerobic treatment of wastewater. By 1993, full chlorine dioxide substitution was completed (100%). These modifications significantly reduced detrimental environmental effects caused by elevated BOD, organochlorines (e.g. dioxins, furans, chlorinated resin acids and chlorophenols), and colour, as indicated by monitoring. For example, surveys conducted on the Athabasca River in winter 2015 (Tondu et al. 2017) did not detect the same large changes in phenols, chlorinated phenols, resin acids, and trace organics in the receiving water over background concentrations that were observed in the 1980s (Noton et al. 1989).

These results suggest that Upper Athabasca River water quality has improved owing to pulp and paper industry advancements in wastewater treatment processes (Tondu et al. 2017). High nutrient loading by nitrogen and phosphorus (Chambers et al. 2000) and oxygen demanding substances, however, are still of concern for Athabasca River water quality (Tondu et al. 2017).

4.4 RIVER IMPACT ANALYSIS

A river impact analysis was completed using the available effluent and river data to identify variables whose loadings are most likely to cause a change in river water quality. This was determined by identifying variables where median effluent concentrations exceeded median river concentrations by a factor of more than ten (Western Resource Solutions 2003). River water quality data upstream of the discharge points were available for the coal and pulp and paper facilities, but not for municipal facilities, so this analysis was limited to the coal and pulp and paper sectors.

The median effluent concentrations of twenty-four variables were more than ten times the river concentrations (Table 4-2). All of these were from the pulp and paper dataset; only two of the variables (e.g., sulphate, sodium) also exceeded the ratio of 10 in coal data. The most common variables were nutrients (e.g., phosphorus and nitrogen compounds), total or dissolved metals, major ions (e.g., chloride, sodium, potassium) and indicators of organic pollution (e.g., BOD, DOC, TOC). All three forms of phosphorus were over 100 times the river concentrations and among the top five in this list, demonstrating the significant impact on river phosphorus concentrations from pulp and paper mills. BOD showed the overall second-largest effluent-river ratio.

Table 4-2
Variables in industrial discharge that are more than ten times ambient river background

Variable	Effluent/ River Ratio	Variable	Effluent/ River Ratio
Orthophosphate	1347	Total Zinc	34
cBOD	688	Dissolved Organic Carbon	32
Beryllium Total	543	Total Nitrogen	29
Total Dissolved Phosphorus	409	Total Kjeldahl Nitrogen	29
Total Phosphorus	161	Dissolved Organic Nitrogen	22
Dissolved Manganese	124	Dissolved Cobalt	20
Total Sodium	104 (18)*	Dissolved Kjeldahl Nitrogen	19
Total Potassium	58	Sulphate	17 (33)*
Total Organic Carbon	56	Ammonia	16
Dissolved Zinc	47	Total Dissolved Nitrogen	16
Sulphide	42	Chloride	15
Total Manganese	39	Dissolved Tin	14

Notes: *All ratios are from pulp and paper discharges, ratios in parentheses are from coal discharges. No ratios were calculated for municipal discharges because no suitable upstream river data were available.
Ratios were calculated dividing the median of effluent concentrations by the median of upstream river concentrations. All parameters had <50% non-detects (Appendix B).

4.5 PRIORITIZATION OF VARIABLES OF CONCERN

A semi-quantitative scoring system was applied to the list of potential VOCs to prioritize variables using above criteria. Each criterion was broken down into four rating scores that ranged from no evidence for impact (0) to High potential for impact (3), with two intermediate classes (Table 4-3). The rating boundaries were chosen to provide a preliminary relative rating between variables and did not represent any specific scientific thresholds.

The priority rating (score) was completed for each of the sectors and criteria (Appendix F). All available individual scores from each criterion were averaged to calculate an overall score. All potential variables of concern were ranked according to the overall score and all variables with an average score of >1 or any average sector-specific score of 2 or more were included in the final list of VOCs (Table 4-4). This ranking can be updated as more data become available and more parameters added if a different cut-off score was chosen.

Table 4-3
Scoring criteria for prioritizing Variables of Concern

Priority Rating	Guideline Exceedance	Literature Review	River Impact
3	>50% exceeded	Clear concern	Effluent >10x river
2	>20%-50% exceeded	Possible concern	Effluent >5 to 10x river
1	>0%-20% exceeded	Monitored, detected, or mentioned	Effluent >1 to 5x river
0	None exceeded	Not mentioned	Effluent = or < river

4.6 RECOMMENDED VARIABLES OF CONCERN

The list of potential variables of concern based on the criteria listed in section 4.1 consisted of 58 variables (Appendix F). Variables with an average score of ≥1 (22 variables) and variables with any individual criterion score of 2 (2 variables) were selected as a preliminary list of VOCs (Table 4-4).

The leading VOCs were TP, TN, TSS, and BOD, due to their prominence in all effluent types and their impact on the river. DO is an important VOC as an indicator of BOD impacts to the river. Selenium is of large importance due to coal mining but also pulp and paper. Other metals feature on the list, as well as conductivity, fecal coliforms, sulphate and sulphide, phenolic compounds and chloride.

Table 4-4
Preliminary list of Variables of Concern

Variable of Concern	Criteria Score	Criteria Rating Description
TP	2.2	Key VOC for pulp and paper and municipal effluent, orders of magnitude higher than river concentrations
TN	2.2	No guideline, but parameter of concern for pulp and paper and municipalities and 29 times higher than river concentrations
TSS/ turbidity	1.7	Potential guideline exceedances in all sectors, identified VOC for coal and municipalities.
cBOD, BOD_5	1.7	Identified VOC for pulp and paper and municipalities, 2 orders of magnitude higher in pulp and paper effluent than in rivers, exceeds WSER standard in some municipal and pulp and paper samples
DO	1.6	Does not meet guidelines in some coal and municipal effluents, identified VOC for pulp and paper and municipal effluents.
Se T	1.6	Clear concern for coal mines, guideline exceedance observed in coal and pulp and paper, literature mention for municipalities
Zn T	1.5	Frequent exceedance in pulp and paper and municipal effluent, identified in the literature for coal and municipal, > 10 times river concentrations for pulp and paper
Cd T	1.2	Frequent guideline exceedance and > 10 times river concentrations for pulp and paper, some exceedances in coal, possible concern for municipalities
Nitrate-N	1.2	Guideline exceedances in all sectors, possible concern for municipalities, > 10 times river concentrations for pulp and paper
Fecal coliforms	1.2	Frequent guideline exceedance and potential concern for municipalities
Nitrite-N	1.1	Guideline exceedances in all sectors, potential concern for municipalities
Sulphate	1.1	Frequent guideline exceedance in pulp and paper, > 10 times river concentrations for coal and pulp and paper

Variable of Concern	Criteria Score	Criteria Rating Description
Conductivity	1.1	> 10 times river levels for pulp and paper, possible concern for pulp and paper and municipalities
Ammonia-N	1.1	Frequent guideline exceedance (99%) and clear concern for municipalities, > 10 times river concentrations for pulp and paper
Ortho-P	1.1	Potential concern identified for all sectors, more than three orders of magnitude elevated over river background for pulp and paper
TDP	1.1	Potential concern identified for all sectors, more than two orders of magnitude elevated over river background for pulp and paper
Sulphide	1.1	Frequent exceedance for pulp and paper, some for coal, > 10 times river concentrations in pulp and paper
Phenolic compounds	1.0	Potential concern identified in literature for pulp and paper and municipalities
Co T	1.0	Frequent exceedances in pulp and paper, some in coal, potential concern for municipal
Fe D	1.0	Guideline exceedances in coal and municipal, potential concern for municipalities
Al D	1.0	Some exceedances for coal and pulp and paper, somewhat elevated above river concentrations in coal and pulp and paper
Chloride	0.8	> 10 times river concentrations for pulp and paper
Colour	0.4	Potential concern for pulp and paper

5 Monitoring Program Evaluation and Recommendations

5.1 CURRENT EFFLUENT MONITORING PROGRAM

5.1.1 Municipalities

Municipal wastewater effluent monitoring and reporting were reviewed for all municipalities with EPEA approval requirements. Hinton is not included here as the municipal wastewater is treated together with pulp mill wastewater. All municipalities must monitor cBOD and TSS, three must measure pH, and two must measure total phosphorus (TP) and ammonia-N (Table 5-1). Four of the six plants sample at least weekly for some variables and a few variables are measured less frequently. Whitecourt is the only municipality that measures three basic variables daily. All municipalities report monthly and/or annually.

After facility upgrades that are planned for 2019 and 2020, Slave Lake will monitor whole effluent acute lethality (LC50) to rainbow trout at least once per year.

Table 5-1
Current municipal wastewater effluent monitoring requirements

Municipality	Variables Measured	Frequency of sampling	Frequency of reporting
Athabasca	cBOD, TSS, pH, temp	weekly	monthly & annual
Barrhead	cBOD, TSS, TP, ammonia-N, pH, chlorine	weekly to monthly	monthly & annual
Edson	cBOD, TSS	weekly	monthly & annual
Slave Lake	cBOD, TSS, TP, ammonia-N, pH	weekly to monthly (differed before/after upgrade)	monthly & annual
Slave Lake	acute lethality (trout)	Minimum of yearly	annual
Westlock	cBOD, TSS	Once per release	annual
Whitecourt	BOD, cBOD, TSS	daily	monthly & annual

5.1.2 Coal Mines

Coal mining industrial wastewater effluent monitoring and reporting requirements were reviewed for Cheviot, Coal Valley, Gregg River, Luscar, Obed, and Vista coal mines. These coal mines have major and minor ponds that collect process water and surface water runoff from the mine footprint and release effluent to the receiving environment. All ponds are monitored on a weekly or monthly basis for four laboratory-based water quality variables and three visual observation criteria (Table 5-2). In addition, wastewater handling facilities are monitored for additional variables that vary among mines, in variable list and frequency (Table 5-2).

Twice yearly, all coal mines conduct whole effluent acute lethality tests with rainbow trout and/or *Daphnia magna* depending on the sample type (Table 5-2). Details of the variables and tests are tabulated in Appendix G (“AB coal approvals review.xlsx”).

Gregg River Mine is in the decommissioning and reclamation phase and therefore has different monitoring requirements including monthly TSS, pH, visible foam monitoring, and annual selenium monitoring. All six of the coal mines conduct additional monitoring. Gregg River is required to annually monitor all receiving streams impacted by the mine for selenium. The other five coal mines annually monitor several upstream and downstream locations relative to effluent releases for inorganic variables listed in the currently applicable Canadian Water Quality Guidelines for the protection of aquatic life (CCME 2018), BOD, BTEX, colour, oil & grease, phenols, TP, sulphate, TDS, temperature, total sulphide, selenium, hardness, TSS. The results must be reported on a monthly and annual basis.

Table 5-2
Current wastewater effluent monitoring requirements for all coal mines in Upper Athabasca Region

Coal Mine	Sample Location	Variables	Sample Frequency	Reporting Frequency
All	Major and Minor ponds	TSS, turbidity, pH, nitrate-N, floating solids, visible foam, oil or other substances	Ranges from daily to monthly	Monthly & Annually
All	Major ponds	Whole effluent toxicity test: 96h acute lethality test (rainbow trout)[3], 48h acute lethality (*D. magna*)[4]	Twice a year Summer/fall	Monthly & Annually
Coal Valley, Luscar, Obed	Plant WW Disposal Area or WW handling facilities	Selenium, hardness	Monthly or unspecified	Annually
Cheviot, Luscar	Plant WW Disposal Area or WW handling facilities	Ammonia-N, nitrate-N	Monthly or unspecified	Annually
Coal Valley, Cheviot, Luscar, Obed	Plant WW Disposal Area or WW handling facilities	Inorganic variables, BOD, BTEX, color, oil & grease, phenols, TP, sulphate, TDS, temp, sulphide, and TSS	Monthly or unspecified	Annually
Coal Valley	WW handling facilities	Organic priority pollutants	Annually during discharge	Annually

[3] Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout, Environment Canada, Environment Protection Series 1/RM/13, July 1990, as amended
[4] Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Daphnia Magna, Environment Canada, Environment Protection Series 1/RM/14, July 1990, as amended

5.1.3 Pulp and Paper

Provincial monitoring and reporting requirements for pulp and paper mill wastewater were reviewed for Alberta Newsprint Company (ANC), Slave Lake Pulp (SLP), Millar Western, Alberta-Pacific (AlPac), and Hinton Pulp (Table 5-3). Pulp and paper mills are required to monitor the largest number of variables of the three industries reviewed, including general variables, nutrients, metals and relevant organics (Table 5-3). Detailed lists of variables included in EPEA approvals slightly vary among the mills. Ambient monitoring is also conducted by all pulp mills except Hinton Pulp. The pulp mills create background monitoring survey plans that include water quality variables, sediment variables, and benthic algae/ SOD analytical variables. Background sampling locations and frequency, and reporting frequency are not dictated in the EPEA approvals.

Table 5-3
Current provincial pulp and paper mill wastewater effluent monitoring requirements

Pulp Mills	Variables	Sample Frequency	Reporting Frequency
All	BOD_5, COD, TSS, colour, pH, temperature, conductivity, TOC, DOC, nutrients (ammonia-N, nitrate-N, nitrite-N, TP, TKN, dissolved phosphorus, dissolved Kjeldahl nitrogen), total phenols,	Daily to monthly, except total phenols (monthly/ annually)	Monthly & Annually
	BOD_u, heavy metals, organic priority pollutants	Annual to once every 5 years	
	Whole effluent toxicity test: 96h acute lethality test (rainbow trout), 48h acute lethality (*D. magna*), sub-lethal toxicity test (fathead minnow[5], *C. dubia*[6], *S. capricornutum*[7])	Monthly, weekly, twice per year, respectively	
All except Hinton	Major ions, including sulphate	Every 2 years or every 5 years (ANC)	
SLP, Millar Western, Hinton	Ammonia-N	Monthly with trout bioassay	

[5] Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnows, Environment Canada, Environment Protection Series 1/RM/22, February 1992, as amended
[6] Biological Test Method: Test of Reproduction and Survival Using the Cladoceran *Ceriodaphnia dubia*, Environment Canada, Environment Protection Series 1/RM/21, February 1992, as amended
[7] Biological Test Method: Growth Inhibition Test Using the Freshwater Alga *Selenastrum capricornutum*, Environment Canada, Environment Protection Series, November 1992, as amended

Pulp Mills	Variables	Sample Frequency	Reporting Frequency
AlPac	Sulphides, toluene	Monthly to annual	
Millar Western, Hinton	Resin acids and fatty acids	Monthly with trout bioassay	Monthly & Annually
Hinton	Chlorinated phenolics	January, February, and March	
SLP, Millar Western	DPTA and/or EDTA	Monthly	
SLP	Fecal coliforms	Monthly	
AlPac, Hinton	AOX, chlorate/chlorite, chloroform, dioxins and furans (per Federal regulations)	Weekly to annually	
AlPac	TON	Monthly	

BODu = ultimate BOD[8].
Detailed lists of organic and metal groups are available in individual facility approval documents.

5.2 IDEALIZED MONITORING PROGRAM

This section presents recommendations on an ideal effluent monitoring program for discharges in the Upper Athabasca Region. The intent is to provide a prototype monitoring program that could serve as a condition of the respective discharger's EPEA approval to operate. The purpose of the monitoring programs is to provide the regulatory bodies AER and AEP with information on:

1) the degree of compliance of a facility with their EPEA approval to operate;
2) the individual facility's impact on the receiving environment; and
3) the combined effect of multiple facilities in a river reach or region on the receiving environment.

The idealized monitoring programs described in this section were built upon existing monitoring requirements for the dischargers. Generally, the existing monitoring programs were considered relevant for the dischargers. The proposed changes in the idealized monitoring programs mainly consist of additional variables, analyses, differing sampling frequency, and different reporting formats. The idealized monitoring programs contain two components:

1) sector-wide consistent monitoring requirements that deal with common variables of concern;
2) customized program components to accommodate site-specific conditions at individual facilities; and
3) monitoring recommendations for all point source dischargers.

[8] = maximum **BOD** exerted by the wastewater. The time required to achieve the **ultimate BOD** depends upon the characteristics of the wastewater, i.e., chemical composition of the organic matter present in the wastewater and its biodegradable properties and temperature of incubation.

5.2.1 Municipalities

The proposed idealized monitoring program is a hybrid of existing monitoring programs, but none of the reviewed current municipal monitoring programs includes all components of the idealized program. On top of the standard cBOD and TSS, all municipalities should be measuring total phosphorus as this is a main parameter of concern in the Upper Athabasca Region, and total ammonia as the main parameter of concern for municipal discharges (Table 5-4). In addition, *field* pH and temperature should be recorded to allow un-ionized ammonia calculations. Effluent volumes are required for loading estimates (see section 5.2.4.3). Variables that can change quickly and seasonally, such as temperature and pH, should be measured weekly to properly assess variations in un-ionized ammonia in the effluent.

Table 5-4
Idealized effluent monitoring program for municipalities

Variables	Frequency of sampling	Frequency of reporting
cBOD, TSS, pH, temp, effluent flows	weekly	Monthly – data report for weekly parameters Annual for all parameters and total loadings
TP, ammonia-N	monthly	

The federal *Wastewater Systems Effluent Regulation* gives communities explicit guidance with respect to monitoring requirements for TSS, BOD and un-ionized ammonia based on the facility size. The intent is that the provinces and federal government harmonize their regulatory requirements via federal-provincial “equivalency agreements”, as completed in Saskatchewan, for example, and have one-window reporting through the Provinces. Until that happens, municipalities will continue to report to the provincial and federal governments separately.

5.2.2 Coal Mines

The existing coal mine wastewater monitoring programs are comprehensive and suitable but vary among facilities. Since coal pond discharge is likely related to precipitation events, the daily sampling frequency currently in place in many mines is appropriate to detect short-term exceedances.

The main recommended addition to coal mine monitoring programs is selenium in any water that is discharged. Currently the selenium monitoring is limited to receiving water locations on a seasonal basis.

We recommend adding sublethal toxicity testing for coal mines as is done for pulp and paper mills. In addition, we recommend consistent toxicity tests and species tested. Some approvals require using *D. magna*, others *C. dubia*, and both are cladocerans; therefore, one should be selected for consistency among facilities in the sector. Ideally, the most stringent tests previously done should be chosen. The test of *C. dubia* may be more practical, as a three-brood chronic toxicity test on *C. dubia* only requires 5-8 days as opposed to 21-24 days for *D. magna* (Environment Canada 2007), considerably reducing cost, required sample volume and turnover times.

The potential for calcite deposition in the watershed should be assessed for each coal mine using site-specific conditions, because calcite deposition downstream of coal mine discharges has the potential to significantly impact aquatic habitat in mountain streams (Teck Resources 2014). For effluent monitoring programs, hardness, calcium, carbonate and magnesium should be monitored and the calcite index calculated. In addition, other influencing factors for calcite deposition, such as pH, stream morphology and groundwater-surface water interaction at each site should be studied to assess risk of calcite formation in the watershed.

There are some other data gaps that should be addressed through an effluent characterization program, such as PAHs that were elevated in the Obed mine spill plume (see section 5.2.4.1).

Table 5-5
Idealized effluent monitoring program for coal mines

Sample Location	Variables	Sample Frequency	Reporting Frequency
Major and Minor ponds	*Grab*: **Selenium,** TSS, turbidity, pH, nitrate-N *Visual*: floating solids, visible foam, oil or other substances	Daily for TSS, turbidity, pH, all visual Monthly for nitrate and selenium	Monthly & Annually
Major ponds	Whole effluent toxicity test: 96h acute lethality test (rainbow trout), 48h acute lethality (*D. magna*), **sub-lethal toxicity test (fathead minnow, *C. dubia, S. capricornutum*)**	Twice a year Summer/fall acute Annually sub-lethal	Monthly & Annually
Plant WW Disposal Area or WW handling facilities	*Dependent on site-specific effluent characterization:* Selenium, hardness, **calcium, magnesium, carbonate**, ammonia-N, nitrate-N, inorganic variables, BOD, BTEX, color, oil & grease, phenols, TP, sulphate, TDS, temp, sulphide, and TSS, Organic priority pollutants	Monthly during discharge	Annually

Note: Bold type indicates recommended additions to existing monitoring programs.

5.2.3 Pulp and Paper

The existing pulp and paper mill monitoring programs are comprehensive and suitable but vary among facilities. Recommendations for additions are major ions, including sulphate, for all facilities (not required in Hinton), sulphide, and hardness. Chloride, sulphide and sulphate were variables of concern identified in this study. Hardness is not a VOC but many metal guidelines, including those for identified VOCs (e.g., Cd, Zn), depend on hardness and reporting and assessment would be facilitated by including hardness. Slave Lake pulp is the only facility currently monitoring hardness. An increase in monitoring frequency of heavy metals from annually to monthly is recommended since there are several metals VOCs for pulp and paper and the seasonality analysis has shown large variations between samples from two subsequent months (Section 3.5).

In addition, it is recommended to evaluate the list of VOCs for each individual facility by considering the technology and process chemicals used. Many mills have been upgraded significantly in the recent past, therefore the VOCs may now differ from what they were ten years ago. As for coal mines, it is recommended to use a consistent set of toxicity tests and species tested among all pulp and paper facilities, prioritizing the most stringent tests.

Table 5-6
Idealized effluent monitoring program for pulp and paper mills

Variables	Sample Frequency	Reporting Frequency
BOD_5, BOD_u, COD, TSS, colour, pH, temperature, conductivity, **Major ions**, **sulphide**, **hardness,** TOC, DOC, heavy metals, nutrients (ammonia-N, nitrate-N, nitrite-N, TP, TKN, dissolved phosphorus, dissolved Kjeldahl nitrogen), total phenols, organic priority pollutants	Daily TSS, conductivity, temperature, pH Weekly: BOD_5, COD, colour Annually or every 5 years: total phenols, organic priority pollutants, BOD_u **Monthly all other variables**	Monthly and Annually
Whole effluent toxicity test: 96h acute lethality test (rainbow trout), 48h acute lethality (*D. magna*), sub-lethal toxicity test (fathead minnow, *C. dubia, S. capricornutum*)	Monthly, weekly, twice per year, respectively	Monthly and Annually

Note: Bold type indicates recommended additions or modifications to existing monitoring programs.

5.2.4 All Sectors

This section presents recommended changes or additions to effluent monitoring that apply to all sectors.

5.2.4.1 One-Time Effluent Characterization

The limited current knowledge and data availability for most of the VOCs does not warrant inclusion in regular approval monitoring. To fill this knowledge gap, the degree of concern of these VOCs should be confirmed in a one-year effluent characterization study similar to what CCME (2008) suggests for municipal effluents. In the province of Alberta, there is a precedent for this in the Industrial Heartland and Capital Region, where Alberta Environment and Parks developed and implemented an effluent characterization to assist with the development of a surface water management framework (Government of Alberta 2015).

Municipalities should follow CCME Strategy monitoring requirements for different-sized facilities (CCME 2008). The Strategy provides recommendations on a hierarchical set of effluent characterization programs where the number and types of variables and sampling frequency increase with facility size, as was implemented through the identification monitoring requirements in the *Wastewater Systems Effluent Regulations*. Basic sampling requirements include the national performance standards listed in section 4.3.1. Depending on facility size, this program is complemented by sampling of nutrients, pathogens, metals and organic compounds and toxicity testing. This accommodates the increasing complexity and volumes of raw wastewater in larger municipalities due to serviced land uses, which can include businesses, industry and institutions, and contributions of water treatment plant residual waste. Monitoring requirements should therefore be determined on an individual facility basis.

Effluent characterization for coal mines may be guided by the proposed coal mining effluent regulations (ECCC 2017). To properly characterize effluents, at least quarterly sampling, but ideally monthly sampling is recommended for any variables exhibiting seasonal variation (see Table 3-4). This monitoring frequency should be applied to all monitoring variables as it is unlikely that sufficient data will become available to characterize seasonality for all variables of concern.

Effluent characterization studies for 45 pulp and paper mills have been completed in the Province of Quebec. These studies consisted of a comprehensive 3-day effluent characterization for 250 variables and a one-year monthly monitoring program of a subset (approximately 40 variables) (Sustainable Development, Environment and Parks, Quebec 2008). The frequency and degree of chronic and acute guideline exceedances, together with effluent volumes, consideration of cumulative effects of multiple facilities in the reach and importance of individual parameters was then used to determine effluent criteria for each facility (Sustainable Development, Environment and Parks, Quebec 2008).

5.2.4.2 Receiving Water Studies

Impacts of a discharge on the receiving surface waters are site-specific. The river impact analysis completed in this study was based on limited data and therefore cannot be used as a reliable indicator for impacts of individual facilities on receiving waters. Considerations of effluent volume and receiving water volume and spatial (among sites) and temporal (seasonal, interannual) variability in receiving water quality were lacking. The actual impact of a discharge on the receiving water environment can only be elucidated with a site-specific receiving water impact study.

We recommend completing a receiving water impact study for all facilities to identify additional variables of concern that may need to be regulated or monitored. This should allow characterizing receiving waters throughout multiple seasons, either based on existing river monitoring data or new data collection. Some municipalities have already completed these as a condition of their approval to operate. Although pulp and paper and coal mines already have receiving environment datasets through EEM and EPEA creek monitoring, respectively, additional data and analysis are needed. A consistent methodology should be employed, such as according to the provincial water quality based effluent limits procedure manual (Alberta Environmental Protection 1995) or federal guidance (CCME 2008). Site-specific study requirements should be confirmed with AEP or AER aquatic scientists.

5.2.4.3 Volume and Loadings

We recommend that the owner or operators of all facilities record or estimate the total monthly volume of effluent discharged from each discharge point for each month where there is an effluent discharge. The total monthly volume of effluent could either be based on flow rates, by using a monitoring system that provides a continuous measure of the volume of effluent, or by a suitable estimation method in the absence of monitoring equipment. This monitoring requirement should vary by facility size, for example, in BC discharges of > 5000 m^3/d effluent are required to record volume on a daily basis, with smaller facilities only recording volume once or twice a week.

From the volume of effluent, the operator could then calculate mass loadings of variables of concern to the receiving waters. This would require the owner or operator of a coal mine to record the monthly or annual loadings of total selenium, total nitrate, and TSS discharged through each discharge point. The same principle could be applied to municipal and pulp and paper effluent discharges based on their VOCs. The only facilities currently reporting loadings are pulp and paper mills, for a small number of VOCs (e.g., BOD, COD, colour, TSS).

5.2.4.4 Reporting

The current format of reporting is inconsistent among facilities of the same sector and unsuitable to data compilation and analysis in most cases. We propose the following recommendations for reporting requirements for all facilities discharging wastewater in the Upper Athabasca Region:

- Presentation of all raw, individual measurements in tables, separate from any required summary statistics for reporting;
- Submission of monthly and annual reports in pdf format as required for approval reporting;
- Inclusion of effluent volumes and loadings for key VOCs in regular reporting;
- Monthly and annual reports always accompanied by a full effluent quality dataset in spreadsheet format replicated from pdf report;

- All data should include the following metadata to clearly identify each measurement:
    - geographic location (in a recognized geographic coordinate system suitable for mapping),
    - type of discharge (effluent, upstream river, downstream river, pond, etc.)
    - variable,
    - method detection limit,
    - unit,
    - QA/QC data if applicable,
    - date and time of sampling,
    - method of collection (grab versus composite versus visual, field versus lab); and
- Consistent reporting for all facilities within each sector; i.e., one consistent template for reporting for the municipal, pulp and paper and coal mining sector. Ideally, one template for all sectors that accommodates differences between sectors. This will also help streamline regulatory review of reporting documents and facilitate the identification of gaps and issues of concern.

5.3 DATABASE AND TEMPLATE FOR EFFLUENT REPORTING

A data template was developed to accommodate the recommendations on reporting provided in section 5.2.4.4 and submitted to AEP in electronic format. The template can be used to request and compile effluent monitoring data collected by facility operators in the watershed. The goal of this template is to achieve more consistency and accessibility of effluent monitoring data. At the same time, it provides clear and simple instructions to operators for compiling the monitoring data.

6 Data Gaps and Recommendations

This study was completed based on a limited number of available datasets and therefore our understanding of effluent quality in the Upper Athabasca Region remains incomplete. Our analysis relied on existing datasets; therefore, unknown or emerging contaminants were not considered and are therefore a data gap. We have identified information and data gaps and provide recommendations to fill these data gaps (Table 6-1). The main limitation is the lack of consistency and completeness in effluent quality data across sectors and individual facilities. The list of VOCs therefore may not be complete and the order of importance of variables in the list may not exactly represent their relative importance. In addition, using detection limit values for non-detects may have influenced the river impact analysis, although most VOCs are expected to be above detection in effluents. Despite these weaknesses, the combination of three lines of evidence provides confidence that the major variables of concern have been included.

Table 6-1
Data Gaps and Study Limitations and Recommendations to Address them

Data Gaps / Study Limitations	Recommendations to Address Gaps
Not enough dischargers represented:	obtain data for at least one other coal mine obtain data for at least 2 more municipalities
Missing variable groups for all sectors	Request one annual effluent characterization program from all large dischargers, OR Conduct a 4-season synoptic survey that includes major point dischargers in the region
Dataset size not sufficient to evaluate concern for variables, e.g., frequency of exceedance and river impact analysis results for smaller datasets may not be reliable	Obtaining data from more facilities may address this
Upstream data not available for municipalities, therefore VOC list lacks information on river impacts from municipalities	Collect upstream data from WQBEL studies of municipalities, OR use existing AEP water quality datasets where available
No data on emerging contaminants	Consider monitoring of emerging contaminants in effluent characterization programs of the Upper Athabasca Region

7 Summary and Conclusions

This study compiled, analyzed and evaluated data and information on effluent quality in the Upper Athabasca Region. As a result, variables of concern were identified and recommendations provided for effluent monitoring programs. The key conclusions of the study are summarized in the sections below.

7.1 DATA

- Limited effluent quality data was readily available for analysis. The analyzed dataset included 2 out of many municipalities in the region, 2 out of 5 coal mines; and 5 out of 5 pulp mills.
- The sample size was small for most parameter groups (approximately 12 and lower), especially for metals and organic compounds.
- Seasonality analysis was limited but indicated significant seasonal and between-month variation in some effluent quality variables, such as nutrients, cBOD and metals.

7.2 VOCS

- Available effluent data, literature review and high-level river impact analysis allowed identifying 58 potential variables of concern.
- A semi-quantitative rating system was applied to the potential VOC list to prioritize VOCs. Criteria were guideline exceedance, literature review and river-impact analysis. This prioritization exercise resulted in 24 recommended VOCs. These included:
    - Phosphorus due to a significant impact on rivers from pulp and paper mills and importance in municipal effluents,
    - BOD/cBOD to reflect the fact that pulp and paper mills are a large contributor of oxygen-depleting substances to the Athabasca River, and cBOD as important municipal effluent indicator,
    - Selenium due to its wide-spread occurrence in coal discharges and impact on fish health downstream from coal mining,
    - Several other heavy metals, other nutrients, conductivity, phenolic compounds, colour, as key variables of concern in a sector or their occurrence in several effluent types.

7.3 MONITORING PROGRAMS

- Idealized effluent monitoring programs were presented for each sector. These build upon and were generally very similar to existing monitoring programs.
- The following recommendations were provided for additions and changes to sector-specific monitoring programs:
    - Always monitor ammonia, temperature, and pH together for municipalities to allow assessing un-ionized ammonia,
    - Include TP in municipal effluent monitoring programs,
    - Add selenium, variables associated with calcite deposition potential (e.g., calcium, carbonate, magnesium, hardness), and sublethal toxicity testing to coal mining monitoring,

  - Add sulphide and hardness to pulp and paper monitoring, consistently monitor major ions, and increase heavy metal monitoring frequency from annually to at least quarterly or monthly.
- The following recommendations were provided for additions and changes to monitoring programs for all sectors:
  - Complete a one-time effluent characterization of an extended dataset to confirm list of VOCs,
  - Complete one-time receiving water impact study to identify site-specific constraints on effluent quality,
  - Include effluent volumes and loadings in monitoring and reporting to better support cumulative effects management efforts, and
  - homogenize and improve reporting requirements, which includes the submission of spreadsheet-format duplicates of data with annual and monthly reporting in pdf, including relevant metadata.

7.4 RECOMMENDATIONS

This study was based on a limited amount of effluent quality and river data, in particular for coal mines and municipalities. It is recommended to collect more effluent and river data for these sectors to increase our confidence in the results of identification and prioritization of VOCs. Coal mine and municipal effluent data are available in pdf format from annual reports and can be extracted. Obtaining original data from the facilities themselves may be an alternative approach. Additional river data from upstream locations of municipal discharges may be obtained from the AEP ambient water quality database. This would help improving the river impact analysis and thereby increase confidence in the VOC prioritization as well.

Closure

This report was prepared for Alberta Environment and Parks to characterize point discharges in the Upper Athabasca River, identify variables of concern and develop recommendations for future effluent monitoring programs.

The services provided by Associated Environmental Consultants Inc. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
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References

Alberta Energy Regulator 2014. Alberta coal mining wastewater guidelines. Adopted from Alberta Environment, originally published March 1998.

Alberta Environment and Parks 2018. Environmental Quality Guidelines for Alberta Surface Waters. Water Policy Branch, Alberta Environment and Parks. Edmonton, Alberta.

Alberta Environmental Protection 1995. Water quality based effluent limits Procedure Manual.

Alberta Environmental Protection 1996. Northern River Basins Study Report to the Ministers.

Canadian Council of Ministers of the Environment 2018. Canadian Environmental Quality Guidelines. Canadian Water Quality Guidelines. http://ceqg-rcqe.ccme.ca/en/index.html.

Canadian Council of Ministers of the Environment 2008. Canada-wide strategy for the management of municipal wastewater effluent. Technical Supplement 2: Environmental Risk Assessment: Framework and Guidance.

Casey, R. 2005. Results of Aquatic Studies in the McLeod and Upper Smokey River Systems. Retrieved from http://environmentgovabca/info/library/7743pdf

Casey, R., & Siwik, P. 2000. Concentrations of Selenium in Surface Water, Sediment and Fish from the Mcleod, Pembina and Smoky Rivers: Results of Surveys from Fall 1998 to Fall 1999 Interim Report. Water Sciences Branch. Retrieved from http://www3.gov.ab.ca/env/info/infocentre/publist.cfm

Chambers, P. A., Scrimgeour, G. J., & Pietroniro, A. 1997. Winter Oxygen Conditions in Ice-Covered Rivers: The Impact of Pulp Mill and Municipal Effluents. Population (English Edition), 2806, 2796–2806. https://doi.org/10.1139/cjfas-54-12-2796

Chambers, P. A., Dale, A. R., Scrimgeour, G. J., & Bothwell, M. L. 2000. Nutrient enrichment of northern rivers in response to pulp mill and municipal discharges. Journal of Aquatic Ecosystem Stress and Recovery, 8, 53–66. https://doi.org/10.1021/ie00046a004

Cooke, C.A., Schwindt, C., Davies, M., Donahue, W.F., & Azim, E. 2016. Initial environmental impacts of the Obed Mountain coal mine process water spill into the Athabasca River (Alberta, Canada). Science of the Total Environment, 557–558 (2016) 502–509.

Environment Canada 2007. Biological test method: reproduction and survival test using the cladoceran *Ceriodaphnia dubia*. Report EPS 1/RM/21. 2nd edition. February 2007.

Government of Alberta 2015. Water Management Framework for the Industrial Heartland and Capital Region: Effluent Characterization Program. https://open.alberta.ca/publications/effluent-characterization-program.

Hatfield Consultants 2011. State of the Watershed Report: Phase 1. Prepared for Athabasca Watershed Council.

Northern River Ecosystem Initiative (NREI) 2004. Key Findings of the Northern River Ecosystem Initiative.

R Core Team 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Sustainable Development, Environment and Parks, Quebec 2008. Guidelines for applying environmental disposal objectives to industrial waste in aquatic environment. French. (Lignes directrices pour l'utilisation des objectifs environnementaux de rejet relatifs aux rejets industrielles dans le milieu aquatique). Accessed March 26, 2019 at http://www.environnement.gouv.qc.ca/eau/eaux-usees/industrielles-en.htm.

Teck Resources 2014. Elk Valley Water Quality Plan. Submitted to British Columbia Minister of Environment.

Tondu, J.M.E. 2017. Longitudinal water quality patterns in the Athabasca River: winter synoptic survey (2015). Alberta Environment and Parks. 176 pp.

Western Resource Solutions 2003. Development of reach specific water quality objectives for variables of concern in the lower Athabasca River: Identification of variables of concern and assessment of the adequacy of available guidelines. Prepared for Cumulative Environmental Management Association.

Appendix A - List of Analyzed Datasets

electronic appendix

Appendix B - Summary Statistics and Seasonality

Analyte	Minimum	1. Quartile	Median	Mean	3. Quartile	Maximum	Standard Deviation	Coefficient of Variation	90th Percentile	n	Guidelines	Exceedances	%exceedances	# of Non detects	% Non detects
Acenaphthene	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Acenaphthylene	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0.2	4			0%	4	100%
Acridine	0.05	0.05	0.075	0.075	0.1	0.1	0.028868	0.38490018	0.1	4			0%	4	100%
Aldrin	0.04	0.04	0.04	0.04	0.04	0.04	0	0	0.04	4			0%	4	100%
Alkalinity (Total as CaCO3)	256	321.25	337.5	327	338.75	348	24.83399	0.07594494	345.5	12			0%	0	0%
alpha BHC	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
alpha Chlordane	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Aluminum (dissolved)	0.01	0.01	0.02	0.0225	0.0325	0.04	0.015	0.66666667	0.037	4	0.05	0	0%	0	0%
Aluminum (total)	0.06	0.1125	0.15	0.165	0.2025	0.3	0.10083	0.61109024	0.261	4			0%	0	0%
Ammonia (Total as N)	0.1	13.275	20.45	18.85229	24.3	71.6	8.815425	0.46760504	27.75	236	1.38	234	99%	0	0%
Ammonia (Un-ionized as N - WSER)	0.07	0.16	0.26	0.365862	0.51	1.33	0.313169	0.8559769	0.702	29			0%	0	0%
Anthracene	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	4			0%	4	100%
Antimony (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Antimony (total)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Arsenic (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Arsenic (total)	0	0	0	0	0	0	0	NA	0	4	0.005	0	0%	0	0%
Barium (dissolved)	0.04	0.07	0.095	0.0975	0.1225	0.16	0.05058	0.51876892	0.145	4			0%	0	0%
Barium (total)	0.07	0.085	0.11	0.12	0.145	0.19	0.052915	0.44095855	0.172	4			0%	0	0%
Benz(a)anthracene	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	4			0%	4	100%
Benzene (ug/L)	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4	40	0	0%	4	100%
Benzo(a)pyrene	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	4			0%	4	100%
Benzo(b)fluoranthene	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Benzo(g,h,i)perylene	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Benzo(k)fluoranthene	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Beryllium (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Beryllium (total)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Bicarbonate (HCO3)	307	388.75	411.5	396	413	425	33.49627	0.08458654	422.3	12			0%	0	0%
Bismuth (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Bismuth (total)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
BOD Carbonaceous	1	5	9	10.03852	13	56	6.869705	0.68433434	19	257	25	8	3%	0	0%
Boron (dissolved)	0.16	0.16	0.165	0.1675	0.1725	0.18	0.009574	0.05715983	0.177	4			0%	0	0%
Boron (total)	0.16	0.1675	0.17	0.2625	0.265	0.55	0.191725	0.73037954	0.436	4	1.5	0	0%	0	0%
Bromodichloromethane	1	1	1	1	1	1	0	0	1	4			0%	4	100%
Bromoform	1	1	1	1	1	1	0	0	1	4			0%	4	100%
Cadmium (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Cadmium (total)	0	0	0	0	0	0	0	NA	0	4	0.00026	0	0%	4	100%
Calcium (dissolved)	42.6	55.025	63	62.61875	69.25	81.3	10.36824	0.16557716	75.25	16			0%	0	0%
Calcium (total)	46.5	50.85	54.15	54.625	57.925	63.7	7.203414	0.13187027	61.39	4			0%	0	0%
Calculated Un-ionized Ammonia	0.28	0.55	0.82	0.826667	1.1	1.38	0.55003	0.66535924	1.268	3			0%	0	0%
Carbontetrachloride	0.5	0.5	0.75	0.75	1	1	0.288675	0.38490018	1	4			0%	4	100%
Carbonate (CO3)	5	5	5	5.5	5	11	1.732051	0.31491833	5	12			0%	11	92%
F1 (C6-C10)	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1	4			0%	4	100%
F2 (C10-C16)	0.4	0.4	0.4	0.4	0.4	0.4	0	0	0.4	3			0%	3	100%
F3 (C16-C34)	0.4	0.4	0.4	0.52	0.58	0.76	0.207846	0.39970403	0.688	3			0%	2	67%
Chemical Oxygen Demand	51	64.75	72.5	84.1	106.5	127	26.65187	0.31690691	117.1	10			0%	0	0%
Chloride	69	85.8	87.35	92	99.525	118	12.76608	0.13876171	104.7	12	120	0	0%	0	0%
Chlorine (Total)	0	0.01	0.02	0.033758	0.03	0.36	0.042354	1.25463051	0.092	149	0.0005	133	89%	8	5%
Chlorobenzene	1	1	1	1	1	1	0	0	1	4			0%	4	100%
Chloroform	1	1	1	1.325	1.325	2.3	0.65	0.49056604	1.91	4			0%	3	75%
Chromium (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Chromium (dissolved Hexavalent)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Chromium (dissolved Trivalent)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Chromium (Hexavalent)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Chromium (Total)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Chromium (Trivalent)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Chrysene	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Cobalt (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Cobalt (total)	0	0	0	0	0	0	0	NA	0	4	0.0013	0	0%	0	0%
Conductivity (EC)	933	995.75	1060	1054	1095	1180	67.06442	0.06362848	1110	12			0%	0	0%
Copper (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Copper (total)	0	0	0	0.0025	0.0025	0.01	0.005	2	0.007	4	0.028	0	0%	0	0%
Cyanide (Free)	0	0	0	0.004545	0.01	0.01	0.005222	1.14891253	0.01	11	0.0052	5	45%	0	0%
DeBDE	1800	3225	4650	4650	6075	7500	4030.509	0.86677605	6930	2			0%	0	0%
Dibenz(a,h)anthracene	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	0	0%
Dibromochloromethane	1	1	1	1	1	1	0	0	1	4			0%	4	100%
Dieldrin	0.04	0.04	0.04	0.04	0.04	0.04	0	0	0.04	4			0%	4	100%
Endosulfan I	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Endosulfan II	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Endrin	0.02	0.02	0.025	0.025	0.03	0.03	0.005774	0.23094011	0.03	4			0%	4	100%
EPHw10 19	250	250	250	250	250	250	0	0	250	3			0%	3	100%
EPHw19 32	250	250	250	533.3333	675	1100	490.7477	0.92015199	930	3			0%	2	67%
Fluoranthene	0.03	0.03	0.03	0.03	0.03	0.03	0	0	0.03	4			0%	4	100%
Fluorene	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Fluoride	0.02	0.13	0.395	0.335625	0.5	0.54	0.187793	0.55953253	0.53	16			0%	4	25%
gamma BHC Lindane	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
gamma Chlordane	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Hardness (Total as CaCO3)	152	211.5	232.5	234.1875	260.75	310	42.41418	0.18111205	285.5	16			0%	0	0%
Heptachlor	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Heptachlor.epoxide	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%

Analyte	Minimum	1. Quartile	Median	Mean	3. Quartile	Maximum	Standard Deviation	Coefficient of Variation	90th Percentile	n	Guidelines	Exceedances	%exceedances	# of Non detects	% Non detects
Hydroxide (OH)	5	5	5	5	5	5	0	0	5	12			0%	12	100%
Indeno[1,2,3-cd]pyrene	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	4	100%
Ion Balance	96.4	97.65	102	102.2167	104	114	5.604192	0.0548266	110.3	12			0%	0	0%
Iron (dissolved)	0.03	0.0725	0.16	0.315	0.38	1.06	0.363998	1.15554877	0.88	10	0.3	3	30%	2	20%
Iron (total)	0.89	1.085	1.96	1.985	2.86	3.13	1.128938	0.56873428	3.022	4			0%	0	0%
Lead (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Lead (total)	0	0	0	0	0	0	0	NA	0	4	0.0067	0	0%	0	0%
Lithium (dissolved)	0.02	0.02	0.02	0.02	0.02	0.02	0	0	0.02	4			0%	0	0%
Lithium (total)	0.02	0.02	0.02	0.02	0.02	0.02	0	0	0.02	4			0%	0	0%
m,p-Xylene	1	1	1	1	1	1	0	0	1	4			0%	4	100%
Magnesium (dissolved)	11.1	17	18.85	18.9125	21.375	26.1	4.20981	0.22259405	23.9	16			0%	0	0%
Magnesium (total)	12	12.825	13.85	14.125	15.15	16.8	2.077458	0.1470767	16.14	4			0%	0	0%
Manganese (dissolved)	0.01	0.0625	0.1	0.412	0.7675	1.19	0.465088	1.1288539	1.055	10			0%	0	0%
Manganese (total)	0.79	0.85	1.03	1.0325	1.2125	1.28	0.238939	0.23141756	1.253	4			0%	0	0%
Mercury (dissolved)	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	4			0%	0	0%
Mercury (total)	0.005	0.005	0.005	0.006263	0.005	0.0151	0.003571	0.57020188	0.00803	8	0.005	1	13%	7	88%
Methoxychlor	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	4			0%	0	0%
Methyl Mercury (Total)	0	0	0	0	0	0	0	NA	0	2			0%	0	0%
Methylene chloride	3	3	3	3	3	3	0	0	3	4			0%	4	100%
Mirex	0.05	0.05	0.05	0.05	0.05	0.05	0	0	0.05	3			0%	3	100%
Molybdenum (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Molybdenum (total)	0	0	0	0	0	0	0	NA	0	4	0.073	0	0%	0	0%
E.Coli	32	128	630	2773	3275	9800	4708.804	1.69809019	7190	4			0%	0	0%
Fecal Coliforms	1	30.85	210.25	2703.737	3718.75	20050	5243.524	1.93936209	6681	30	100	18	60%	5	17%
Total Coliforms	240	1545	2840	6020	4375	24200	9042.053	1.50200214	14450	6			0%		0%
Naphthalene	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0.2	4			0%	4	100%
Nickel (dissolved)	0	0.0075	0.01	0.0075	0.01	0.01	0.005	0.66666667	0.01	4			0%	0	0%
Nickel (total)	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	4	0.086	0	0%	0	0%
Nitrate (as N)	0.02	0.035	0.175	0.6675	0.9625	3.71	1.03205	1.54614193	1.81	16	3	1	6%	1	6%
Nitrate+Nitrite (as N)	0.02	0.0575	0.285	1.0275	1.0025	6.37	1.720517	1.67446945	2.72	16			0%	1	6%
Nitrite (as N)	0.01	0.025	0.075	0.365	0.2625	2.66	0.723077	1.98103222	1.015	16	0.06	8	50%	2	13%
o-Xylene	1	1	1	1	1	1	0	0	1	4			0%	4	100%
Orthophosphate (dissolved as P)	1.16	1.16	1.16	1.16	1.16	1.16	NA	NA	1.16	1			0%	0	0%
Dissolved Oxygen	1.43	3.0225	4.24	5.25293	6.305	20	3.432733	0.6534892	9.36	256	>6.5	201	79%	0	0%
p.p.DDT	0.04	0.04	0.04	0.04	0.04	0.04	0	0	0.04	4			0%	4	100%
PCB1016	0.05	0.05	0.05	0.0625	0.0625	0.1	0.025	0.4	0.085	4			0%	4	100%
PCB1221	0.05	0.05	0.05	0.0625	0.0625	0.1	0.025	0.4	0.085	4			0%	4	100%
PCB1232	0.05	0.05	0.05	0.0625	0.0625	0.1	0.025	0.4	0.085	4			0%	4	100%
PCB1242	0.05	0.05	0.05	0.0625	0.0625	0.1	0.025	0.4	0.085	4			0%	4	100%
PCB1248	0.05	0.05	0.05	0.0625	0.0625	0.1	0.025	0.4	0.085	4			0%	4	100%
PCB1254	0.05	0.05	0.05	0.0625	0.0625	0.1	0.025	0.4	0.085	4			0%	4	100%
PCB1260	0.05	0.05	0.05	0.0625	0.0625	0.1	0.025	0.4	0.085	4			0%	4	100%
PCB1262	0.05	0.05	0.05	0.05	0.05	0.05	NA	NA	0.05	1			0%	1	100%
PCB1268	0.05	0.05	0.05	0.05	0.05	0.05	NA	NA	0.05	1			0%	1	100%
Pentachlorophenol	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4			0%	4	100%
Perfluoro.n.Octanoic.Acid..PFOA.	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
Perfluorobutane.Sulfonate..PFBS.	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
Perfluorobutanoic.acid	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
Perfluorodecane.Sulfonate	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
Perfluorodecanoic.Acid..PFDA.	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
Perfluorododecanoic.Acid..PFDoA.	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
Perfluoroheptane.sulfonate	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
Perfluoroheptanoic.Acid..PFHpA.	0	0.01	0.02	0.016667	0.025	0.03	0.015275	0.91651514	0.028	3			0%	1	33%
Perfluorohexane.Sulfonate..PFHxS.	0.02	0.02	0.02	0.023333	0.025	0.03	0.005774	0.24743583	0.028	3			0%	2	67%
Perfluorohexanoic.Acid..PFHxA.	0.02	0.02	0.02	0.02	0.02	0.02	0	0	0.02	3			0%	3	100%
Perfluorononanoic.Acid..PFNA.	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
Perfluorooctane.Sulfonamide..PFOSA.	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
Perfluorooctane.Sulfonate..PFOS.	0.01	0.015	0.02	0.016667	0.02	0.02	0.005774	0.34641016	0.02	3			0%	2	67%
Perfluoropentanoic.Acid..PFPeA.	0.01	0.015	0.02	0.016667	0.02	0.02	0.005774	0.34641016	0.02	3			0%	2	67%
Perfluorotetradecanoic.Acid	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
Perfluorotridecanoic.Acid	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
Perfluoroundecanoic.Acid..PFUnA.	0	0.01	0.02	0.013333	0.02	0.02	0.011547	0.8660254	0.02	3			0%	2	67%
pH	7.12	7.7	7.9	7.86767	8	9	0.313423	0.03983682	8.2	176	6.5 to 9.5	0	0%	0	0%
pH field measurement	8.17	8.32	8.47	8.493333	8.655	8.84	0.335609	0.03951439	8.766	3	6.5 to 9.5	0	0%	0	0%
pH at 15C WSER	7.41	7.6525	7.96	7.9075	8.08	8.48	0.349316	0.04417523	8.263	8			0%	0	0%
Phenanthrene	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1	4			0%	4	100%
Phosphorus (dissolved)	0.03	0.1525	0.235	0.376471	0.3775	2.12	0.428718	1.13878269	0.834	34			0%	1	3%
Phosphorus (total)	0.3	0.8	1.91	2.736677	4.605	8.1	2.087162	0.76266284	5.527	232	0.017	232	100%	0	0%

Analyte	Minimum	1. Quartile	Median	Mean	3. Quartile	Maximum	Standard Deviation	Coefficient of Variation	90th Percentile	n	Guidelines	Exceedances	%exceedances	# of Non detects	% Non detects
Potassium (dissolved)	11.2	12.9	16.1	16.7875	17.55	27.3	4.863041	0.28968226	24.7	16			0%	0	0%
Potassium (total)	11.9	12.05	12.9	12.9	13.75	13.9	1.045626	0.08105626	13.84	4			0%	0	0%
Pyrene	0.02	0.02	0.02	0.0225	0.0225	0.03	0.005	0.22222222	0.027	4			0%	3	75%
Quinoline	0.05	0.05	0.05	0.0625	0.0625	0.1	0.025	0.4	0.085	4			0%	4	100%
Selenium (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Selenium (total)	0	0	0	0	0	0	0	NA	0	4	0.002	0	0%	0	0%
Silicon (dissolved)	6.2	6.875	7.7	7.675	8.5	9.1	1.281601	0.16698379	8.86	4			0%	0	0%
Silicon (total)	7.2	7.425	8.15	8.125	8.85	9	0.906918	0.11162066	8.94	4			0%	0	0%
Silver (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	4	100%
Silver (total)	0	0	0	0	0	0	0	NA	0	4	0.00025	0	0%	0	0%
Sodium (dissolved)	49.6	82.025	87.4	82.91875	90.45	108	16.81361	0.20277216	98.2	16			0%	0	0%
Sodium (total)	53.1	54.3	56.75	66.1	68.55	97.8	21.26923	0.32177347	86.1	4			0%	0	0%
Strontium (dissolved)	0.24	0.2925	0.31	0.3075	0.325	0.37	0.053151	0.1728479	0.352	4			0%	0	0%
Strontium (total)	0.26	0.2975	0.315	0.3125	0.33	0.36	0.04113	0.1316156	0.348	4			0%	0	0%
Sulfate	47.6	55.05	60.45	62.55	67.85	86.8	11.41534	0.18249945	74.42	12			0%	0	0%
Sulfur (dissolved)	6	6.75	7.5	7.5	8.25	9	1.290994	0.17213259	8.7	4			0%	0	0%
Sulfur (total)	7	7.375	8.25	8.125	9	9	1.030776	0.12686479	9	4			0%	0	0%
Surfactants	0.11	0.11	0.11	0.11	0.11	0.11	NA	NA	0.11	1			0%	0	0%
Surfactants..as.MBAS.	0.05	0.05	0.055	0.06	0.065	0.08	0.014142	0.23570226	0.074	4			0%	0	0%
TDS Calculated	493	525.5	545	550.25	578.5	605	36.24945	0.06587815	595.9	12			0%	0	0%
Tellurium (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Tellurium (total)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Temperature	8	16	20	19.22222	24	25	5.048483	0.26263784	25	27			0%	0	0%
Temperature(field measurement)	-0.5	1	3.5	8.03125	15.625	22	7.573033	0.94294579	19	144			0%	0	0%
Tetrachloroethene	1	1	1	1	1	1	0	0	1	4			0%	4	100%
Thallium (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Thallium (total)	0	0	0	0	0	0	0	NA	0	4	0.0008	0	0%	0	0%
Thorium (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Thorium (total)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Tin (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Tin (total)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Titanium (dissolved)	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	4			0%	0	0%
Titanium (total)	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	4			0%	0	0%
Toluene (ug/L)	1	1	1	1	1	1	0	0	1	4	0.5	4	100%	4	100%
Total Chlorinated Phenols (mono.penta)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Total.Extractable.Hydrocarbons..TEH.	0.2	0.2	0.31	0.48	0.59	1.1	0.426146	0.88780316	0.896	4			0%	2	50%
Total Kjeldahl Nitrogen	15.7	25	28.2	27.02813	29.275	34.6	4.067276	0.15048309	31.45	32			0%	0	0%
Total Nitrogen	15.7	22.4	27.7	25.34444	28.2	30	4.731308	0.18668029	29.36	9			0%	0	0%
Total PCBs	0.05	0.05	0.05	0.0625	0.0625	0.1	0.025	0.4	0.085	4			0%	4	100%
Total Suspended Solids	2	8	12.25	17.25115	20	80	14.08955	0.81673106	39.73	262	25	49	19%	0	0%
Toxaphene	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4			0%	4	100%
Trichloroethene	1	1	1	1	1	1	0	0	1	4			0%	4	100%
Turbidity	7.39	8.75	10.295	10.875	12.2	16.2	3.191468	0.29346835	14.4	6			0%	0	0%
Uranium (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	4	100%
Uranium (total)	0	0	0	0	0	0	0	NA	0	4	0.015	0	0%	4	100%
Vanadium (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	0	0%
Vanadium (total)	0	0	0	0	0	0	0	NA	0	4			0%	4	100%
Vinyl chloride	1	1	1.5	1.5	2	2	0.57735	0.38490018	2	4			0%	4	100%
X1.1.1.2.Tetrachloroethane	1	1	1	1	1	1	0	0	1	4			0%	4	100%
X1.1.2.2.Tetrachloroethane	0.5	0.5	0.75	0.75	1	1	0.288675	0.38490018	1	4			0%	4	100%
X1.1.Dichloroethene	1	1	1	1	1	1	0	0	1	4			0%	4	100%
X1.2.Dichlorobenzene	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4			0%	4	100%
X1.2.Dichloroethane	1	1	1	1	1	1	0	0	1	4			0%	4	100%
X1.4.Dichlorobenzene	1	1	1	1	1	1	0	0	1	4			0%	4	100%
X1.Methylnaphthalene	0.1	0.175	0.2	0.175	0.2	0.2	0.05	0.28571429	0.2	4			0%	4	100%
X2.2..3.3..4.4..5.5..6.NoBDE	780	780	780	780	780	780	NA	NA	780	1			0%	0	0%
X2.2..3.3..4.4..5.6.6..NoBDE	800	800	800	800	800	800	NA	NA	800	1			0%	0	0%
X2.2..3.3..4.4..6.6..OcBDE	31	31	31	31	31	31	NA	NA	31	1			0%	0	0%
X2.2..3.3..4.5..6.6..OcBDE	27	27	27	27	27	27	NA	NA	27	1			0%	0	0%
X2.2..3.3..4.5.5..6.6..NoBDE	370	370	370	370	370	370	NA	NA	370	1			0%	0	0%
X2.2..3.4.4..5..6.HpBDE	35	38.25	41.5	41.5	44.75	48	9.192388	0.22150333	46.7	2			0%	0	0%
X2.2..3.4.4..5..HxBDE	43	43	43	43	43	43	NA	NA	43	1			0%	0	0%
X2.2..3.4.4..5.5..6.OcBDE	29	29	29	29	29	29	NA	NA	29	1			0%	0	0%
X2.2..3.4.4..6.HxBDE	27	27	27	27	27	27	NA	NA	27	1			0%	0	0%
X2.2..3.4.4..PeBDE	34	50	66	66	82	98	45.25483	0.6856793	91.6	2			0%	0	0%
X2.2..4.4..5.5..HxBDE	86	107	128	128	149	170	59.39697	0.46403883	161.6	2			0%	0	0%
X2.2..4.4..5.6..HxBDE	100	115	130	130	145	160	42.42641	0.32635698	154	2			0%	0	0%
X2.2..4.4..5.PeBDE	57	498.5	940	1065.667	1570	2200	1077.013	1.01064688	1948	3			0%	0	0%
X2.2..4.4..6.PeBDE	12	116.5	221	221	325.5	430	295.5706	1.33742369	388.2	2			0%	0	0%
X2.2..4.4..TeBDE	61	580.5	1100	1053.667	1550	2000	970.33	0.92090795	1820	3			0%	0	0%
X2.2..4.5..TeBDE	83	109.75	136.5	136.5	163.25	190	75.66043	0.55428883	179.3	2			0%	0	0%
X2.2..4.TrBDE	13	16.75	20.5	20.5	24.25	28	10.6066	0.51739521	26.5	2			0%	0	0%
X2.3..4.4..TeBDE	50	52.25	54.5	54.5	56.75	59	6.363961	0.11676993	58.1	2			0%	0	0%
X2.3.4.5...2.3.5.6.Tetrachlorophenol	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4			0%	4	100%
X2.3.4.6.Tetrachlorophenol	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4			0%	4	100%
X2.3.4.Trichlorophenol	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4			0%	4	100%

Analyte	Minimum	1. Quartile	Median	Mean	3. Quartile	Maximum	Standard Deviation	Coefficient of Variation	90th Percentile	n	Guidelines	Exceedances	%exceedances	# of Non detects	% Non detects
X2.3.5.Trichlorophenol	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4			0%	4	100%
X2.3.6.Trichlorophenol	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4			0%	4	100%
X2.3.Dichlorophenol	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0.2	4			0%	4	100%
X2.4...2.5.Dichlorophenol	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0.2	4			0%	4	100%
X2.4.4..TrBDE	13	24	35	48	65.5	96	43	0.89583333	83.8	3			0%	0	0%
X2.4.5.Trichlorophenol	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4			0%	4	100%
X2.4.6.Trichlorophenol	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4			0%	0	0%
X2.6.Dichlorophenol	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0.2	4			0%	0	0%
X2.Chlorophenol	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1	4			0%	4	100%
X2.Methylnaphthalene	0.1	0.175	0.2	0.175	0.2	0.2	0.05	0.28571429	0.2	4			0%	4	100%
X3...4.Chlorophenol	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1	4			0%	4	100%
X3.4.5.Trichlorophenol	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	4			0%	4	100%
X3.4.Dichlorophenol	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0.2	4			0%	4	100%
X3.5.Dichlorophenol	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0.2	4			0%	4	100%
X4.4..DiBDE	6	7.95	9.9	10.63333	12.95	16	5.040172	0.47399736	14.78	3			0%	0	0%
Xylenes (total)	2	2	2	2	2	2	0	0	2	4			0%	4	100%
Zinc (dissolved)	0.01	0.01	0.01	0.015	0.015	0.03	0.01	0.66666667	0.024	4			0%	0	0%
Zinc (total)	0.01	0.0175	0.02	0.0225	0.025	0.04	0.012583	0.559247	0.034	4	0.03	1	25%	0	0%
Zirconium (dissolved)	0	0	0	0	0	0	0	NA	0	4			0%	4	100%
Zirconium (total)	0	0	0	0	0	0	0	NA	0	4			0%	4	100%

Analyte	Minimum	1. Quartile	Median	Mean	3. Quartile	Maximum	Standard deviation	Coefficient of variation	90th Percentile	n	Guideline	Exceedances	% exceedance	Non detects	% Non detects
Alkalinity (Total as CaCO3)	144	305.75	378	418.1667	492.25	889	207.1595	0.49539938	626.2	12			0%	0	0%
Aluminium	0.0081	0.117	0.2265	0.322809	0.40125	2.15	0.390886	1.21088865	0.6803	32			0%	0	0%
Aluminium (Filtered)	0.0022	0.00835	0.0132	1.0303	0.08105	10.8	3.241421	3.14609431	0.293	11	0.05	3	27%	0	0%
Ammonia N	0.05	0.05	0.05	0.094813	0.05175	0.721	0.142777	1.50589205	0.1269	32	1.38	0	0%	24	75%
Antimony	0.00013	0.000337	5.00E-04	0.000485	5.00E-04	0.00172	0.000285	0.58861714	0.000634	32			0%	11	34%
Antimony (Filtered)	1.00E-04	1.00E-04	0.00033	0.000301	5.00E-04	5.00E-04	0.000188	0.62605448	5.00E-04	11			0%	8	73%
Arsenic	0.00039	0.000615	0.000845	0.000992	0.001182	0.00336	0.000587	0.5916768	0.001545	32	0.005	0	0%	0	0%
Arsenic (Filtered)	0.00011	0.00018	5.00E-04	0.00106	0.001155	0.00421	0.001373	1.29544482	0.00314	11			0%	1	9%
Barium	0.0617	0.1075	0.125	0.135894	0.1575	0.293	0.048805	0.35914245	0.185	32			0%	0	0%
Barium (Filtered)	0.0394	0.09135	0.153	0.341191	0.4385	1.3	0.416889	1.22186533	0.883	11			0%	0	0%
Benzene	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	0	0	5.00E-04	39	0.04	0	0%	39	100%
Beryllium	1.00E-04	1.00E-04	0.00016	0.000279	5.00E-04	5.00E-04	0.000194	0.69633208	5.00E-04	32			0%	30	94%
Beryllium (Filtered)	1.00E-04	1.00E-04	0.00012	0.000304	5.00E-04	0.00108	0.000314	1.03428619	5.00E-04	11			0%	8	73%
Bicarbonate	176	360.5	444.5	490.0833	561.75	1010	234.9984	0.4795071	753.6	12			0%	0	0%
Biochemical Oxygen Demand	2	2	2	2.253125	2.425	3.7	0.448643	0.19912019	2.88	32			0%	21	66%
Bismuth	5.00E-05	5.00E-05	7.50E-05	0.000139	0.00025	0.00025	9.70E-05	0.69990694	0.00025	32			0%	30	94%
Bismuth (Filtered)	5.00E-05	5.00E-05	5.00E-05	1.00E-04	1.00E-04	0.00025	9.30E-05	0.9258201	0.00025	8			0%	7	88%
Carbonaceous BOD	2	2	2	2	2	2	NA	NA	2	1			0%	1	100%
Boron	0.0093	0.0202	0.0765	0.072753	0.09625	0.283	0.058935	0.81006746	0.1066	32	1.5	0	0%	1	3%
Boron (Filtered)	0.012	0.03495	0.079	0.110991	0.1555	0.36	0.104469	0.94124309	0.199	11			0%	1	9%
Cadmium	5.00E-06	2.00E-05	2.50E-05	4.70E-05	6.80E-05	0.000285	5.20E-05	1.11628233	9.28E-05	32	0.00026	1	3%	10	31%
Cadmium (Filtered)	5.00E-06	2.20E-05	2.70E-05	4.60E-05	5.70E-05	0.000166	4.90E-05	1.04608393	9.45E-05	11			0%	3	27%
Calcium	16.3	33.925	41.35	44.53421	50.625	112	19.4892	0.43762305	69.39	38			0%	0	0%
Calcium (Filtered)	0.71	30.9	41	43.33047	50	115	21.7884	0.50284244	71.42	43			0%	0	0%
Carbonate	5	5	5	12.04167	9.175	45.5	13.61206	1.13041307	32.74	12			0%	6	50%
Cesium	1.20E-05	5.00E-05	1.00E-04	0.000118	0.00016	0.000459	9.40E-05	0.79722357	0.000201	32			0%	5	16%
Cesium (Filtered)	4.20E-05	4.40E-05	4.60E-05	4.60E-05	4.80E-05	5.00E-05	6.00E-06	0.12297509	4.92E-05	2			0%	0	0%
Chloride	0.5	1.34	2.21	3.019167	2.8175	11.2	3.097839	1.02605773	6.542	12	120	0	0%	3	25%
Chromium	1.00E-04	0.000218	5.00E-04	0.000598	0.000738	0.00308	0.000585	0.97888177	0.00099	32			0%	12	38%
Chromium (Filtered)	1.00E-04	0.000125	0.00021	0.001618	5.00E-04	0.0152	0.004508	2.78590112	0.00057	11			0%	4	36%
Chromium (hexavalent)	5.00E-04	5.00E-04	5.00E-04	0.000694	0.001	0.001	0.000248	0.3569597	0.001	31	0.001	0	0%	31	100%
Chromium (Trivalent)	1.00E-04	0.000255	5.00E-04	0.000614	0.000745	0.00308	0.000588	0.95728071	0.001	31	0.0089	0	0%	11	35%
Cobalt	1.00E-04	0.000295	0.000445	0.000445	5.00E-04	0.00162	0.000259	0.5811224	0.000518	32	0.0013	1	3%	14	44%
Cobalt (Filtered)	1.00E-04	0.00014	0.00025	0.00148	0.00052	0.0132	0.003892	2.62958181	6.00E-04	11			0%	3	27%
Colour	2	9.3	12.2	15.75161	14.95	92.3	16.10942	1.02271526	20.2	31			0%	1	3%
Converted TSS	0	8	8	9.239962	10	16	2.096115	0.22685317	12	3163			0%	0	0%
Copper	0.00056	0.001	0.002175	0.002021	0.0025	0.00631	0.001179	0.58315022	0.002887	32	0.028	0	0%	15	47%
Copper (Filtered)	0.00039	0.000505	0.0011	0.003008	0.00194	0.0205	0.005874	1.95265077	0.0034	11			0%	1	9%
Cyanide (weak acid dissociable)	0.001	0.001	0.002	0.00229	0.002	0.02	0.003319	1.44895286	0.002	31	0.0052	1	3%	30	97%
Dissolved Oxygen	1.64	7.7	8	8.170147	8.2625	17.25	2.363714	0.28931109	10.466	68	>6.5	6	9%	0	0%
Electrical Conductivity	299	586.25	755.5	827.0833	961.75	1670	413.0506	0.49940629	1429	12			0%	0	0%
Ethylbenzene	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	0	0	5.00E-04	39	0.09	0	0%	39	100%
F1	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1	39	0.15	0	0%	39	100%
F1 BTEX	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1	39			0%	39	100%
F2	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1	39	0.11	0	0%	39	100%
F3	0.25	0.25	0.25	0.25	0.25	0.25	0	0	0.25	39			0%	39	100%
F4	0.25	0.25	0.25	0.25	0.25	0.25	0	0	0.25	39			0%	39	100%
Flow	0	0	6.912	1971.907	721.44	81069	5045.524	2.55870289	7418.3	1833			0%	0	0%
Fluoride	0.02	0.06225	0.11	0.459583	0.1645	3.27	0.951709	2.07080737	1.1878	12			0%	2	17%
Freeboard	0	1	1.5	2.032307	2	20	1.837535	0.9041619	3.5	3797			0%	0	0%
Hardness (as CaCO3)	2.2	104	131	149.5767	175.5	423	78.76275	0.52657081	234	43			0%	0	0%
Hydroxide	5	5	5	5	5	5	0	0	5	12			0%	11	92%
Ionic Balance	96.8	101	104.5	104.1167	106.75	111	4.468442	0.04291764	109	12			0%	0	0%
Iron	0.03	0.0935	0.1815	0.338219	0.3725	2.8	0.505843	1.49560786	0.7014	32			0%	0	0%
Iron (Filtered)	0.01	0.03	0.149	1.758545	0.395	15	4.485561	2.55072211	3.14	11	0.3	4	36%	3	27%
Lead	5.00E-05	0.000211	0.00025	0.000374	0.000415	0.00218	0.000381	1.01920504	0.000574	32	0.0067	0	0%	13	41%
Lead (Filtered)	5.00E-05	6.60E-05	0.000154	0.001316	0.00027	0.0127	0.003778	2.8696269	0.00047	11			0%	5	45%
Lithium	0.0014	0.00645	0.01245	0.011456	0.015125	0.0213	0.005298	0.46243528	0.01774	32			0%	5	16%
Lithium (Filtered)	0.012	0.0142	0.0144	0.01768	0.0214	0.0264	0.006021	0.34055223	0.0244	5			0%	0	0%
Magnesium	3.48	6.605	8.5	10.82526	12	37.6	6.847795	0.63257542	19.95	38			0%	0	0%
Magnesium (Filtered)	0.11	6.255	8.03	10.0514	11.6	33	6.463169	0.64301209	19.88	43			0%	0	0%
Manganese	0.00556	0.01795	0.0507	0.052244	0.076025	0.121	0.032169	0.61574505	0.08664	32			0%	0	0%
Manganese (Filtered)	0.00205	0.0167	0.0757	0.141377	0.237	0.407	0.140805	0.99595499	0.291	11			0%	1	9%
Mercury	5.00E-06	5.00E-06	5.00E-06	7.00E-06	5.00E-06	5.00E-05	9.00E-06	1.20579022	6.90E-06	31	0.000005	4	13%	29	94%
Mercury (Filtered)	5.00E-06	5.00E-06	5.00E-06	9.00E-06	1.10E-05	1.70E-05	7.00E-06	0.77196874	1.50E-05	3			0%	1	33%
Molybdenum	0.00038	0.002463	0.019	0.022805	0.037625	0.12	0.02437	1.06861908	0.04302	32	0.073	1	3%	0	0%
Molybdenum (Filtered)	0.000151	0.000754	0.00188	0.004239	0.0041	0.0228	0.006658	1.57047179	0.00842	11			0%	0	0%
Nickel	5.00E-04	0.001778	0.0025	0.002414	0.002525	0.00607	0.00111	0.45962565	0.00312	32	0.086	0	0%	10	31%
Nickel (Filtered)	5.00E-04	0.001075	0.0025	0.003426	0.00262	0.0199	0.00554	1.61681406	0.00303	11			0%	3	27%
Nitrate + Nitrite (as N)	0.022	0.022	0.022	0.1205	0.11	0.78	0.214681	1.78158814	0.1748	12			0%	8	67%
Nitrate(as N)	0.02	0.02	0.054	0.945704	0.5185	11.6	2.140298	2.26317794	3.112	335	3	36	11%	137	41%
Nitrite (as N)	0.01	0.01	0.01	0.019341	0.0215	0.078	0.015864	0.82023892	0.0491	44	0.06	1	2%	28	64%
Oil and Grease	1	1	1	1.606061	1	5	1.456438	0.90683886	5	33			0%	0	0%
pH	6.8	8	8.2	8.216296	8.43	12.56	0.353089	0.04297423	8.63	1555	6.5 to 9.5	2	0%	0	0%
pH (lab)	7.47	8.1125	8.255	8.244048	8.415	8.69	0.243401	0.02952449	8.534	42			0%	0	0%
Phenols 4AAP	0.001	0.001	0.001	0.001003	0.001	0.0011	1.80E-05	0.01790278	0.001	31	0.004	0	0%	30	97%
Phosphorus	0.02	0.02	0.022	0.031161	0.045	0.07	0.015027	0.48222835	0.05	31	0.017	31	100%	14	45%
Phosphorus (by ICP)	0.05	0.05	0.0945	0.143875	0.25	0.25	0.093436	0.64942561	0.25	32			0%	25	78%

Analyte	Minimum	1. Quartile	Median	Mean	3. Quartile	Maximum	Standard deviation	Coefficient of variation	90th Percentile	n	Guideline	Exceedances	% exceedance	Non detects	% Non detects
Phosphorus (by ICP Filtered)	0.05	0.06675	0.0835	0.0835	0.10025	0.117	0.047376	0.56737909	0.1103	2			0%	0	0%
Potassium	1.26	2.375	3.65	3.539474	4.87	6.18	1.434221	0.40520732	5.198	38			0%	1	3%
Potassium (Filtered)	1.39	1.9225	2.185	2.434167	3.13	3.82	0.851335	0.34974409	3.67	12			0%	0	0%
Rubidium	0.0012	0.001985	0.006175	0.005808	0.00827	0.0132	0.003764	0.6481053	0.011498	32			0%	0	0%
Rubidium (Filtered)	0.00101	0.00134	0.00167	0.00167	0.002	0.00233	0.000933	0.55891075	0.002198	2			0%	0	0%
Selenium	1.00E-04	0.001152	0.002265	0.002609	0.002647	0.0135	0.002705	1.03684834	0.003601	32	0.002	20	63%	2	6%
Selenium (Filtered)	5.00E-05	6.00E-05	0.000115	0.000362	0.00029	0.00242	0.000692	1.91431901	0.00037	11			0%	3	27%
Silicon	0.79	2.2	2.785	2.77625	3.5725	5.55	1.046496	0.37694577	3.972	32			0%	0	0%
Silicon (Filtered)	2.62	3.215	3.81	3.81	4.405	5	1.682914	0.44170975	4.762	2			0%	0	0%
Silver	1.00E-05	1.00E-05	2.00E-05	2.80E-05	5.00E-05	5.00E-05	1.90E-05	0.67430835	5.00E-05	32	0.00025	0	0%	28	88%
Silver (Filtered)	1.00E-05	1.00E-05	1.00E-05	3.50E-05	5.00E-05	9.50E-05	3.10E-05	0.90246938	7.80E-05	11			0%	8	73%
Sodium	5.54	40.825	112	105.7574	161.75	305	74.5387	0.7048086	185.3	38			0%	0	0%
Sodium (Filtered)	33.5	49.35	91.7	150.125	225.5	434	131.6708	0.87707459	301.7	12			0%	0	0%
Strontium	0.154	0.462	0.61	0.590062	0.7135	1.28	0.224751	0.38089312	0.8135	32			0%	0	0%
Strontium (Filtered)	0.0372	0.26	0.4505	0.588275	0.7695	1.35	0.499566	0.8492053	1.35	8			0%	0	0%
Styrene	0.001	0.001	0.001	0.001	0.001	0.001	0	0	0.001	10	0.072	0	0%	10	100%
Sulphate	0.3	44.6	102	115.5233	200.5	283	81.86875	0.70867768	220.8	43	309	0	0%	2	5%
Sulphide	0.0015	0.0015	0.0015	0.002216	0.0015	0.0159	0.002678	1.20833312	0.0023	31	0.0019	5	16%	26	84%
Sulphur (as S)	3.3	23.9	55.05	50.44844	76.75	96.6	29.05073	0.57584989	85.58	32			0%	0	0%
Sulphur (as S Filtered)	0.58	3.76	6.94	6.94	10.12	13.3	8.994398	1.2960228	12.028	2			0%	0	0%
Tellurium	2.00E-04	2.00E-04	0.000425	0.000573	0.001	0.001	0.000379	0.6616755	0.001	32			0%	30	94%
Tellurium (Filtered)	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	0	0	2.00E-04	2			0%	1	50%
Thallium	1.00E-05	1.00E-05	2.70E-05	3.00E-05	5.00E-05	5.00E-05	1.80E-05	0.60525527	5.00E-05	32	0.0008	0	0%	25	78%
Thallium (Filtered)	1.00E-05	1.40E-05	5.00E-05	5.60E-05	6.40E-05	0.000218	6.10E-05	1.10237846	9.80E-05	11			0%	4	36%
Thorium	1.00E-04	0.000115	0.000355	0.000336	5.00E-04	0.00101	0.000214	0.63711988	5.00E-04	32			0%	24	75%
Thorium (Filtered)	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	0	0	1.00E-04	2			0%	1	50%
Tin	1.00E-04	1.00E-04	0.000185	0.000283	5.00E-04	5.00E-04	0.000191	0.67522052	5.00E-04	32			0%	27	84%
Tin (Filtered)	1.00E-04	1.00E-04	0.00026	0.000417	5.00E-04	0.00174	0.000475	1.13828575	5.00E-04	11			0%	8	73%
Titanium	3.00E-04	0.0015	0.00224	0.003627	0.004008	0.0269	0.004664	1.2861361	0.005963	32			0%	7	22%
Titanium (Filtered)	3.00E-04	0.000335	0.00118	0.008634	0.00167	0.0846	0.025208	2.91972245	0.0027	11			0%	4	36%
Toluene	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	0	0	5.00E-04	39	0.0005	0	0%	39	100%
Total Dissolved Solids	172	351.25	469.5	526.4167	615.5	1100	288.5813	0.54819942	982.1	12			0%	0	0%
Total Dissolved Solids (Filtered)	94	255	453	435.283	577	783	187.592	0.4309655	651.4	53			0%	0	0%
Total Suspended Solids	3	3	5.3	20.00437	14.4	2450	107.1345	5.35555488	37.7	641	25	104	16%	181	28%
Total Suspended Solids (average)	0	8	8	11.09072	10	2450	44.61453	4.0226905	14	3243			0%	0	0%
Total Suspended Solids(field lab)	3	3.8	8.9	27.9837	26.225	1032	71.5949	2.55844993	52.82	1000	25	260	26%	194	19%
Total Suspended Solids (monthly average)	3	7.329032	7.9	56.54031	12.7	2450	335.166	5.92791221	20.14	53			0%	0	0%
Tungsten	1.00E-04	1.00E-04	5.00E-04	0.000473	0.000622	0.001	0.000282	0.59514701	0.000866	32			0%	19	59%
Tungsten (Filtered)	1.00E-04	0.000145	0.00019	0.00019	0.000235	0.00028	0.000127	0.66989064	0.000262	2			0%	0	0%
Turbidity	0	2.87	6.82	15.43392	17.81	1585	38.21168	2.47582412	35.3	3717			0%	0	0%
Uranium	0.000166	0.002505	0.0064	0.007396	0.01225	0.0154	0.0053	0.71653781	0.01476	32	0.015	2	6%	0	0%
Uranium (Filtered)	0.000171	0.000267	0.00119	0.001711	0.002925	0.00491	0.001634	0.95456255	0.00333	11			0%	0	0%
Vanadium	5.00E-04	0.000893	0.001635	0.00173	0.0025	0.00568	0.001095	0.63313319	0.0025	32			0%	16	50%
Vanadium (Filtered)	5.00E-04	5.00E-04	5.00E-04	0.003127	0.0025	0.0234	0.006786	2.16990383	0.0025	11			0%	9	82%
Xylene(m p)	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	0	0	5.00E-04	39			0%	39	100%
Xylene (o)	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	0	0	5.00E-04	39			0%	39	100%
Xylenes Total	0.00071	0.00071	0.00071	0.00071	0.00071	0.00071	0	0	0.00071	39	0.03	0	0%	39	100%
Zinc	0.003	0.0033	0.0101	0.009844	0.015	0.0209	0.006185	0.62830098	0.015	32	0.03	0	0%	21	66%
Zinc (Filtered)	0.0014	0.00265	0.0041	0.010164	0.00715	0.0655	0.018577	1.82774731	0.011	11			0%	0	0%
Zirconium	6.00E-05	0.000184	3.00E-04	0.000296	0.00031	0.00071	0.00016	0.54095595	0.000542	32			0%	11	34%
Zirconium (Filtered)	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	0	0	3.00E-04	2			0%	1	50%

Analyte	Minimum	1. Quartile	Median	Mean	3. Quartile	Maximum	Standard deviation	Coefficient of variation	90th Percentile	n	Guideline	Exceedances	% exceedances	Non detects	% Non detects
Alkalinity (as CaCO3 in mg/L)	148	218	311	1347.273	2520	3200	1308.422	0.9711633	2820	11			0%	0	0%
Aluminum(Dissolved mg/L)	0.0106	0.0329	0.0475	0.09725	0.125	0.365	0.108509	1.1157705	0.2171	12	0.05	5	42%	2	17%
Aluminum (Total mg/L)	0.03	0.06575	0.1165	0.180742	0.291	0.473	0.152254	0.8423858	0.3915	12			0%	2	17%
Ammonia (mg/L)	0.005	0.025225	0.08115	0.175967	0.20125	0.62	0.221005	1.2559459	0.541	12	1.38	0	0%	1	8%
Antimony (Dissolved mg/L)	1.00E-04	0.000146	4.00E-04	0.001172	0.001	0.008	0.002205	1.8819422	0.00154	12			0%	11	92%
Antimony (Total mg/L)	1.00E-04	0.000188	0.00045	0.001204	0.001	0.008	0.002191	1.8196362	0.00154	12			0%	3	25%
Arsenic (Total mg/L)	1.00E-04	6.00E-04	0.00116	0.001638	0.001692	0.008	0.002081	1.2699959	0.00179	12	0.005	1	8%	4	33%
Arsenic (Dissolved mg/L)	1.00E-04	0.00061	0.00109	0.001522	0.0014	0.008	0.002098	1.3786421	0.00158	12			0%	4	33%
Avg DO (mg/L)	0.1	5.5	6.3	6.212133	7.08	10.9	1.278076	0.2057387	7.7	3624			0%	0	0%
Barium (Dissolved mg/L)	0.043	0.20125	0.2565	0.264083	0.33025	0.469	0.120975	0.4580947	0.4303	12			0%	0	0%
Barium (Total mg/L)	0.0467	0.208	0.2715	0.268642	0.324	0.47	0.117917	0.4389366	0.4071	12			0%	0	0%
Beryllium (Total mg/L)	2.50E-05	0.000425	0.001	0.00336	0.00425	0.02	0.00556	1.6545378	0.005	12			0%	12	100%
Bicarbonate (mg/L)	181	291	1375	1634.667	2912.5	3620	1452.539	0.8885845	3226	12			0%	0	0%
BOD (kg/d)	0.66	204.6	370.96	699.3238	707.52	8208	882.3504	1.2617193	1991.16	13502			0%	0	0%
BOD (mg/L)	2	4.25	12.3	21.4	25.35	100	28.38126	1.3262272	34.2	11	25	3	27%	3	27%
BOD (ppm)	1	9.8225	21.1	24.89057	34	270	19.76407	0.7940386	49	13502		5490	41%	0	0%
Boron (mg/L)	0.025	0.04825	0.075	0.62775	0.5825	2.84	1.042329	1.6604213	2.102	12			0%	7	58%
Boron (Total mg/L)	0.04	0.05	0.09	0.641417	0.57	2.64	1.046741	1.6319199	2.412	12	1.5	3	25%	7	58%
Cadmium (Dissolved mg/L)	1.00E-05	5.00E-05	0.000162	0.002699	0.001855	0.019	0.00558	2.0677198	0.006679	12			0%	7	58%
Cadmium (Total mg/L)	5.00E-05	0.00024	0.000516	0.003848	0.00241	0.026	0.007636	1.9843072	0.010123	12	0.00026	8	67%	3	25%
Calcium (mg/L)	37.6	37.6	37.6	37.6	37.6	37.6			37.6	1			0%	0	0%
Calcium (Total mg/L)	29.9	38.675	74.05	75.65	99.025	136	35.81811	0.4734714	120.7	12			0%	0	0%
Carbon Dissolved Inorganic (mg/L)	10	39.55	67.25	263.4167	549.5	690	276.139	1.0482972	560.3	12			0%	1	8%
Carbon Dissolved Organic (mg/L)	14.7	35.025	131.95	186.6	306	522	180.7566	0.9686851	428.4	12			0%	0	0%
Carbon Total Organic (mg/L)	13.4	41.6	248	243.6	408	507	218.0724	0.895207	467.4	5			0%	0	0%
Carbonate (mg/L)	5	5	5	54.475	78.975	299	85.89219	1.5767267	99.21	12			0%	8	67%
Chloride (mg/L)	4.03	18.675	27.9	47.51917	66.025	166	45.92633	0.9664801	90.58	12	120	1	8%	0	0%
Chlorophyll_a (ug/L)	0.0899	1.27	4	3.62099	4.45	8.64	2.746966	0.7586229	7.164	10			0%	4	40%
Chromium (Dissolved mg/L)	0.00033	0.00071	0.005	6.420893	0.031725	76.9	22.19517	3.456711	0.05271	12			0%	5	42%
Chromium (Total mg/L)	0.00044	0.00212	0.005	0.01066	0.01155	0.0396	0.013795	1.2941131	0.0315	12			0%	5	42%
Cobalt (Dissolved mg/L)	1.00E-04	0.000465	0.002	0.001726	0.00225	0.0047	0.001338	0.7754313	0.00285	12			0%	5	42%
Cobalt (Total mg/L)	2.00E-04	0.000552	0.002	0.002082	0.003225	0.005	0.001587	0.76222	0.00396	12	0.0013	8	67%	4	33%
COD (kg/d)	19.64	9805.81	14236.08	19901.16	31995.45	90650.4	13534.34	0.6800777	39547.96	9889			0%	0	0%
COD (ppm)	55	364	770	745.1645	1040	3525	391.9651	0.5260115	1234.9	14762			0%	0	0%
COD Total	31	554.25	719	2348.878	1048	58852.299	5935.732	2.5270502	1488.4	3662			0%	0	0%
Colour (CU)	18.28	211	1123.5	1191.664	1879	5536	1066.702	0.8951369	2670	7360			0%	0	0%
Colour (kg/d)	39.46	3603.87	16474.99	17706.29	23673.308	136451.67	14277.35	0.8063436	39510.48	7360			0%	0	0%
Conductivity (uS/cm)	294	1130	2240	3411	5795	6500	2487.525	0.7292657	6470	11			0%	0	0%
Copper (Dissolved mg/L)	0.00046	7.00E-04	0.00565	0.006158	0.00875	0.0194	0.005973	0.9701092	0.01199	12			0%	1	8%
Copper (Total mg/L)	0.00062	0.00097	0.0059	0.00797	0.013775	0.02	0.007733	0.9702129	0.01949	12	0.028	0	0%	2	17%
Beryllium (Dissolved mg/L)	2.50E-05	0.000425	0.001	0.002194	0.00275	0.01	0.003012	1.3730367	0.005	12			0%	12	100%
Dissolved Organic Nitrogen (mg/L)	0.05	0.32175	1.6565	1.9185	2.8075	5.08	1.951652	1.0172799	4.005	6			0%	1	17%
FixedSS (mg/L)	5	6.5	10	9.233333	10	20	4.062989	0.4400349	10.72	12			0%	8	67%
Flow (m3/day)	0	12104.415	14556.65	39478.43	83253.375	149800	38981.64	0.9874163	101500	22990			0%	49	0%
Hardness (mg/L)	142	165.25	278	271.25	340.25	443	107.5336	0.3964373	428.3	12			0%	0	0%
Hydroxide (mg/L)	5	5	5	8.75	5	50	12.99038	1.484615	5	12			0%	12	100%
Ion Balance	86.3	98.25	99.8	100.5	105.5	110	6.68431	0.0665105	107	11			0%	0	0%
Iron (Dissolved mg/L)	0.012	0.04125	0.0965	0.10125	0.1425	0.24	0.075086	0.7415915	0.177	8	0.3	0	0%	3	38%
Iron (Total mg/L)	0.03	0.0805	0.119	0.205833	0.3725	0.592	0.187011	0.9085571	0.4286	12			0%	3	25%
Lead (Dissolved mg/L)	1.00E-04	1.00E-04	0.000325	0.000465	5.00E-04	0.002	0.000552	1.1867643	0.00095	12			0%	9	75%
Lead (Total mg/L)	1.00E-04	0.000215	5.00E-04	0.000556	0.000622	0.002	0.000529	0.9523853	0.000969	12	0.0067	0	0%	6	50%
Lithium (Dissolved mg/L)	0.003	0.005525	0.01065	0.020292	0.0275	0.06	0.020757	1.0229307	0.05	12			0%	5	42%
Lithium (Total mg/L)	0.0032	0.009975	0.0144	0.028	0.03125	0.12	0.032956	1.1770011	0.05	12			0%	6	50%
Magnesium (mg/L)	11.8	11.8	11.8	11.8	11.8	11.8			11.8	1			0%	0	0%
Magnesium (Total mg/L)	10.8	12.875	16.65	20.5	20.6	46.5	11.19017	0.5458622	36.47	12			0%	0	0%
Manganese (Dissolved mg/L)	0.0034	0.19445	0.62	2.07515	0.986	13	4.433755	2.1365951	4.712	8			0%	0	0%
Manganese (Total mg/L)	0.0376	0.262	0.456	0.545875	0.81525	1.25	0.404612	0.7412164	1.0512	12			0%	0	0%
Max Conductivity	1	2244.4	3863.2	3898.315	5466.3	9780	1737.007	0.445579	6267.05	17006			0%	0	0%
Mercury (Dissolved mg/L)	5.00E-06	5.00E-06	5.00E-05	8.80E-05	1.00E-04	5.00E-04	0.000142	1.612	1.00E-04	11			0%	11	100%
Mercury (Total mg/L)	5.00E-06	1.80E-05	5.00E-05	9.10E-05	1.00E-04	5.00E-04	0.000135	1.4876297	1.00E-04	12	0.000005	0	0%	11	92%
Min Conductivity	483	1737	2008.8	1998.746	2266.2	3754.6	397.3583	0.1988038	2500.6	7605			0%	0	0%
Molybdenum (Dissolved mg/L)	0.00025	5.00E-04	0.00216	0.002424	0.005	0.005	0.002063	0.851322	0.005	12			0%	7	58%
Molybdenum (Total mg/L)	0.00039	5.00E-04	0.00235	0.00249	0.005	0.005	0.002035	0.8173283	0.005	12	0.073	0	0%	6	50%
Month	1	4	7	6.523911	10	12	3.448786	0.5286379	11	23023			0%	3	0%
Nickel (Dissolved mg/L)	5.00E-04	0.00362	0.0041	0.004654	0.005125	0.0139	0.003332	0.7159646	0.00595	12			0%	0	0%
Nickel (Total mg/L)	0.00065	0.003925	0.00455	0.005018	0.005175	0.0149	0.003583	0.7140492	0.00687	12	0.086	0	0%	4	33%
Nitrate (mg/L)	0.01	0.03125	0.102	0.2551	0.147	1.66	0.501306	1.9651368	0.4378	10	3	0	0%	5	50%
Nitrate+Nitrite (mg/L)	0.006	0.02655	0.0481	0.10474	0.14875	0.348	0.11649	1.1121822	0.2652	10			0%	6	60%
Nitrite (mg/L)	0.002	0.01125	0.0372	0.04564	0.05	0.15	0.047053	1.0309649	0.105	10	0.06	2	20%	0	0%
Dissolved Kjeldahl Nitrogen (mg/L)	0.476	0.8245	2.715	2.817417	4.9025	5.91	2.105188	0.747205	5.42	12			0%	0	0%
Total Nitrogen (mg/L)	0.804	1.50275	5.23	7.596917	11.9	22.5	7.675558	1.0103518	19.58	12			0%	0	0%
Total Dissolved Nitrogen (mg/L)	0.476	0.9205	2.17	2.896714	4.255	7.28	2.515648	0.8684489	5.84	7			0%	0	0%
Total Kjeldahl Nitrogen (mg/L)	0.792	1.68	5.075	7.5325	11.9	20.7	7.260638	0.9639081	19.49	12			0%	0	0%
pH	7.8	8.195	8.29	8.330909	8.52	9.08	0.361288	0.0433672	8.58	11	6.5 to 9.5	0	0%	0	0%
pH Max	1.36	7.68	8	7.946605	8.2	9.2	0.396036	0.0498372	8.39	17789			0%	0	0%

Analyte	Minimum	1. Quartile	Median	Mean	3. Quartile	Maximum	Standard deviation	Coefficient of variation	90th Percentile	n	Guideline	Exceedances	% exceedances	Non detects	% Non detects
pH Min	5.82	7.34	7.53	7.556565	7.77	8.7	0.348995	0.0461844	8	7968			0%	0	0%
Ortho-Phosphate (Dissolved mg/L)	0.0141	0.418275	1.3465	1.286775	2.215	2.44	1.185474	0.9212755	2.35	4			0%	0	0%
Phosphorus (Total mg/L)	0.0586	0.8055	1.445	1.590633	2.4125	3.05	1.026029	0.6450444	2.906	12	0.017	12	100%	0	0%
Total Dissolved Phosphorus (mg/L)	0.0278	0.619	1.349	1.59465	2.4775	3.52	1.145951	0.7186223	2.875	12			0%	0	0%
Potassium (mg/L)	2.81	2.81	2.81	2.81	2.81	2.81			2.81	1			0%	0	0%
Potassium (Total mg/L)	2.97	24.575	55.8	48.80583	67.525	98.1	28.31745	0.5802063	74.14	12			0%	0	0%
Selenium (Dissolved mg/L)	8.50E-05	0.000475	0.001	0.002209	0.00155	0.01	0.003245	1.4692736	0.0074	12			0%	7	58%
Selenium (Total mg/L)	1.00E-04	0.000868	0.001	0.002558	0.00245	0.01	0.003292	1.287031	0.0077	12	0.002	3	25%	9	75%
Silver (Dissolved mg/L)	1.00E-05	1.80E-05	1.00E-04	0.000248	1.00E-04	0.002	0.000562	2.266724	0.00037	12			0%	12	100%
Silver (Total mg/L)	1.00E-05	4.20E-05	1.00E-04	0.000256	1.00E-04	0.002	0.000559	2.1813591	0.00037	12	0.00025	2	17%	10	83%
Sodium (mg/L)	13.6	13.6	13.6	13.6	13.6	13.6			13.6	1			0%	0	0%
Sodium (Total mg/L)	14.1	161.5	719.5	788.3417	1472.5	1610	657.9598	0.8346125	1519	12			0%	0	0%
Sulphate (mg/L)	10.6	278.75	603.5	587.8833	864.5	1100	376.5748	0.6405605	1094	12	309	7	58%	0	0%
Sulphide (mg/L)	0.002	0.033625	0.0834	0.130258	0.117	0.755	0.203004	1.558474	0.1599	12	0.0019	12	100%	1	8%
TDS Calculated (mg/L)	169	714.5	1510	2314.364	4230	4510	1759.797	0.7603805	4320	11			0%	0	0%
Temp (C)	4	22	27.2	26.23014	30.7	44	5.569512	0.2123325	32.9	17464			0%	0	0%
Thallium (Dissolved mg/L)	1.00E-05	8.00E-05	1.00E-04	0.00027	0.000275	0.001	0.000365	1.35069	0.00095	12			0%	11	92%
Thallium (Total mg/L)	2.00E-05	8.10E-05	1.00E-04	0.000406	5.00E-04	0.002	0.000582	1.4357155	0.00095	12	0.0008	2	17%	11	92%
Tin (Dissolved mg/L)	1.00E-04	0.000175	0.00155	0.017417	0.05	0.05	0.024094	1.3833905	0.05	12			0%	10	83%
Tin (Total mg/L)	1.00E-04	0.00056	0.00125	0.017423	0.05	0.05	0.024083	1.3822005	0.05	12			0%	9	75%
Titanium (Total mg/L)	0.00057	0.003475	0.0055	0.005503	0.007275	0.012	0.003506	0.6370761	0.00975	12			0%	3	25%
Titanium (Dissolved mg/L)	3.00E-04	0.001	0.0023	0.003508	0.005225	0.01	0.003299	0.9403787	0.00839	12			0%	6	50%
TotalSS (mg/L)	9	15.825	39.5	62.175	63.45	289	79.01045	1.2707752	116.4	12	25	7	58%	0	0%
TSS (kg/d)	0	339.56	1159.27	1542.902	2266.085	18678.19	1512.344	0.9801945	3621.8	16847			0%	18	0%
TSS (ppm)	0	18.2	34	50.30279	62	1490	54.84346	1.0902667	104	22953			0%	27	0%
Turbidity (NTU)	6.02	9.78	17.2	24.35273	25.15	95.4	25.27889	1.0380312	35.9	11			0%	0	0%
Uranium (Dissolved mg/L)	1.00E-05	8.40E-05	3.00E-04	0.003699	0.003953	0.0162	0.006238	1.6864483	0.01428	12			0%	3	25%
Uranium (Total mg/L)	1.00E-05	8.80E-05	0.00028	0.003424	0.004022	0.0139	0.005661	1.6531474	0.01291	12	0.015	0	0%	3	25%
Vanadium (Dissolved mg/L)	5.00E-04	0.001	0.00225	0.014246	0.01895	0.054	0.02097	1.4719983	0.04589	12			0%	5	42%
Vanadium (Total mg/L)	0.00054	0.001328	0.00385	0.014884	0.0188	0.051	0.020403	1.3707602	0.04817	12			0%	3	25%
Zinc (Dissolved mg/L)	0.005	0.012025	0.09855	0.267517	0.34775	1.49	0.423808	1.5842297	0.5267	12			0%	1	8%
Zinc (Total mg/L)	0.005	0.040825	0.135	0.30445	0.3975	1.52	0.43102	1.415733	0.5997	12	0.03	10	83%	2	17%

Appendix B4 - Kruskal-Wallis Rank Sum Test for seasonality (differences among months) for Municipal Data

Analyte	Statistic	p value	Degrees of Freedom
Acenaphthene	NaN	NaN	3
Acenaphthylene	NaN	NaN	3
Acridine	3	0.391625	3
Aldrin	NaN	NaN	3
Alkalinity (Total as CaCO3)	7.625887	0.266813	6
alpha BHC	NaN	NaN	3
alpha Chlordane	NaN	NaN	3
Aluminum (dissolved)	3	0.391625	3
Aluminum (total)	3	0.391625	3
Ammonia (Total as N)	50.09944	**6.01E-07**	11
Ammonia (Un-ionized as N - WSER)	18.47289	0.071237	11
Anthracene	NaN	NaN	3
Antimony (dissolved)	NaN	NaN	3
Antimony (total)	NaN	NaN	3
Arsenic (dissolved)	NaN	NaN	3
Arsenic (total)	NaN	NaN	3
Barium (dissolved)	3	0.391625	3
Barium (total)	3	0.391625	3
Benz(a)anthracene	NaN	NaN	3
Benzene (ug/L)	NaN	NaN	3
Benzo(a)pyrene	NaN	NaN	3
Benzo(b)fluoranthene	NaN	NaN	3
Benzo(g,h,i)perylene	NaN	NaN	3
Benzo(k)fluoranthene	NaN	NaN	3
Beryllium (dissolved)	NaN	NaN	3
Beryllium (total)	NaN	NaN	3
Bicarbonate (HCO3)	6.904255	0.329793	6
Bismuth (dissolved)	NaN	NaN	3
Bismuth (total)	NaN	NaN	3
BOD Carbonaceous	68.2754	**2.60E-10**	11
Boron (dissolved)	3	0.391625	3
Boron (total)	3	0.391625	3
Bromodichloromethane	NaN	NaN	3
Bromoform	NaN	NaN	3
Cadmium (dissolved)	NaN	NaN	3
Cadmium (total)	NaN	NaN	3
Calcium (dissolved)	9.643382	0.290953	8
Calcium (total)	3	0.391625	3
Calculated Un-ionized Ammonia	1.5	0.220671	1
Carbontetrachloride	3	0.391625	3
Carbonate (CO3)	2	0.919699	6
F1 (C6-C10)	NaN	NaN	3
F2 (C10-C16)	NaN	NaN	2
F3 (C16-C34)	2	0.367879	2
Chemical Oxygen Demand	8.454545	0.294222	7
Chloride	10.35833	0.11035	6

Analyte	Statistic	p value	Degrees of Freedom
Chlorine (Total)	10.889	0.452609	11
Chlorobenzene	NaN	NaN	3
Chloroform	3	0.391625	3
Chromium (dissolved)	NaN	NaN	3
Chromium (dissolved Hexavalent)	NaN	NaN	3
Chromium (dissolved Trivalent)	NaN	NaN	3
Chromium (Hexavalent)	NaN	NaN	3
Chromium (Total)	NaN	NaN	3
Chromium (Trivalent)	NaN	NaN	3
Chrysene	NaN	NaN	3
Cobalt (dissolved)	NaN	NaN	3
Cobalt (total)	NaN	NaN	3
Conductivity (EC)	7.731954	0.258406	6
Copper (dissolved)	NaN	NaN	3
Copper (total)	3	0.391625	3
Cyanide (Free)	4.5	0.609339	6
DeBDE	1	0.317311	1
Dibenz(a,h)anthracene	NaN	NaN	3
Dibromochloromethane	NaN	NaN	3
Dieldrin	NaN	NaN	3
Endosulfan I	NaN	NaN	3
Endosulfan II	NaN	NaN	3
Endrin	3	0.391625	3
EPHw10 19	NaN	NaN	2
EPHw19 32	2	0.367879	2
Fluoranthene	NaN	NaN	3
Fluorene	NaN	NaN	3
Fluoride	9.556751	0.297523	8
gamma BHC Lindane	NaN	NaN	3
gamma Chlordane	NaN	NaN	3
Hardness (Total as CaCO3)	9.75	0.283013	8
Heptachlor	NaN	NaN	3
Heptachlor.epoxide	NaN	NaN	3
Hydroxide (OH)	NaN	NaN	6
Indeno[1,2,3-cd]pyrene	NaN	NaN	3
Ion Balance	7.794894	0.253518	6
Iron (dissolved)	3.66311	0.722157	6
Iron (total)	3	0.391625	3
Lead (dissolved)	NaN	NaN	3
Lead (total)	NaN	NaN	3
Lithium (dissolved)	NaN	NaN	3
Lithium (total)	NaN	NaN	3
m,p-Xylene	NaN	NaN	3
Magnesium (dissolved)	9.275	0.319631	8
Magnesium (total)	3	0.391625	3
Manganese (dissolved)	4.77439	0.573058	6

Appendix B4 - Kruskal-Wallis Rank Sum Test for seasonality (differences among months) for Municipal Data

Analyte	Statistic	p value	Degrees of Freedom
Manganese (total)	3	0.391625	3
Mercury (dissolved)	NaN	NaN	3
Mercury (total)	7	0.320847	6
Methoxychlor	NaN	NaN	3
Methyl Mercury (Total)	NaN	NaN	1
Methylene chloride	NaN	NaN	3
Mirex	NaN	NaN	2
Molybdenum (dissolved)	NaN	NaN	3
Molybdenum (total)	NaN	NaN	3
E.Coli	3	0.391625	3
Fecal Coliforms	20.39791	**0.040173**	11
Total Coliforms	4.428571	0.218751	3
Naphthalene	NaN	NaN	3
Nickel (dissolved)	3	0.391625	3
Nickel (total)	NaN	NaN	3
Nitrate (as N)	12.66604	0.123868	8
Nitrate+Nitrite (as N)	13.05037	0.110128	8
Nitrite (as N)	11.44619	0.177676	8
o-Xylene	NaN	NaN	3
Orthophosphate (dissolved as P)	n.t.	n.t.	n.t.
Dissolved Oxygen	63.90126	**1.73E-09**	11
p.p.DDT	NaN	NaN	3
PCB1016	3	0.391625	3
PCB1221	3	0.391625	3
PCB1232	3	0.391625	3
PCB1242	3	0.391625	3
PCB1248	3	0.391625	3
PCB1254	3	0.391625	3
PCB1260	3	0.391625	3
PCB1262	n.t.	n.t.	n.t.
PCB1268	n.t.	n.t.	n.t.
Pentachlorophenol	NaN	NaN	3
Perfluoro.n.Octanoic.Acid..PFOA.	2	0.367879	2
Perfluorobutane.Sulfonate..PFBS.	2	0.367879	2
Perfluorobutanoic.acid	2	0.367879	2
Perfluorodecane.Sulfonate	2	0.367879	2
Perfluorodecanoic.Acid..PFDA.	2	0.367879	2
Perfluorododecanoic.Acid..PFDoA.	2	0.367879	2
Perfluoroheptane.sulfonate	2	0.367879	2
Perfluoroheptanoic.Acid..PFHpA.	2	0.367879	2
Perfluorohexane.Sulfonate..PFHxS.	2	0.367879	2
Perfluorohexanoic.Acid..PFHxA.	NaN	NaN	2
Perfluorononanoic.Acid..PFNA.	2	0.367879	2
Perfluorooctane.Sulfonamide..PFOSA.	2	0.367879	2
Perfluorooctane.Sulfonate..PFOS.	2	0.367879	2
Perfluoropentanoic.Acid..PFPeA.	2	0.367879	2

Appendix B4 - Kruskal-Wallis Rank Sum Test for seasonality (differences among months) for Municipal Data

Analyte	Statistic	p value	Degrees of Freedom
Perfluorotetradecanoic.Acid	2	0.367879	2
Perfluorotridecanoic.Acid	2	0.367879	2
Perfluoroundecanoic.Acid..PFUnA.	2	0.367879	2
pH	29.28849	**0.002047**	11
pH field measurement	1.5	0.220671	1
pH at 15C WSER	4.541667	0.337635	4
Phenanthrene	NaN	NaN	3
Phosphorus (dissolved)	20.17403	**0.04301**	11
Phosphorus (total)	69.07027	**1.83E-10**	11
Potassium (dissolved)	10.26627	0.246832	8
Potassium (total)	3	0.391625	3
Pyrene	3	0.391625	3
Quinoline	3	0.391625	3
Selenium (dissolved)	NaN	NaN	3
Selenium (total)	NaN	NaN	3
Silicon (dissolved)	3	0.391625	3
Silicon (total)	3	0.391625	3
Silver (dissolved)	NaN	NaN	3
Silver (total)	NaN	NaN	3
Sodium (dissolved)	10.83088	0.211467	8
Sodium (total)	3	0.391625	3
Strontium (dissolved)	3	0.391625	3
Strontium (total)	3	0.391625	3
Sulfate	9.230769	0.16101	6
Sulfur (dissolved)	3	0.391625	3
Sulfur (total)	3	0.391625	3
Surfactants	n.t.	n.t.	n.t.
Surfactants..as.MBAS.	3	0.391625	3
TDS Calculated	10.13462	0.119096	6
Tellurium (dissolved)	NaN	NaN	3
Tellurium (total)	NaN	NaN	3
Temperature	17.87368	0.084558	11
Temperature(field measurement)	61.43003	**5.02E-09**	11
Tetrachloroethene	NaN	NaN	3
Thallium (dissolved)	NaN	NaN	3
Thallium (total)	NaN	NaN	3
Thorium (dissolved)	NaN	NaN	3
Thorium (total)	NaN	NaN	3
Tin (dissolved)	NaN	NaN	3
Tin (total)	NaN	NaN	3
Titanium (dissolved)	NaN	NaN	3
Titanium (total)	NaN	NaN	3
Toluene (ug/L)	NaN	NaN	3
Total Chlorinated Phenols (mono.penta)	NaN	NaN	3
Total.Extractable.Hydrocarbons..TEH.	3	0.391625	3
Total Kjeldahl Nitrogen	15.92083	0.144096	11

Analyte	Statistic	p value	Degrees of Freedom
Total Nitrogen	1.655462	0.798791	4
Total PCBs	3	0.391625	3
Total Suspended Solids	35.67037	**1.92E-04**	11
Toxaphene	NaN	NaN	3
Trichloroethene	NaN	NaN	3
Turbidity	4.857143	0.302272	4
Uranium (dissolved)	NaN	NaN	3
Uranium (total)	NaN	NaN	3
Vanadium (dissolved)	NaN	NaN	3
Vanadium (total)	NaN	NaN	3
Vinyl chloride	3	0.391625	3
X1.1.1.2.Tetrachloroethane	NaN	NaN	3
X1.1.2.2.Tetrachloroethane	3	0.391625	3
X1.1.Dichloroethene	NaN	NaN	3
X1.2.Dichlorobenzene	NaN	NaN	3
X1.2.Dichloroethane	NaN	NaN	3
X1.4.Dichlorobenzene	NaN	NaN	3
X1.Methylnaphthalene	3	0.391625	3
X2.2..3.3..4.4..5.5..6.NoBDE	n.t.	n.t.	n.t.
X2.2..3.3..4.4..5.6.6..NoBDE	n.t.	n.t.	n.t.
X2.2..3.3..4.4..6.6..OcBDE	n.t.	n.t.	n.t.
X2.2..3.3..4.5..6.6..OcBDE	n.t.	n.t.	n.t.
X2.2..3.3..4.5.5..6.6..NoBDE	n.t.	n.t.	n.t.
X2.2..3.4.4..5..6.HpBDE	1	0.317311	1
X2.2..3.4.4..5..HxBDE	n.t.	n.t.	n.t.
X2.2..3.4.4..5.5..6.OcBDE	n.t.	n.t.	n.t.
X2.2..3.4.4..6.HxBDE	n.t.	n.t.	n.t.
X2.2..3.4.4..PeBDE	1	0.317311	1
X2.2..4.4..5.5..HxBDE	1	0.317311	1
X2.2..4.4..5.6..HxBDE	1	0.317311	1
X2.2..4.4..5.PeBDE	2	0.367879	2
X2.2..4.4..6.PeBDE	1	0.317311	1
X2.2..4.4..TeBDE	2	0.367879	2
X2.2..4.5..TeBDE	1	0.317311	1
X2.2..4.TrBDE	1	0.317311	1
X2.3..4.4..TeBDE	1	0.317311	1
X2.3.4.5...2.3.5.6.Tetrachlorophenol	NaN	NaN	3
X2.3.4.6.Tetrachlorophenol	NaN	NaN	3
X2.3.4.Trichlorophenol	NaN	NaN	3
X2.3.5.Trichlorophenol	NaN	NaN	3
X2.3.6.Trichlorophenol	NaN	NaN	3
X2.3.Dichlorophenol	NaN	NaN	3
X2.4...2.5.Dichlorophenol	NaN	NaN	3
X2.4.4..TrBDE	2	0.367879	2
X2.4.5.Trichlorophenol	NaN	NaN	3
X2.4.6.Trichlorophenol	NaN	NaN	3

Analyte	Statistic	p value	Degrees of Freedom
X2.6.Dichlorophenol	NaN	NaN	3
X2.Chlorophenol	NaN	NaN	3
X2.Methylnaphthalene	3	0.391625	3
X3...4.Chlorophenol	NaN	NaN	3
X3.4.5.Trichlorophenol	NaN	NaN	3
X3.4.Dichlorophenol	NaN	NaN	3
X3.5.Dichlorophenol	NaN	NaN	3
X4.4..DiBDE	2	0.367879	2
Xylenes (total)	NaN	NaN	3
Zinc (dissolved)	3	0.391625	3
Zinc (total)	3	0.391625	3
Zirconium (dissolved)	NaN	NaN	3
Zirconium (total)	NaN	NaN	3

NaN = no result due to too many ties (likely caused by censored data)

n.t. = not tested because only data from one month were available

p<0.05

Appendix B5 - Kruskal-Wallis Rank Sum Test for seasonality (differences among months) for Coal Data

Analyte	Statistic	p value	Degrees of freedom
Alkalinity (Total as CaCO3)	1.846154	0.174231	1
Aluminium	6.325867	0.502256	7
Aluminium (Filtered)	0	1	1
Ammonia (as N)	27.10044	**3.20E-04**	7
Antimony	17.7188	**0.013305**	7
Antimony (Filtered)	0.561458	0.453673	1
Arsenic	8.805189	0.266947	7
Arsenic (Filtered)	0.041667	0.838256	1
Barium	6.189641	0.517789	7
Barium (Filtered)	3.375	0.066193	1
Benzene	NaN	NaN	7
Beryllium	22.67206	**0.001944**	7
Beryllium (Filtered)	0.420918	0.516479	1
Bicarbonate	2.336538	0.12637	1
Biochemical Oxygen Demand	14.8435	**0.038059**	7
Bismuth	23.69803	**0.001287**	7
Bismuth (Filtered)	n.t.	n.t.	n.t.
Carbonaceous BOD	n.t.	n.t.	n.t.
Boron	15.74563	**0.027545**	7
Boron (Filtered)	1.5	0.220671	1
Cadmium	14.28248	**0.046379**	7
Cadmium (Filtered)	2.678843	0.10169	1
Calcium	5.688994	0.576496	7
Calcium (Filtered)	4.952185	0.665798	7
Carbonate	1.291304	0.255808	1
Cesium	5.19576	0.636087	7
Cesium (Filtered)	n.t.	n.t.	n.t.
Chloride	0.029359	0.863952	1
Chromium	10.90794	0.142685	7
Chromium (Filtered)	0.010512	0.918337	1
Chromium (hexavalent)	30	**9.50E-05**	7
Chromium (Trivalent)	11.2928	0.126347	7
Cobalt	15.63501	**0.028668**	7
Cobalt (Filtered)	0.094178	0.758931	1
Colour	9.106278	0.245116	7
Converted TSS	244.5661	**3.97E-49**	7
Copper	15.9067	**0.025983**	7
Copper (Filtered)	1.041667	0.307434	1
Cyanide (weak acid dissociable)	28.075	**2.13E-04**	7
Dissolved Oxygen	33.58559	**2.06E-05**	7
Electrical Conductivity	2.884615	0.089429	1
Ethylbenzene	NaN	NaN	7
F1	NaN	NaN	7
F1 BTEX	NaN	NaN	7
F2	NaN	NaN	7
F3	NaN	NaN	7

Appendix B5 - Kruskal-Wallis Rank Sum Test for seasonality (differences among months) for Coal Data

Analyte	Statistic	p value	Degrees of freedom
F4	NaN	NaN	7
Flow	98.42713	**2.28E-18**	7
Fluoride	0.461538	0.496906	1
Freeboard	9.890584	0.194859	7
Hardness (as CaCO3)	5.648248	0.581368	7
Hydroxide	NaN	NaN	1
Ionic Balance	0.262367	0.608498	1
Iron	10.57134	0.158441	7
Iron (Filtered)	0.094178	0.758931	1
Lead	5.886601	0.553051	7
Lead (Filtered)	0.042636	0.836413	1
Lithium	18.98363	**0.008239**	7
Lithium (Filtered)	0.333333	0.563703	1
Magnesium	6.197931	0.516838	7
Magnesium (Filtered)	5.879598	0.553876	7
Manganese	13.68624	0.057052	7
Manganese (Filtered)	0.166667	0.683091	1
Mercury	5.694774	0.575806	7
Mercury (Filtered)	n.t.	n.t.	n.t.
Molybdenum	14.43876	**0.043906**	7
Molybdenum (Filtered)	2.041667	0.153042	1
Nickel	7.714497	0.358441	7
Nickel (Filtered)	0.042438	0.836787	1
Nitrate + Nitrite (as N)	0.912611	0.339423	1
Nitrate(as N)	42.69249	**1.00E-06**	8
Nitrite (as N)	14.6178	**0.041223**	7
Oil and Grease	32	**4.06E-05**	7
pH	264.2906	**1.60E-52**	8
pH (lab)	11.652	0.112599	7
Phenols 4AAP	14.5	**0.04297**	7
Phosphorus	1.187329	0.991216	7
Phosphorus (by ICP)	25.9541	**5.13E-04**	7
Phosphorus (by ICP - Filtered)	n.t.	n.t.	n.t.
Potassium	15.57548	**0.029291**	7
Potassium (Filtered)	2.344737	0.125707	1
Rubidium	12.53093	0.084396	7
Rubidium (Filtered)	n.t.	n.t.	n.t.
Selenium	6.837418	0.446002	7
Selenium (Filtered)	1.506849	0.21962	1
Silicon	2.169198	0.949885	7
Silicon (Filtered)	n.t.	n.t.	n.t.
Silver	21.8376	**0.002709**	7
Silver (Filtered)	0.11395	0.735691	1
Sodium	15.78134	**0.027191**	7
Sodium (Filtered)	4.153846	**0.04154**	1
Strontium	21.88194	**0.002662**	7

Appendix B5 - Kruskal-Wallis Rank Sum Test for seasonality (differences among months) for Coal Data

Analyte	Statistic	p value	Degrees of freedom
Strontium (Filtered)	n.t.	n.t.	
Styrene	NaN	NaN	3
Sulphate	20.14612	**0.005263**	7
Sulphide	6.393008	0.49468	7
Sulphur (as S)	13.75884	0.055641	7
Sulphur (as S - Filtered)	n.t.	n.t.	n.t.
Tellurium	23.48998	**0.0014**	7
Tellurium (Filtered)	n.t.	n.t.	n.t.
Thallium	26.2748	**4.50E-04**	7
Thallium (Filtered)	0.381944	0.536564	1
Thorium	16.99421	**0.017434**	7
Thorium (Filtered)	n.t.	n.t.	n.t.
Tin	22.30143	**0.002254**	7
Tin (Filtered)	0.103125	0.748111	1
Titanium	5.201946	0.635334	7
Titanium (Filtered)	0.042636	0.836413	1
Toluene	NaN	NaN	7
Total Dissolved Solids	3.490385	0.061726	1
Total Dissolved Solids (Filtered)	18.07096	**0.011654**	7
Total Suspended Solids	90.66602	**9.03E-17**	7
Total Suspended Solids (average)	259.6738	**2.41E-52**	7
Total Suspended Solids(field lab)	211.5723	**2.32E-41**	8
Total Suspended Solids (monthly average)	6.117409	**0.013386**	1
Tungsten	20.27021	**0.005015**	7
Tungsten (Filtered)	n.t.	n.t.	n.t.
Turbidity	508.7852	**9.17E-105**	8
Uranium	13.90911	0.052822	7
Uranium (Filtered)	1.5	0.220671	1
Vanadium	14.3298	**0.045617**	7
Vanadium (Filtered)	0.916667	0.338352	1
Xylene(m p)	NaN	NaN	7
Xylene (o)	NaN	NaN	7
Xylenes Total	NaN	NaN	7
Zinc	18.54775	**0.009729**	7
Zinc (Filtered)	1.5	0.220671	1
Zirconium	11.82151	0.106583	7
Zirconium (Filtered)	n.t.	n.t.	n.t.

NaN = no result due to too many ties (likely caused by censored data)

n.t. = not tested because only data from one month were available

p<0.05

Appendix B6 - Kruskal-Wallis Rank Sum Test for seasonality (differences among months) for Pulp and Paper Mill Data

Analyte	Statistic	p value	Degrees of freedom
Alkalinity (as CaCO3 in mg/L)	2.5	0.113846	1
Aluminum(Dissolved mg/L)	0.184615	0.667436	1
Aluminum (Total mg/L)	0.046154	0.829896	1
Ammonia (mg/L)	0.184615	0.667436	1
Antimony (Dissolved mg/L)	4.765343	**0.029038**	1
Antimony (Total mg/L)	4.714286	**0.029913**	1
Arsenic (Total mg/L)	4.631579	**0.031389**	1
Arsenic (Dissolved mg/L)	4.631579	**0.031389**	1
Avg DO (mg/L)	839.7366	**5.54E-173**	11
Barium (Dissolved mg/L)	0.184615	0.667436	1
Barium (Total mg/L)	0.184615	0.667436	1
Beryllium (Total mg/L)	3.006406	0.082936	1
Bicarbonate (mg/L)	2.953846	0.085673	1
BOD (kg/d)	132.1952	**6.26E-23**	11
BOD (mg/L)	1.395231	0.237524	1
BOD (ppm)	119.6254	**2.16E-20**	11
Boron (mg/L)	0.427338	0.513298	1
Boron (Total mg/L)	0.427338	0.513298	1
Cadmium (Dissolved mg/L)	3.06087	0.080199	1
Cadmium (Total mg/L)	2.261538	0.132622	1
Calcium (mg/L)	n.t.	n.t.	n.t.
Calcium (Total mg/L)	1.661538	0.197396	1
Carbon Dissolved Inorganic (mg/L)	2.953846	0.085673	1
Carbon Dissolved Organic (mg/L)	1.661538	0.197396	1
Carbon Total Organic (mg/L)	1.333333	0.248213	1
Carbonate (mg/L)	0.229565	0.631846	1
Chloride (mg/L)	0.184615	0.667436	1
Chlorophyll_a (ug/L)	0.27439	0.600402	1
Chromium (Dissolved mg/L)	3.006406	0.082936	1
Chromium (Total mg/L)	3.791489	0.051514	1
Cobalt (Dissolved mg/L)	1.685106	0.194247	1
Cobalt (Total mg/L)	4.631579	**0.031389**	1
COD (kg/d)	56.49872	**4.11E-08**	11
COD (ppm)	40.85578	**2.55E-05**	11
COD Total	28.06853	**0.00316**	11
Colour (CU)	37.97105	**7.91E-05**	11
Colour (kg/d)	33.94169	**3.70E-04**	11
Conductivity (uS/cm)	1.6	0.205903	1
Copper (Dissolved mg/L)	2.953846	0.085673	1
Copper (Total mg/L)	4.615385	**0.031686**	1
Beryllium (Dissolved mg/L)	3.017143	0.082388	1
Dissolved Organic Nitrogen (mg/L)	n.t.	n.t.	n.t.
FixedSS (mg/L)	0.453435	0.500708	1
Flow (m3/day)	21.68607	**0.026921**	11
Hardness (mg/L)	0.046154	0.829896	1
Hydroxide (mg/L)	0.2	0.654721	1

Appendix B6 - Kruskal-Wallis Rank Sum Test for seasonality (differences among months) for Pulp and Paper Mill Data

Analyte	Statistic	p value	Degrees of freedom
Ion Balance	0	1	1
Iron (Dissolved mg/L)	n.t.	n.t.	n.t.
Iron (Total mg/L)	1.153846	0.282745	1
Lead (Dissolved mg/L)	1.728	0.188667	1
Lead (Total mg/L)	2.277465	0.131266	1
Lithium (Dissolved mg/L)	2.964211	0.085126	1
Lithium (Total mg/L)	2.277465	0.131266	1
Magnesium (mg/L)	n.t.	n.t.	n.t.
Magnesium (Total mg/L)	0.289474	0.590558	1
Manganese (Dissolved mg/L)	n.t.	n.t.	n.t.
Manganese (Total mg/L)	0.184615	0.667436	1
Max Conductivity	48.82752	**1.02E-06**	11
Mercury (Dissolved mg/L)	0.980198	0.32215	1
Mercury (Total mg/L)	1.773134	0.182995	1
Min Conductivity	676.7395	**5.21E-138**	11
Molybdenum (Dissolved mg/L)	3.105882	0.07801	1
Molybdenum (Total mg/L)	3.072	0.079651	1
Month	n.t.	n.t.	n.t.
Nickel (Dissolved mg/L)	0.184615	0.667436	1
Nickel (Total mg/L)	2.261538	0.132622	1
Nitrate (mg/L)	n.t.	n.t.	n.t.
Nitrate+Nitrite (mg/L)	0.272727	0.601508	1
Nitrite (mg/L)	n.t.	n.t.	n.t.
Dissolved Kjeldahl Nitrogen (mg/L)	1.661538	0.197396	1
Total Nitrogen (mg/L)	1.153846	0.282745	1
Total Dissolved Nitrogen (mg/L)	n.t.	n.t.	n.t.
Total Kjeldahl Nitrogen (mg/L)	1.157895	0.281903	1
pH	0.90411	0.341682	1
pH Max	80.03362	**1.45E-12**	11
pH Min	124.8406	**1.92E-21**	11
Ortho-Phosphate (Dissolved mg/L)	n.t.	n.t.	n.t.
Phosphorus (Total mg/L)	0.738462	0.390154	1
Total Dissolved Phosphorus (mg/L)	0	1	1
Potassium (mg/L)	n.t.	n.t.	n.t.
Potassium (Total mg/L)	1.153846	0.282745	1
Selenium (Dissolved mg/L)	3.06087	0.080199	1
Selenium (Total mg/L)	2.293617	0.129907	1
Silver (Dissolved mg/L)	5.038168	**0.024795**	1
Silver (Total mg/L)	4.962406	**0.025904**	1
Sodium (mg/L)	n.t.	n.t.	n.t.
Sodium (Total mg/L)	1.153846	0.282745	1
Sulphate (mg/L)	0.741053	0.389324	1
Sulphide (mg/L)	0.738462	0.390154	1
TDS Calculated (mg/L)	2.5	0.113846	1
Temp (C)	3497.755	**0**	11
Thallium (Dissolved mg/L)	2.801887	0.094153	1

Appendix B6 - Kruskal-Wallis Rank Sum Test for seasonality (differences among months) for Pulp and Paper Mill Data

Analyte	Statistic	p value	Degrees of freedom
Thallium (Total mg/L)	2.352	0.125122	1
Tin (Dissolved mg/L)	3.117343	0.077463	1
Tin (Total mg/L)	3.072	0.079651	1
Titanium (Total mg/L)	2.261538	0.132622	1
Titanium (Dissolved mg/L)	1.667368	0.196611	1
TotalSS (mg/L)	1.153846	0.282745	1
TSS (kg/d)	142.1396	**5.98E-25**	11
TSS (ppm)	307.5277	**2.27E-59**	11
Turbidity (NTU)	2	0.157299	1
Uranium (Dissolved mg/L)	4.647887	**0.031092**	1
Uranium (Total mg/L)	4.615385	**0.031686**	1
Vanadium (Dissolved mg/L)	3.791489	0.051514	1
Vanadium (Total mg/L)	3.751579	0.052758	1
Zinc (Dissolved mg/L)	2.261538	0.132622	1
Zinc (Total mg/L)	1.661538	0.197396	1

n.t. = not tested because only data from one month were available

p<0.05

Appendix C - Monthly Boxplots

electronic appendix

Appendix D - Summary of Literature Review

electronic appendix

Appendix E - Results of River Impact Analysis

Variable	median US	median EFF	Eff/US
Alkalinity..T..as.CaCO3	NA	378	NA
Aluminium	0.037	0.2265	6.1
Aluminium..Filtered.	NA	0.0132	NA
Ammonia.as.N	0.05	0.05	1
Antimony	1.00E-04	5.00E-04	5.0
Antimony..Filtered.	NA	0.00033	NA
Arsenic	0.00053	0.000845	1.6
Arsenic..Filtered.	NA	5.00E-04	NA
Barium	0.0538	0.125	2.3
Barium..Filtered.	NA	0.153	NA
Benzene	5.00E-04	5.00E-04	1
Beryllium	1.00E-04	0.00016	1.6
Beryllium..Filtered.	NA	0.00012	NA
Bicarbonate	NA	444.5	NA
Biochemical.Oxygen.Demand	2	2	1
Bismuth	5.00E-05	7.50E-05	1.5
Bismuth..Filtered.	NA	5.00E-05	NA
BOD.Carbonaceous	NA	2	NA
Boron	0.01	0.0765	7.7
Boron..Filtered.	NA	0.079	NA
Cadmium	NA	2.50E-05	NA
Cadmium..Filtered.	NA	2.71E-05	NA
Calcium	14.8	41.35	2.8
Calcium..Filtered.	13.9	41	2.9
Carbonate	NA	5	NA
Cesium	NA	1.00E-04	NA
Cesium..Filtered.	NA	4.60E-05	NA
Chloride	NA	2.21	NA
Chromium	4.00E-04	5.00E-04	1.3
Chromium..Filtered.	NA	0.00021	NA
Chromium..hexavalent.	5.00E-04	5.00E-04	1
Chromium..Trivalent.	4.00E-04	5.00E-04	1.3
Cobalt	1.00E-04	0.000445	4.5
Cobalt..Filtered.	NA	0.00025	NA
Colour	31.5	12.2	0.387302
Converted.TSS	NA	8	NA
Copper	NA	0.002175	NA
Copper..Filtered.	NA	0.0011	NA
Cyanide..WAD.	0.002	0.002	1
Dissolved.Oxygen	NA	8	NA
Electrical.Conductivity..lab.	NA	755.5	NA
Ethylbenzene	5.00E-04	5.00E-04	1
F1	0.1	0.1	1
F1.BTEX	0.1	0.1	1
F2	0.1	0.1	1
F3	0.25	0.25	1

Variable	median US	median EFF	Eff/US
F4	0.25	0.25	1
Flow	NA	6.912	NA
Fluoride	NA	0.11	NA
Freeboard	NA	1.5	NA
Hardness.as.CaCO3	44.7	131	2.9
Hydroxide	NA	5	NA
Ionic.Balance	NA	104.5	NA
Iron	NA	0.1815	NA
Iron..Filtered.	NA	0.149	NA
Lead	5.90E-05	0.00025	4.2
Lead..Filtered.	NA	0.000154	NA
Lithium	NA	0.01245	NA
Lithium..Filtered.	NA	0.0144	NA
Magnesium	2.47	8.5	3.4
Magnesium..Filtered.	2.44	8.03	3.3
Manganese	0.015	0.0507	3.4
Manganese..Filtered.	NA	0.0757	NA
Mercury	NA	5.00E-06	NA
Mercury..Filtered.	NA	5.20E-06	NA
Molybdenum	NA	0.019	NA
Molybdenum..Filtered.	NA	0.00188	NA
Nickel	5.00E-04	0.0025	5.0
Nickel..Filtered.	NA	0.0025	NA
Nitrate...Nitrite.N	NA	0.022	NA
Nitrate..as.N.	NA	0.054	NA
Nitrite..as.N.	NA	0.01	NA
Oil.and.Grease	1	1	1
pH	NA	8.2	NA
pH..Lab.	NA	8.255	NA
Phenols..4AAP.	0.001	0.001	1
Phosphorus	0.02	0.022	1.1
Phosphorus.by.ICP	NA	0.0945	NA
Phosphorus.by.ICP..Filtered.	NA	0.0835	NA
Potassium	0.5	3.65	7.3
Potassium...Filtered.	NA	2.185	NA
Rubidium	NA	0.006175	NA
Rubidium..Filtered.	NA	0.00167	NA
Selenium	NA	0.002265	NA
Selenium..Filtered.	NA	0.000115	NA
Silicon	NA	2.785	NA
Silicon..Filtered.	NA	3.81	NA
Silver	1.00E-05	1.95E-05	2.0
Silver..Filtered.	NA	1.00E-05	NA
Sodium	6.2	112	18.1
Sodium...Filtered.	NA	91.7	NA
Strontium	0.145	0.61	4.2

Variable	median US	median EFF	Eff/US
Strontium..Filtered.	NA	0.4505	NA
Styrene	NA	0.001	NA
Sulphate	3.06	102	33.3
Sulphide	NA	0.0015	NA
Sulphur.as.S	NA	55.05	NA
Sulphur.as.S..Filtered.	NA	6.94	NA
Tellurium	NA	0.000425	NA
Tellurium..Filtered.	NA	2.00E-04	NA
Thallium	1.00E-05	2.75E-05	2.8
Thallium..Filtered.	NA	5.00E-05	NA
Thorium	NA	0.000355	NA
Thorium..Filtered.	NA	1.00E-04	NA
Tin	1.00E-04	0.000185	1.9
Tin..Filtered.	NA	0.00026	NA
Titanium	0.00053	0.00224	4.2
Titanium..Filtered.	NA	0.00118	NA
Toluene	5.00E-04	5.00E-04	1
Total.Dissolved.Solids	NA	469.5	NA
Total.Dissolved.Solids..Filtered.	90	453	5.0
Total.Suspended.Solids	NA	5.3	NA
Tungsten	NA	5.00E-04	NA
Tungsten..Filtered.	NA	0.00019	NA
Turbidity	NA	6.82	NA
Uranium	NA	0.0064	NA
Uranium..Filtered.	NA	0.00119	NA
Vanadium	5.00E-04	0.001635	3.3
Vanadium..Filtered.	NA	5.00E-04	NA
Xylene..m...p.	5.00E-04	5.00E-04	1
Xylene..o.	5.00E-04	5.00E-04	1
Xylenes.Total	0.00071	0.00071	1
Zinc	0.003	0.0101	3.4
Zinc..Filtered.	NA	0.0041	NA
Zirconium	NA	3.00E-04	NA
Zirconium..Filtered.	NA	3.00E-04	NA

Variable	MedianUS	MedianEFF	EFF/US
Alkalinity.CaCO3..mg.L.	118.5	311	2.6
Aluminum.Dissolved..mg.L	0.0109	0.0475	4.4
Aluminum.Total..mg.L.	0.149	0.1165	0.8
Ammonia..mg.L.	0.005	0.08115	16
Antimony.Dissolved.mg.L.	1.00E-04	4.00E-04	4.0
Antimony.Total..mg.L.	0.00011	0.00045	4.1
Arsenic.Total..mg.L.	0.00042	0.00116	2.8
Arsenic.Total.mg.L.	4.00E-04	0.00109	2.7
Barium.Dissolved..mg.L.	0.06		0.0
Barium.Total..mg.L.	0.0638	0.2565	4.0
Beryllium.Total..mg.L.	5.00E-04	0.2715	543
Bicarbonate..mg.L.	146	0.001	0.0
BOD..mg.L.	2	1375	688
Boron.Boron..mg.L.	0.024	0.075	3.1
Boron.Total..mg.L.	0.019	0.09	4.7
Cadmium.Dissolved..mg.L.	5.00E-05	0.000162	3.2
Cadmium.Total..mg.L.	5.00E-05	0.000516	10.3
Calcium..mg.L.	43.3	37.6	0.9
Calcium.Total..mg.L.	41.2	74.05	1.8
Carbon.Dissolved.Inorgani	25.8	67.25	2.6
Carbon.Dissolved.Organic.	4.065	131.95	32
Carbon.Total.Organic..mg.	4.42	248	56
Carbonate..mg.L.	5	5	1.0
Chloride..mg.L.	1.85	27.9	15
Chlorophyll_a..ug.L.	1.56	4	2.6
Chromium.Dissolved..mg.L	0.005	0.005	1.0
Chromium.Total..mg.L.	0.00131	0.005	3.8
Cobalt.Dissolved..mg.L.	1.00E-04	0.002	20
Cobalt.Total..mg.L.	0.00059	0.002	3.4
Conductivity..uS.cm.	309	2240	7.2
Copper.Dissolved..mg.L.	0.00081	0.00565	7.0
Copper.Total..mg.L.	0.001	0.0059	5.9
DissBeryllium.mg.L.	5.00E-04	0.001	2.0
Dissolved.Organic.Nitroger	0.0755	1.6565	22
FixedSS..mg.L.	9.6	10	1.0
Hardness..mg.L.	154	278	1.8
Hydroxide..mg.L.	5	5	1.0
Ion.Balance....	97.2	99.8	1.0
Iron.Dissolved..mg.L.	0.032	0.0965	3.0
Iron.Total..mg.L.	0.228	0.119	0.5
Lead.Dissolved..mg.L.	1.00E-04	0.000325	3.3
Lead.Total..mg.L.	0.00017	5.00E-04	2.9
Lithium.Dissolved..mg.L.	0.005	0.01065	2.1
Lithium.Total..mg.L.	0.01	0.0144	1.4
Magnesium..mg.L.	11.75	11.8	1.0
Magnesium.Total..mg.L.	12.6	16.65	1.3

Variable	MedianUS	MedianEFF	EFF/US
Manganese.Dissolved..mg	0.005	0.62	124
Manganese.Total..mg.L.	0.0116	0.456	39
Mercury.Dissolved..mg.L.	5.00E-05	5.00E-05	1.0
Mercury.Total..mg.L.	5.00E-05	5.00E-05	1.0
Molybdenum.Dissolved..m	0.000947	0.00216	2.3
Molybdenum.Total..mg.L.	0.00106	0.00235	2.2
Nickel.Dissolved..mg.L.	0.00139	0.0041	2.9
Nickel.Total..mg.L.	0.002	0.00455	2.3
Nitrate..mg.L.	0.01	0.102	10.2
Nitrate.Nitrite..mg.L.	0.006	0.0481	8.0
Nitrite..mg.L.	0.01	0.0372	3.7
Nitrogen.Dissolved.Kjeldah	0.14	2.715	19
Nitrogen.Total..mg.L.	0.18	5.23	29
Nitrogen.Total.Dissolved..r	0.136	2.17	16
Nitrogen.Total.Kjeldahl..m	0.178	5.075	29
pH	8.2	8.29	1.0
Phosphate.Ortho.Dissolved	0.001	1.3465	1347
Phosphorus.Total..mg.L.	0.009	1.445	161
Phosphorus.Total.Dissolve	0.0033	1.349	409
Potassium..mg.L.	1.205	2.81	2.3
Potassium.Total..mg.L.	0.954	55.8	58
Selenium.Dissolved..mg.L.	4.00E-04	0.001	2.5
Selenium.Total..mg.L.	5.00E-04	0.001	2.0
Silver.Dissolved..mg.L.	1.00E-05	1.00E-04	10.0
Silver.Total..mg.L.	1.40E-05	1.00E-04	7.1
Sodium..mg.L.	8	13.6	1.7
Sodium.Total..mg.L.	6.94	719.5	104
Sulphate..mg.L.	36	603.5	17
Sulphide..mg.L.	0.002	0.0834	42
TDS.Calculated..mg.L.	187	1510	8.1
Thallium.Dissolved..mg.L.	1.00E-04	1.00E-04	1.0
Thallium.Total..mg.L.	1.00E-04	1.00E-04	1.0
Tin.Dissolved..mg.L.	0.00011	0.00155	14
Tin.Total..mg.L.	0.00015	0.00125	8.3
Titanium.Total..mg.L.	0.003	0.0055	1.8
Titanium.Total..mg.L..1	0.001	0.0023	2.3
TotalSS..mg.L.	8.5	39.5	4.6
Turb..NTU.	5.49	17.2	3.1
Uranium.Dissolved..mg.L.	0.000495	3.00E-04	0.6
Uranium.Total..mg.L.	0.000517	0.00028	0.5
Vanadium.Dissolved..mg.L	0.001	0.00225	2.3
Vanadium.Total..mg.L.	0.001	0.00385	3.9
Zinc.Dissolved..mg.L.	0.0021	0.09855	47
Zinc.Total..mg.L.	0.004	0.135	34

Appendix F - Ranking of Potential Variables of Concern

Parameter	coal	P&P	Mun	Avg Guideline	coal	P&P	mun	Avg Lit Review	coal	P&P	mun	Avg River Impact	Average all criteria	Avg Coal	Avg PPM	Avg Mun	Uncertainty score (# n.d.)
TP	n.d.	n.d.	n.d.	n.d.	1	3	3	2.3	1	3	n.d.	2	2.2	1.0	3	3	5
TN	n.d.	n.d.	n.d.	n.d.	1	2	3	2.0	n.d.	3	n.d.	3	2.2	1	2.5	3	5
TSS/turbidity	2	3	1	2	2	0	3	1.7	n.d.	1	n.d.	1	1.7	2	1.3	2	2
cBOD	0	2	1	1	0	3	3	2.0	n.d.	3	n.d.	3	1.7	0	2.7	2	2
dissolved oxygen	1	n.d.	3	2	0	3	1	1.3	n.d.	n.d.	n.d.	n.d.	1.6	0.5	3	2	4
Se T	3	2	0	1.7	3	0	2	1.7	n.d.	1	n.d.	1	1.6	3.0	1	1	2
Zn T	0	3	2	1.7	1	0	2	1.0	1	3	n.d.	2	1.5	0.7	2	2	1
Cd T	1	3	0	1.3	0	0	2	0.7	n.d.	3	n.d.	3	1.2	0.5	2	1	2
nitrate	1	2	1	1.3	0	0	2	0.7	n.d.	3	n.d.	3	1.2	0.5	1.7	1.5	2
fecal coliforms	n.d.	n.d.	3	3	0	0	1	0.3	n.d.	n.d.	n.d.	n.d.	1.2	0	0	2	5
nitrite	1	2	2	1.7	0	0	2	0.7	n.d.	1	n.d.	1	1.1	0.5	1	2	2
conductivity/ions	n.d.	n.d.	n.d.	n.d.	0	1	1	0.7	n.d.	3	n.d.	3	1.1	0	2	1	5
sulfate	0	3	0	1.0	0	0	1	0.3	3	3	n.d.	3	1.1	1	2	0.5	1
ammonia	0	0	3	1	0	0	3	1.0	0	3	n.d.	1.5	1.1	0	1	3	1
ortho-P	0	0	0	0	1	2	2	1.7	n.d.	3	n.d.	3	1.1	0.5	1.7	1	2
TDP	0	0	0	0	1	2	2	1.7	n.d.	3	n.d.	3	1.1	0.5	1.7	1	2
sulfide	1	3	0	1.3	0	0	1	0.3	n.d.	3	n.d.	3	1.1	0.5	2	0.5	2
phenolic compounds	n.d.	n.d.	n.d.	n.d.	0	2	1	1.0	n.d.	n.d.	n.d.	n.d.	1.0	0	2	1	6
Co T	1	3	0	1.3	0	0	2	0.7	1	1	n.d.	1	1.0	0.7	1.3	1	1
Fe D	2	0	2	1.3	0	0	2	0.7	n.d.	1	n.d.	1	1.0	1.0	0.3	2	2
Al D	2	2	0	1.3	0	0	1	0.3	2	1	n.d.	1.5	1.0	1.3	1	0.5	1
Hg T	1	1	1	1.0	1	0	2	1.0	n.d.	0	n.d.	0	0.9	1.0	0.333	1.5	2
cyanide	1	n.d.	2	1.5	0	0	1	0.3	n.d.	n.d.	n.d.	n.d.	0.8	0.5	0	1.5	4
chloride	0	1	0	0.3	0	2	0	0.7	n.d.	3	n.d.	3	0.8	0	2	0	2
TKN	0	0	0	0	1	0	2	1.0	n.d.	3	n.d.	3	0.8	0.5	1.0	1	2
Na	0	0	0	0	0	1	1	0.7	2	3	n.d.	2.5	0.8	0.7	1.3	0.5	1
K	0	0	0	0	0	1	1	0.7	2	3	n.d.	2.5	0.8	0.7	1.3	0.5	1
B T	0	2	0	0.7	0	0	1	0.3	2	1	n.d.	1.5	0.7	0.7	1	0.5	1
Ag T	0	1	0	0.3	0	0	2	0.7	1	2	n.d.	1.5	0.7	0.3	1	1	1
PAHs total	n.d.	n.d.	*	n.d.	1	0	1	0.7	n.d.	n.d.	n.d.	n.d.	0.7	1	0	1	6

Appendix F - Ranking of Potential Variables of Concern

Parameter	coal	P&P	Mun	Avg Guideline	coal	P&P	mun	Avg Lit Review	coal	P&P	mun	Avg River Impact	Average all criteria	Avg Coal	Avg PPM	Avg Mun	Uncertainty score (# n.d.)
As T	0	1	0	0.3	1	0	1	0.7	1	1	n.d.	1	0.6	0.7	0.7	0.5	1
Pb T	0	0	0	0	1	0	2	1.0	1	1	n.d.	1	0.6	0.7	0.3	1	1
naphthalene	n.d.	0	1	0.5	1	0	1	0.7	n.d.	n.d.	n.d.	n.d.	0.6	1	0	1	4
phenanthrene	n.d.	0	1	0.5	1	0	1	0.7	n.d.	n.d.	n.d.	n.d.	0.6	1	0	1	4
pyrene	n.d.	0	1	0.5	1	0	1	0.7	n.d.	n.d.	n.d.	n.d.	0.6	1	0	1	4
Mn T	0	0	0	0	0	0	1	0.3	1	3	n.d.	2	0.5	0.3	1.0	0.5	1
colour	n.d.	n.d.	n.d.	n.d.	0	2	0	0.7	0	n.d.	n.d.	n.d.	0.5	0	2	0	5
Cu T	0	0	0	0	0	0	2	0.7	n.d.	2	n.d.	2	0.5	0.0	0.7	1	2
Cr T	0	n.d.	0	0	0	0	2	0.7	1	1	n.d.	1	0.5	0.3	0.5	1	2
Mn D	0	0	0	0	0	0	1	0.3	n.d.	3	n.d.	3	0.5	0	1.0	0.5	2
Zn D	0	0	0	0	0	0	1	0.3	n.d.	3	n.d.	3	0.5	0	1.0	0.5	2
Co D	0	0	0	0	0	0	1	0.3	n.d.	3	n.d.	3	0.5	0	1.0	0.5	2
Sn D	0	0	0	0	0	0	1	0.3	n.d.	3	n.d.	3	0.5	0	1.0	0.5	2
Mb T	1	0	0	0.3	0	0	1	0.3	n.d.	1	n.d.	1	0.4	0.5	0.3	0.5	2
anthracene	n.d.	1	0	0.5	0	0	1	0.3	n.d.	n.d.	n.d.	n.d.	0.4	0	0.5	0.5	4
Be T	0	0	0	0	0	0	0	0.0	1	3	n.d.	2	0.4	0.3	1.0	0	1
acenaphtene	n.d.	0	0	0	1	0	1	0.7	n.d.	n.d.	n.d.	n.d.	0.4	1	0	0.5	4
fluorene	n.d.	0	0	0	1	0	1	0.7	n.d.	n.d.	n.d.	n.d.	0.4	1	0	0.5	4
Tl T	0	1	0	0.3	0	0	1	0.3	1	0	n.d.	0.5	0.4	0.3	0.3	0.5	1
TOC	0	0	0	0	0	0	0	0.0	n.d.	3	n.d.	3	0.3	0	1.0	0	2
DOC	0	0	0	0	0	0	0	0.0	n.d.	3	n.d.	3	0.3	0	1.0	0	2
DON	0	0	0	0	0	0	0	0.0	n.d.	3	n.d.	3	0.3	0	1.0	0	2
DKN	0	0	0	0	0	0	0	0.0	n.d.	3	n.d.	3	0.3	0	1.0	0	2
TDN	0	0	0	0	0	0	0	0.0	n.d.	3	n.d.	3	0.3	0	1.0	0	2
V D	n.d.	n.d.	n.d.	n.d.	0	0	1	0.3	n.d.	n.d.	n.d.	n.d.	0.3	0	0	1	6
U T	1	0	0	0.3	0	0	1	0.3	n.d.	0	n.d.	0	0.3	0.5	0	0.5	2
toluene	n.d.	0	0	0	0	0	1	0.3	n.d.	n.d.	n.d.	n.d.	0.2	0	0	0.5	4
pH	0	0	0	0	0	0	1	0.3	n.d.	0	n.d.	0	0.1	0	0	0.5	2

n.d. = no data

Appendix G - Wastewater Monitoring Requirements for Coal Mines in the Upper Athabasca Region

Mine	Parameters Measured	Sample type	Where sampled	Frequency of sampling	Frequency of reporting
Cheviot- major ponds	Flow	Weir	Ponds using floc	Daily in summer, weekly in winter	Monthly & annually
	TSS	Grab	All ponds	weekly when turbidity >50NTU	Monthly & annually
	Turbidity, pH	Grab	All ponds	3.5/week in summer, weekly in winter	Monthly & annually
	Nitrate-N	Grab	All ponds and MR1,2,3	bi-weekly	Monthly & annually
	Floating solids, visible foam, oil or other substances	visual	All ponds	daily	Monthly & annually
	96h acute lethality test (trout), 48h acute lethality test	grab	Ponds using floc	Twice/yr (June/July and Sept/Oct)	Monthly & annually
Cheviot - minor ponds	TSS, pH	grab	Ponds using floc	weekly	Monthly & annually
	Nitrate-N	Grab	Ponds using floc	monthly	Monthly & annually
	Floating solids, visible foam, oil or other substances	visual	N/A	weekly	Monthly & annually
Cheviot- underground mine discharge	TSS, pH, TDS, DO, sulfide, copper, iron, aluminum	Grab	Thornton Creek us and ds of discharge	monthly	Monthly & annually
Cheviot- deep well discharge	temp, pH, turbidity, DO, TSS, NO3, flow	grab	discharge point prior to mixing in receiving stream	weekly during the first 3 months release period and monthly thereafter during release	Monthly & annually
	total Se	grab	discharge point prior to mixing in receiving stream	monthly	Monthly & annually
	Major ions, TDS, pH, EC, T-alkalinity, dissolved trace metals	Grab	discharge point prior to mixing in receiving stream	twice/yr	Monthly & annually

Mine	Parameters Measured	Sample type	Where sampled	Frequency of sampling	Frequency of reporting
Cheviot (background)-	Inorganic parameters in CCME (2003), BOD, BTEX, colour, oil & grease, phenols, TP, sulfate, TDS, temp, total sulfide, selenium, hardness, TSS	grab	Cheviot ds, Thorton us, Thorton ds, Harris us, Harris ds, McLeod River us (MR1), McLeod River ds (MR2-7), Prospect us, Prospect ds, Whitehorse Creek	Quarterly (Jan or Feb, May or June, Sept or Oct plus one storm run-off event)	2016,2018, 2020(approval ends Oct 2020)
Coal Valley- major ponds	Flow	Weir	Ponds using floc	3/week in summer, weekly in winter	Monthly & annually
	turbidity	Grab	Pond perimeter/discharge stream	3/week in summer, weekly in winter	Monthly & annually
	pH	grab	Pond perimeter/discharge stream	3/week in summer, weekly in winter	Monthly & annually
	TSS	grab	Ponds using floc	weekly when turbidity >50NTU	Monthly & annually
	Nitrate-N	Grab	Pond perimeter/discharge stream	bi-weekly	Monthly & annually
	Floating solids, visible foam, oil or other substances	visual	Pond perimeter/discharge stream	daily	Monthly & annually
	96h acute lethality test (trout), 48h acute lethality test	grab	Ponds using floc	Twice/yr (June/July and Sept/Oct)	Monthly & annually
Coal Valley- minor ponds	TSS, pH	grab	Pond perimeter/discharge stream	weekly	Monthly & annually

Mine	Parameters Measured	Sample type	Where sampled	Frequency of sampling	Frequency of reporting
	Nitrate-N	Grab	Pond perimeter/discharge stream	monthly	Monthly & annually
	Floating solids, visible foam, oil or other substances	visual	N/A	weekly	Monthly & annually
Coal Valley (background) -	Inorganic parameters in CCME (2003), BOD, BTEX, colour, oil & grease, phenols, TP, sulfate, TDS, temp, total sulfide,	grab	pond perimeter/discharge stream	annually	Annually
Gregg River (reclamation stage)	TSS, pH, visible foam	grab	pond perimeter/discharge stream	monthly (and TSS also during storm events)	annual
	Se	grab	all end pit lakes	annually (Sept or Oct)	annual
	Se	grab	all receiving streams impacted by the mine	twice/year (May/June/July and Sept/Oct)	annual
Coalspur Vista - major ponds	Flow	Weir	Ponds using floc	3/week in summer, weekly in winter	Monthly & annually
	turbidity	Grab	Pond perimeter/discharge stream	3/week in summer, weekly in winter	Monthly & annually
	pH	grab	Pond perimeter/discharge stream	3/week in summer, weekly in winter	Monthly & annually
	TSS	grab	Ponds using floc	weekly when turbidity >50NTU	Monthly & annually
	Nitrate-N	Grab	Pond perimeter/discharge stream	bi-weekly	Monthly & annually
	Floating solids, visible foam, oil or other substances	visual	Pond perimeter/discharge stream	daily	Monthly & annually

Mine	Parameters Measured	Sample type	Where sampled	Frequency of sampling	Frequency of reporting
	96h acute lethality test (trout), 48h acute lethality test	grab	Ponds using floc	Twice/yr (June/July and Sept/Oct)	Monthly & annually
Coalspur Vista - minor ponds	TSS, pH	grab	Pond perimeter/discharge stream	weekly	Monthly & annually
	Nitrate-N	Grab	Pond perimeter/discharge stream	monthly	Monthly & annually
	Floating solids, visible foam, oil or other substances	visual	N/A	weekly	Monthly & annually
Coalspur Vista (background)	Inorganic parameters in CCME (2003), BOD, BTEX, colour, oil & grease, phenols, TP, sulfate, TDS, temp, total sulfide, selenium, hardness, TSS	Grab	McPherson Creek us, McPherson ds, McPherson tributary 2, McLeod River Trib 1, McLeod Trib 1A	Annual	Annual
Luscar - major ponds	Flow	Weir	Ponds using floc	Daily in summer, weekly in winter	Monthly & annually
	TSS	Grab	All ponds	weekly when turbidity >50NTU	Monthly & annually
	Turbidity, pH	Grab	All ponds	3.5/week in summer, weekly in winter	Monthly & annually
	Nitrate-N	Grab	All ponds and MR1,2,3	bi-weekly	Monthly & annually
	Floating solids, visible foam, oil or other substances	visual	All ponds	daily	Monthly & annually
	96h acute lethality test (trout), 48h acute lethality test	grab	Ponds using floc	Twice/yr (June/July and Sept/Oct)	Monthly & annually
Luscar - minor ponds	TSS, pH	grab	Pond perimeter/discharge stream	weekly (summer), monthly (winter)	Monthly & annually

Mine	Parameters Measured	Sample type	Where sampled	Frequency of sampling	Frequency of reporting
	Nitrate-N	Grab	Pond perimeter/discharge stream	monthly	Monthly & annually
	Floating solids, visible foam, oil or other substances	visual	N/A	weekly	Monthly & annually
Luscar - background	Inorganic parameters in CCME (2003), Flow, BOD, BTEX, colour, oil & grease, phenols, TP, sulfate, TDS, temp, total sulfide, selenium, hardness, TSS	grab	Luscar Creek us, Luscar ds, Jarvis Creek us, Jarvis ds, Leyland Creek us, Leyland ds, Sphinx Creek us, Sphinx ds	Quarterly (Jan or Feb, May or June, Sept or Oct plus one storm run-off event)	2012, 2014 (more???)
Obed - major ponds	Flow	Weir	Ponds using floc	3/week in summer, weekly in winter	Monthly & annually
	turbidity, pH	Grab	Pond perimeter/discharge stream	3/week in summer, weekly in winter	Monthly & annually
	TSS	grab	Ponds using floc	3/week when turbidity >50NTU	Monthly & annually
	Nitrate-N	Grab	Pond perimeter/discharge stream	bi-weekly	Monthly & annually
	Floating solids, visible foam, oil or other substances	visual	Pond perimeter/discharge stream	daily	Monthly & annually
	96h acute lethality test (trout), 48h acute lethality test	grab	Ponds using floc	Twice/yr (June/July and Sept/Oct)	Monthly & annually
Obed - minor ponds	TSS, pH	grab	Ponds using floc	weekly	Monthly & annually
	Nitrate-N	Grab	Ponds using floc	monthly	Monthly & annually
	Floating solids, visible foam, oil or other substances	visual	N/A	weekly	Monthly & annually

Mine	Parameters Measured	Sample type	Where sampled	Frequency of sampling	Frequency of reporting
Obed - background	Inorganic parameters in CCME (2003), BOD, BTEX, colour, oil & grease, phenols, TP, sulfate, TDS, temp, total sulfide, selenium, hardness, TSS	Grab	Apetowun Creek us/ds, Roundcroft Creek us/ds, Canyon Creek us/ds, Oldman Creek us, ds, Baseline Creek us/ds	Annual	Annual