Oil Sands Monitoring - Technical Report

Water Quality Trends in the Athabasca, Peace, and Slave rivers from 2012-2019; Including evaluation of previous and current trend methods and influence of approaches for incorporating censored data

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Water Quality Trends in the Athabasca, Peace, and Slave rivers from 2012-2019; Including evaluation of previous and current trend methods and influence of approaches for incorporating censored data

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Executive Summary

In 2011, the Government of Canada and Alberta developed the Joint Oil Sands Monitoring (JOSM) plan, now the Oil Sands Monitoring (OSM). The main goal was to generate information that would allow for the accurate description of both baseline physical and chemical environmental conditions, as well as ecosystem structure and function (Environment Canada and Alberta Environment, 2012). In 2018 the monitoring program generated several technical reports and key component was reporting on seasonal and temporal trends in water quality (Glozier et al., 2018). The overall objective of this report is to provide an update on water quality trend analyses for five mainstem sites; three on the Athabasca River (M3, M7, and M9), and one each in the Peace (M12) and Slave (M11A) rivers. These most recent analyses also include evaluation and comparison of revised statistical approaches.

The specific objectives of the trend analyses included:

1. To evaluate and compare trend results for three Expanded Geographic Area Long-Term (EGA-LT) sites for which trends have been reported for earlier time frames: M9, the furthest downstream site on the Athabasca River; M12, located on the Peace River upstream of the Peace-Athabasca Delta and the Slave River; and M11A, situated on the Slave River downstream of the Peace and Athabasca Rivers.

2. To evaluate and compare trend results for the three sites (M3, M7, and M9) along the Lower Athabasca River (LAR), two of which have not been previously analyzed due to insufficient data: M3, located upstream of oil sands activity and downstream of Fort McMurray and Clearwater River; and M7, situated within the active oil sands region and downstream of the Ells River.

3. To report results in two ways: the estimated slope (mg/l/year) as calculated with the trend analysis and, the annual percent change, and

4. To examine if differences in trends are observed across panel locations at M3 and M7.

Comparison of the LAR (M9) with the EGA-LT revealed spatial patterns in WQ trends within and outside of areas influenced by OS activities. Similar trends in major ions, physicals, and nutrients were observed across all three sites suggesting broad regional drivers. Exceptions included both total phosphorus and particulate carbon which showed decreasing trends only at M9. Dissolved metal trends were more comparable at M9 and M11a, while total metal trends at M12 and M11A displayed patterns opposite to the decreasing trends observed at M9.

Trends across the three LAR sites (M3, M7, M9) showed increasing spatial and temporal variability downstream. Flow-adjusted results revealed that M9 had the highest number of significant trends in major ions and nutrients. Nutrient concentrations generally decreased over time, while total metal concentrations showed consistent decreasing trends at all three sites. M7 and M9 exhibited more significant total metal declines than at M3, indicating that downstream inputs may influence observed WQ conditions. Additionally, significant within-site variability at M3 and M7 highlighted the importance of continued panel sampling to accurately capture local influences such as tributary and wastewater inputs.

Summarizing trend results for a large number of parameters can be very challenging. By grouping parameters based on both the significance and direction of the trend, a subset of 45 parameters showed significant trends at one or both LAR sites downstream of OS activity (M7, M9) but not upstream (M3), suggesting potential OS influence. Comparison with observed trends at M12 further reduced the list to 32 WQ parameters with unique trends occurring in the LAR downstream of OS activity.

Several general observations can be highlighted for trends in the three LAR sites (M3, M7, and M9):

- There were 18 parameters with similar trends at all LAR sites including chloride (increasing), 12 total metals (decreasing), including vanadium, arsenic and mercury, as well as TSS. All decreasing trends were at least in part related to changes in discharge.

- There were 15 parameters which showed increasing trends at only M3

- Finally, 45 parameters showed significant trends at either M7 and/or M9 and not at M3.

Of the 45 parameters that showed significant trends downstream of Oil Sands activities in the LAR, when compared to the results from Peace River (M12), the following highlights emerged:

- There were 10 parameters at M12 that showed trends similar to the downstream LAR sites (M7 and/or M9), including 6 major ions, 1 nutrient, 2 dissolved metals and 1 total metal. These parameters included sulphate, TDS, total dissolved phosphorus, dissolved selenium, and cadmium.

- There were 28 parameters that showed significant trends only at the LAR downstream sites (M7 and/or M9), and not at M12 or M3. These included increasing trends in potassium, NO3/NO2, three dissolved metals and three total metals. However, many decreasing trends were observed in the LAR sites that were not present at M12. These included 10 total metals, 6 dissolved metals including vanadium, 3 total or particulate nutrients and turbidity.

Thus, by examining the patterns among sites, next steps can focus on those parameters that are exhibiting unique trends at the downstream LAR sites.

Finally, recommendations are provided for consideration including the following aspects of OSM WQ monitoring: 1) Subsequent analyses with current data set, 2) Future WQ trend analyses for LAR and EGA-LT sites, and 3) Sampling Frequency.

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1. Introduction

In 2011, the Government of Canada and Alberta developed the Joint Oil Sands Monitoring (JOSM) plan, now the Oil Sands Monitoring (OSM). The main goal was to generate information that would allow for the accurate description of both baseline physical and chemical environmental conditions, as well as ecosystem structure and function (Environment Canada and Alberta Environment, 2012). The monitoring program generated several technical reports on various aspects of the oil sands and surrounding region. One of the reports focused on the surface water quality of waterbodies located on the Athabasca River and within the Peace-Athabasca Delta (Glozier et al., 2018). A key section of this 2018 report focused on analyzing the seasonal and temporal trends of water quality parameters for one site on the mainstem Athabasca River, Athabasca at the 27th baseline (M9). The aim was to determine whether increasing or decreasing trends were observed over the entire period of sampling (1989-2014) compared to the most recent fifteen years (2000-2014), accounting for both seasonal variation and changes in water discharge. Since the 2018 report, an additional five years of consistent data (2015-2019) has become available for M9, and importantly, additional sites now have a longer period of record, where in 2018 insufficient data was available for trend analyses. As there were no samples collected in 2020 (and most of 2021) due to the global pandemic, a temporal data gap exists. Thus, we limited the trend analyses herein to the 8-year period with consistent sampling effort for five mainstem sites. Further, there is more information available on methods used to detect trends more accurately for long-term environmental data. Thus, updated trend analyses are timely both to update the statistical analytical methods and report on the water quality (WQ) trends at additional sites and extended timelines.

Long-term trend analysis using environmental data has been a common reporting tool for many years. There exist several parametric (e.g. regression) and non-parametric (Mann-Kendall) methods for estimating the significance and magnitude of trends for environmental data, including WQ data. The basis of these tests requires long-term sampling of WQ samples, ideally monthly or seasonally, until the number of data points reaches the number required to give sufficient statistical power to the selected statistical test. While both parametric and non-parametric tests can be used, non-parametric tests are often preferred due to the lack of assumptions of normality, and the decreased sensitivity to outlier values, both of which are common in WQ data. Previous reports exploring long-term WQ trends have utilized the non-parametric Seasonal Mann-Kendall test. This test also has the benefit of having procedures that can account for seasonality and the influence of an exogenous variable, such as water discharge, which can frequently influence long-term trends.

Another issue commonly faced when analyzing environmental WQ data, is the prevalence of “censored” data. Censored data is any data for which a measurement from the sample for a particular parameter cannot be reported, either due to a parameter concentration being below (left censored) or above (right censored) the method detection limit. Over the years there have been several different approaches to deal with such censored data. Clearly, the most inappropriate method for handling censored data is to remove it from the dataset entirely. This is highly discouraged as it produces a strong bias in all subsequent tests (Helsel, 2011). For example, left censored data could be incorrectly viewed as a value of zero. This is incorrect, as the censoring has nothing to do with the real sample and is a limitation of analytical laboratory technology. The censored value exists between 0 and the method detection limit. Another common way that environmental scientists have dealt with censored data is by substituting censored values with a specific value, often half the value of the method detection limit. While this has been commonly used (Gilbert, 1987), statisticians view it as a flawed method for handling censored data. Substitution of a single value adds a potentially erroneous signal to datasets that did not previously exist and could bias both the results of the hypothesis test and the trend slopes (Helsel, 2011). Using the Akritas-Theil-Sen (ATS) method has been suggested as an alternative method for trend analysis. The addition of this method to the analysis of OSM and long-term monitoring WQ data would be a valuable addition and could improve the accuracy of the calculated trend slopes and allow for the inclusion of both highly censored data and deal with datasets with multiple detection limits more effectively.

1.1. Objectives

Examining if trends in water quality are occurring at a given site is a key indicator in any adaptive monitoring program, including in OSM. In the adaptive monitoring, often the first step is to ask the question: are changes occurring over time? Subsequent questions include 1) if no changes are detected, is there sufficient power, 2) if changes are detected, are there correlates that may partially explain the trend (particularly relevant in WQ trend analyses is to determine if the change through time is related to concurrent changes in river discharge), and 3) can potential drivers/ sources of the changes be identified, i.e., for OSM, are the changes related to oil sands industrial activities. This final step can be investigated in several stages, the first of which includes comparison of trends among sites, for example, along a longitudinal gradient.

Thus, the overall objective of this report is to provide an update on water quality trend analyses for five mainstem sites; three on the Athabasca River, and one on each of the Peace and Slave rivers. The updated analyses include evaluation and comparison of revised statistical approaches. We also provide specific recommendations for ongoing analyses. The stepwise approach in this report was as follows:

<u>Methods Comparisons:</u>

1. Using the same data set used in Glozier et al., (2018), including the same data screening and removal of outliers, compare results previously reported using both the previous and current methods of trend analysis. This is to confirm whether any changes in significance or direction of trends exist which could be an artifact of moving to new statistical packages/ approaches

2. Assess and compare the trend test results using two methods for handling censored data: the ½ time detection limit substitution and the ATS slope estimator. This comparison evaluates the potential influence (or not) of each method on trend results, highlighting the efficacy of the ATS approach in handling censored data.

<u>Temporal Trend Results:</u>

3. Once statistical approaches were evaluated, report the results of temporal trends from five mainstem sites, three (M3, M7, M9) in the Lower Athabasca River (LAR) and one site in each of the Peace (M12) and Slave (M11A) rivers, using all available data with no temporal gaps (2012 – 2019). These results are reported with and without a flow-adjustment. Two distinct questions for comparison of results among sites were relevant:

- comparison of trend results for the three long term sites previously reported (M9, M12, M11A), subsequently referred to as Expanded Geographic Area Long-Term (EGA-LT), and

- comparison of trend results for the three sites within the LAR (M3, M7, M9) two of which (M3 and M7) have not previously been analyzed due to insufficient data.

It is recognized that setting up these two comparisons creates a duplication of the use of M9 data, but the authors felt the two questions were easier to interpret when analyzed in these two groupings rather than comparison among all sites.

4. Provide trend results for the five mainstem sites in two ways; the estimated slope (mg/l/year) as calculated with the trend analysis and, the annual percent change. These two reporting approaches could be used as potential indicators of change in WQ conditions for which critical effect sizes (CES) could be developed.

<u>Within Site Differences (M3 and M7):</u>

5. Examine if differences in trends are observed across panel locations at M3 and M7 and examine the additional insights that panel sampling offers at these where water quality across the transect may vary due to incomplete mixing.

<u>Projections of trends and potential impacts on WQ:</u>

6. Finally, for those parameters with CCME guidelines, project the 5- and 10-year median concentrations if the calculated trend were to continue, and assess what the potential impact on guideline excursion rates would be.

2. Study Area and Sampling Approaches

2.1. Geographic Region

For this report, the five sites selected to complete temporal trends are locations within the LAR and EGA-LT (Fig.1). The sites were selected due to the length of time they have been monitored, the consistency in sampling approaches, frequency and analytical laboratories, and the higher number of WQ samples collected. In the LAR, three mainstem sites were selected: 1) M3, located downstream of Fort McMurray but upstream of OS activity, 2) M7 which is located within OS activity and downstream of the Ells River, and 3) M9 which is the furthest downstream monitoring site sampled by ECCC. In addition to the LAR, two rivers were included in this report: the Peace River, which flows from the BC Rockies towards Wood Buffalo National Park before its confluence with the outflow from Lake Athabasca and Riviere des Rochers, becoming the Slave River ultimately flowing into Great Slave Lake. Two established

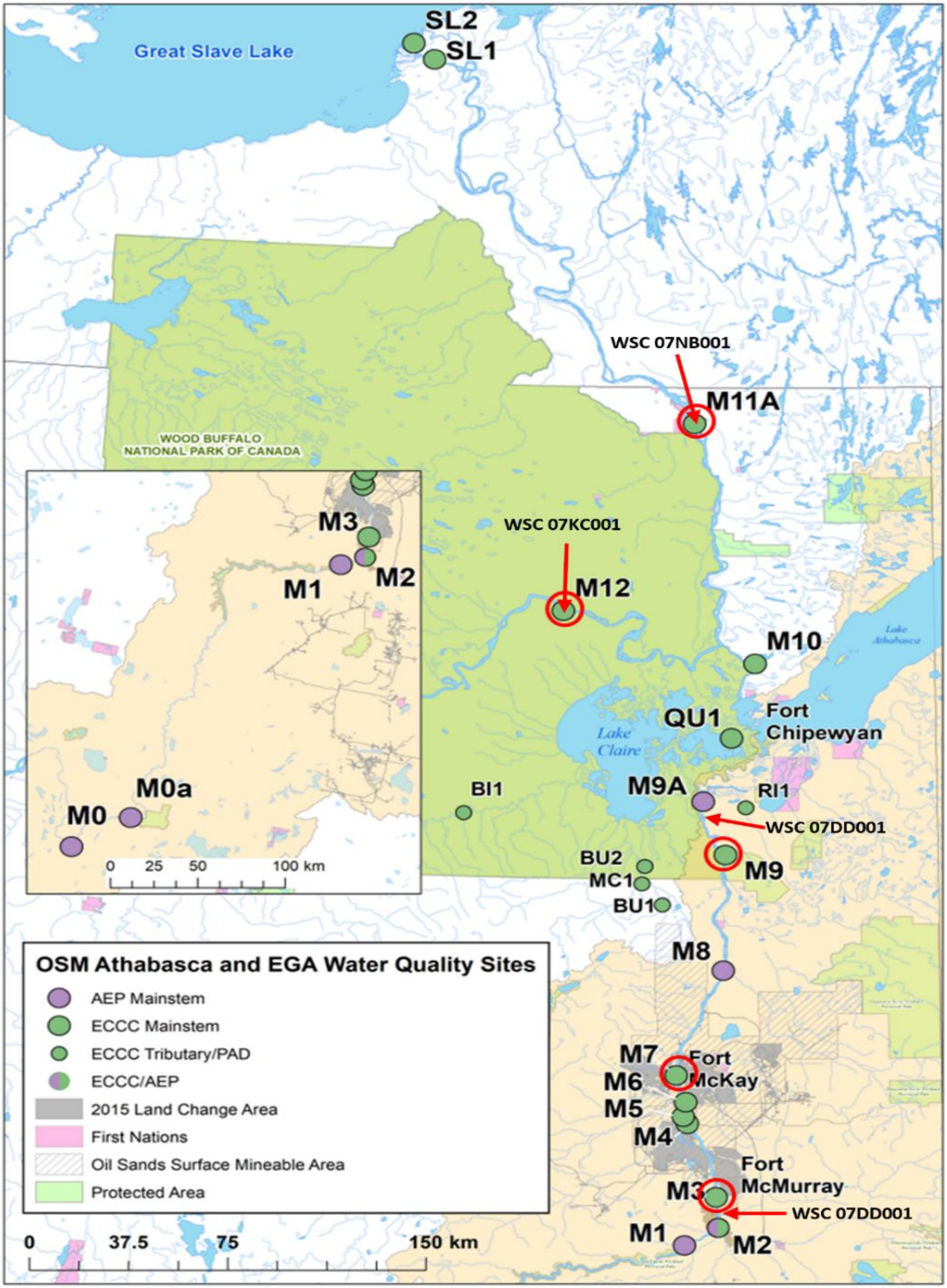

Figure 1. Map of OSM Water Quality sampling sites with the five sites where temporal trends are reported within red circles. The red arrows indicate the approximate location of WSC stations.

monitoring sites were selected from these rivers: Peace River at Peace Point (M12) and Slave River at Fitzgerald (M11A). A more extensive description of the sampling area and rationale for the sites is provided in previous monitoring documents used to develop the program (Environment Canada, 2011a and 2011b, Environment Canada and Alberta Environment, 2012) and in previous technical reports (Glozier et al. 2018, Glozier et al., 2009). Table 1 provides a summary of the rationale for each water quality site's inclusion in the OSM. All five sites are sampled by ECCC, with consistent field sampling methodology and laboratory analytical approaches.

2.2. Field and Data Methods

Water quality samples were collected on all mainstem river sites with a depth integrated sampler, as per the recommendations from Glozier et al., (2018). During open water periods, samples were collected from a boat, while during winter, holes were drilled in the ice and samples were collected through the ice. Detailed methods, as well as methods for other routine sampling are documented in a series of Standard Operating Procedure Documents (ECCC 2018a, 2018b, 2018c, 2018d; Standard Operating Procedures for Water Quality Sampling - Datasets - Oil Sands Monitoring (alberta.ca)).

Sampling effort at each site differed depending on the site-specific objective. Two approaches were used, either a single sample from the deepest river location (thalweg), or sampling at multiple panels across the river channel. At the three long term sites in the Athabasca, Peace and Slave rivers (M9, M12, and M11A), a single sample at the thalweg was collected, as determined on site by cross section depth profiles. Previous work has demonstrated that water is sufficiently mixed across the channel at these sites and upstream inputs are far upstream.

Multiple panel sampling was completed in earlier years at most LAR sites. It was clear that WQ at M3 and M7 varied across the channel and was dependent on parameter and time of year (Glozier et. al., 2018). Recommendations for these sites, as well as other sites in reaches with nearby upstream inputs, included ongoing multiple panel sampling, but with reduction from ten to three panels. Thus, at M3 and M7, a river depth cross section is completed for each sampling time, and the site is divided into 10 equal width panels. Samples are collected at three panels: the thalweg, the "West" (panels 1- 2) and the "East" (panels 9 -10). As the river

Table 1. Rationale of Water Quality and Quantity Monitoring Sites in the Lower Athabasca (Phase 1) and Expanded Geographical Area (Phase 2). An excerpt is provided below of relevant information from Tbl. 3, pg. 57 (Environment Canada and Alberta Environment, 2

Site	Station ID	River	Latitude	Longitude	Site Status	Existing Site Linkages in 2011	Period of Record in 2011	WSC Station	2011 Rationale	2011 Proposed Sampling Frequency	2011 Proposed Parameters/Media
M3	AL07DD0008	Athabasca	56.8388	-111.4155	D/S of Fort McMurray; U/S of OS development	WSC Hydat 07DA001	2012 to present	07DA001	Estimates Athabasca River WQ D/S of Fort McMurray and Clearwater River	Monthly/Biweekly	WQ/Bottom Sediment/Passive Samplers (SPMD, POCIS, DGTs)
M7	AL07DD0007	Athabasca	57.3137	-111.6738	D/S of Ells; U/S of TAR River	New	2012 to present	n/a	Estimates Athabasca River WQ D/S from Ells River/TOTAL Mine/CNHR and U/S of Tar River	Monthly/Biweekly	WQ/Bottom Sediment/Passive Samplers (SPMD, POCIS, DGTs)
M9	AL07DD0001	Athabasca	58.1725	-111.3703	D/S of Firebag and near Embarras Airport	New	1989 to present	07DD001	Estimates Athabasxa River WQ D/S of Firebag River and U/S of Embarras River	Monthly/Biweekly	WQ/Bottom Sediment/Passive Samplers (SPMD, POCIS, DGTs)
M12	AL07KC0001	Peace	59.1139	-112.4264	Peace River at Peace point	ECCC long-term monitoring AL07KC0001, Active Hydrometric WSC 07KC001	Water quality: 1967 to 1976 1989 to present	07KC001	Estimate loadings on the Peace River U/S of the PAD and Slave River, including Peave River oil sands area and Athabasca oil sands lease area wouth of WBNP; coordinated with fish sampling	Monthly/Biweekly	WQ/Bottom Suspended Sediment/Passive / Intergrative Samples
M11A	AL07NB0001	Slave	59.8694	-111.5861	Slave River at Fort Fitzgerald	ECCC long-term monitoring AL07NB0001, Active Hydrometric WSC 07NB001	Water quality: Current Agreement with Alberta: 1988 to present (limited historic data in the 1960s)	07NB001	Estimate loadings from Athabasca and Peace rivers to Salve River	Monthly/Biweekly	WQ/Bottom Suspended Sediment/Passive / Intergrative Samples

profile changes frequently, the exact panel location of the thalweg depends on the cross-section depth profiles at the time of sampling. In some cases, where the thalweg hugged the east or west side, sampling was only conducted within 2 panels. In rare circumstances, where there were two equally dominant thalwegs, and/or there was a sand bar dividing the river within the reach, an additional panel sample may have been taken.

Parameters were analyzed at ECCC National Laboratory for Environmental Testing (NLET) labs. In this report, the WQ analytes are grouped into the following parameter groupings: major ions and physicals, metals, nutrients, and organics. For all comparisons among sites, the sample collected from the thalweg sample was used in trend analyses for consistency and where triplicates were collected, approximately every 10th sampling event, the first triplicate was selected for statistical analysis.

For the flow weighting trend analyses, discharge data used was from the Water Survey of Canada (WSC) stations located upstream of M3 (07DA001) and near M9 (07DD001). The M3 WQ station (AL07DD0008) is within the same river reach (approx. 6.5 km downstream) of the M3 WSC station (Fig. 1). The discharge data used for M9 WQ station (AL07DD0001) was located closer to the mouth, ~25km downstream. However, there currently is not a discharge station near to the WQ M7 station and the M9 WSC station was not fully implemented for reporting discharge until 2015.

To allow flow weighted trend analyses at sites without co-located WSC discharge stations, we were required to assume that, as long as the pattern in discharge was consistent along the LAR between M3 and M9, discharge data from M3 could be used as a surrogate for M7 and as well for the years at M9 with missing discharge data. This approach has been used previously (Glozier et al., 2018 and 2009). Further, for trend analysis we are not attempting to model or create loading estimates so minor differences in absolute discharge values along the LAR were not considered a concern. To demonstrate the similarities in the measured discharge data between M3 (07DA001) and M9 (07DD001), a scatterplot was created with all flow data from 2012 to present (Fig. 2). Discharge for both sites had extensive overlap, although low flow winter samples at M9 tended to be somewhat (14%) greater than at M3. Finally, a correlation test (Spearman's) indicated high correlation (R=0.98) between discharge data from both sites with greater variability during higher discharge periods (Fig. 3). The results from both the scatterplot and the correlation test demonstrate the high level of similarity between the *patterns* in discharge at both locations. The two other sites in this report (M12 and M11A) have co-located WSC discharge data available for the entire period of sampling.

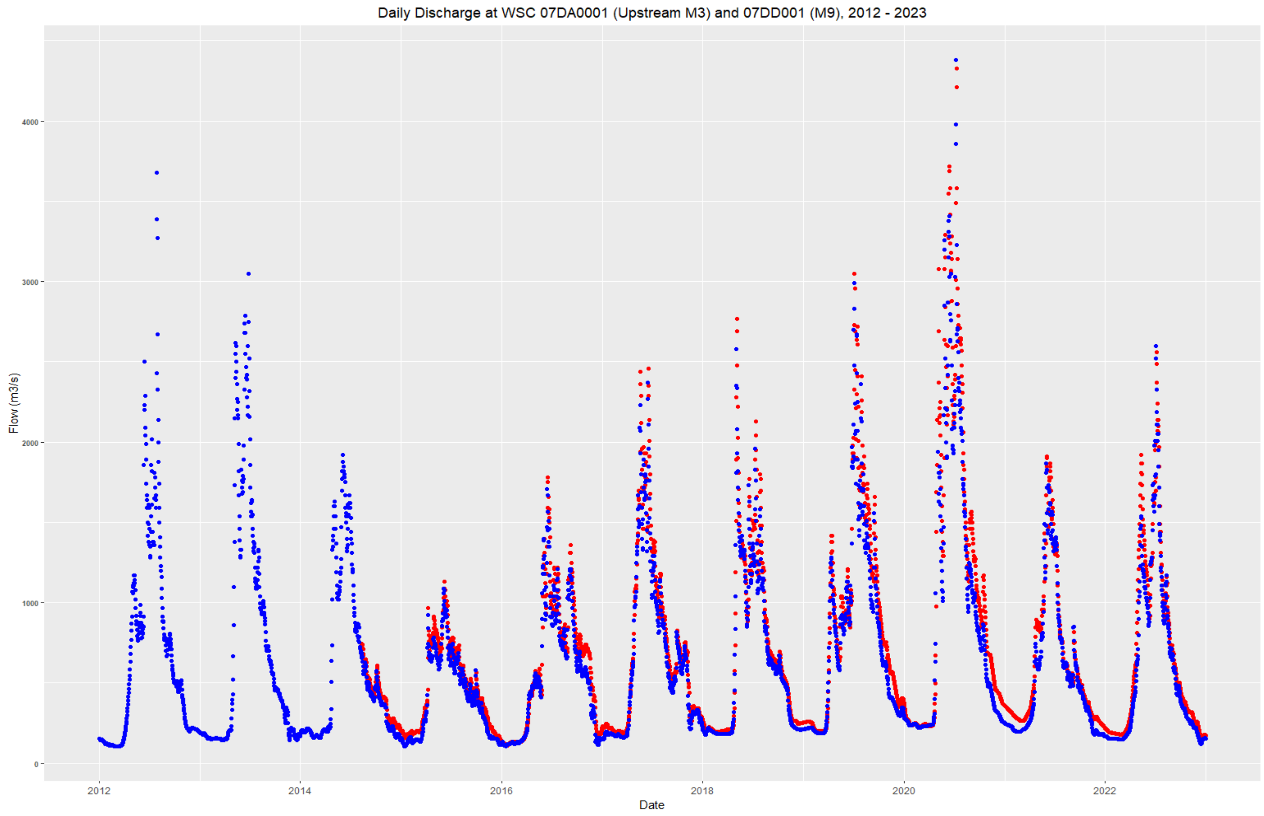

Figure 2. Scatterplot of daily discharge data measures at WSC 07DA001 (Upstream of M3) and 07DD001 (M9). Blue points represent value measured at 07DA001, and red points are values measured at 07DD001.

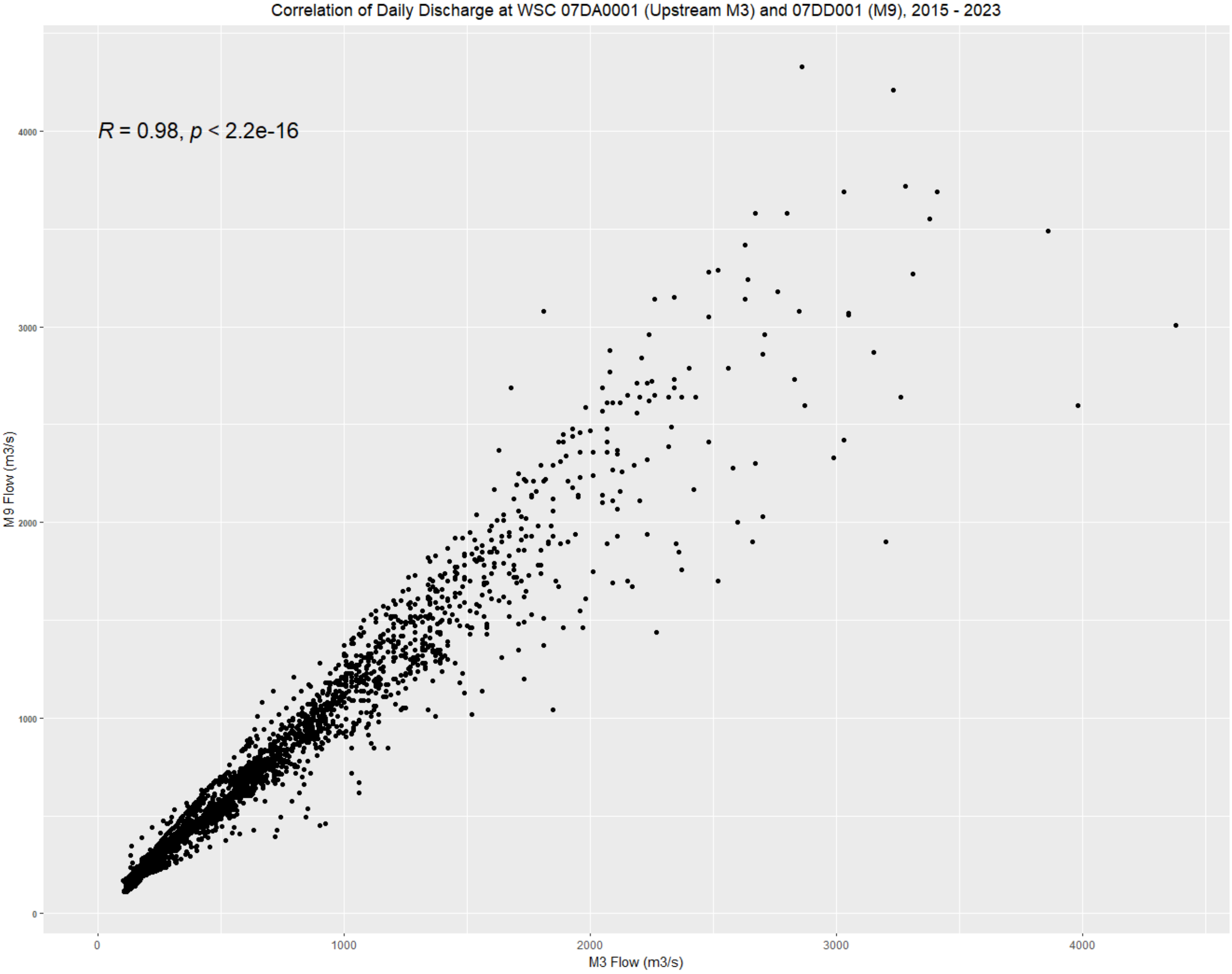

Figure 3. Correlation plot of discharge data collected from WSC Station upstream of M3 (07DA001) and WSC near M9 (07DD0001). A Spearman's rank correlation test was conducted. Results of test are printed in top left section of plot. All values are in m3/second.

3. Statistical Methods and Approaches

3.1. Comparison of previous and current trend analysis techniques.

To assess the WQ parameters for trends, the 2018 report used the Seasonal Mann-Kendall test. This is a non-parametric test that analyzes for monotonic trends (i.e., consistent upwards/downwards) in data that may be influenced by the time of the year it is sampled. It computes a Mann-Kendall test between each of the defined seasons and then combines the results with no comparison made outside of the defined seasonal block and are usually separated by sample month. As WQ samples were not collected each month, hydrometric seasons were defined: Winter (November – April), Spring/Summer (May – July), and Fall (August – October). The hydrometric seasons were originally defined by Glozier et al. (2009) for the Wood Buffalo National Park Water Quality Report and are based on seasonal discharge patterns. These same seasons were used in the current analysis to maintain consistent methodology and data in order to minimize variation between previous and current methodologies. All parameters were sampled over 1989-2014, however for metals there was an analytical method change, so metals data was examined from 2000 onward. Samples reported below the laboratory method detection limit were still included in the WQ datasets but were flagged as a censored value (see more details in Section 3.2). Parameters were only included in the dataset if they had < 50% censored data. Any censored data was substituted with a value equal to half of the method detection limit. Results from the trend analysis were reported without flow-adjustment (concentration) and with flow-adjustment. The software used in the previous report was WQSTAT PLUS Version 9.4.41 (© NIC 1992-

2004). The functions used to compare with results from the previous reports was provided by Dennis Helsel's NPTRENDSEA, SEAKEN, and NPTREND code available through the statistical course, "Applied Environmental Statistics" (© Practical Stats, 2020). These functions run either a Mann-Kendall, a Seasonal Mann-Kendall (SMK), or a SMK with adjustment for a covariate (flow). Censored data was handled in the same manner as the previous report (i.e. ½ detection limit). Data was flow-adjusted by modelling the concentration-flow relationships using locally weighted regress and smoothing scatterplots (LOWESS). The residuals from the LOESS were then run as the flow-adjustment WQ values in the Seasonal Mann-Kendall. All statistical tests in the current report were performed using R and RStudio- an integrated development environment for R (Posit team, 2024; R Core Team, 2024).

3.2. Comparison Between Methods for Analyzing Censored Data

Once we determined that no major differences between the statistical methods existed, trend analyses were performed on the WQ data from all sites outlined above from the LAR and EGA-LT. The period of record chosen was 2012-2019 as this represented consistent sampling that had been conducted since the inception of OSM at the five sites of interest through to the suspension of fieldwork that occurred due to COVID-19 in March of 2020. Sampling was consistently conducted each month, so the same hydrometric seasons defined in the previous report were used for the seasonal adjustment (i.e. Spring/Summer, Fall, Winter). If multiple samples were collected during a month at a site, the sample collected nearest to the middle of the month was selected to ensure similar sampling effort among sites. As previously mentioned, substituting censored values with half of the method detection limit is not the most up to date method for environmental trends analysis. As the trend analysis for the five sites in the LAR and EGA-LT used this method previously, we conducted a second method comparison to examine if any differences existed between the two approaches for handling censored data. The updated approach used functions included in the NADA and NADA2 R packages (Julian & Helsel, 2021; Lee, 2020). The NADA2 packages conduct a slightly varied version of the Thiel-Sen slope estimate in order to handle left (or right) censored data. This method, called the Akritas-Theil-Sen (ATS) slope estimate, functions by setting an initial slope estimate and subtracting this value from the independent variable, and then calculating the Kendall's tau (*S*) between the residuals and the x variables (Akritas et al., 1995). The slope is defined by the result that will produce an *S* of zero. This prevents the addition of an erroneous signal which can occur with censored data (Helsel, 2011) and allows for the inclusion of data with multiple reporting limits. The test also uses a permutational seasonal Mann-Kendall, where values within seasonal blocks are reorganized and re-run in different positions over a large number (ex. 4999) of repeated tests. Flow-adjustment was conducted using a generalized additive model (GAM) smooth on censored Y vs X, which removes the effect of the covariate (flow). The ATS is then performed on the GAM residuals. In any instance where no censored data was present, LOWESS was used for flow-adjustment. Flow was treated as a covariate for all parameters to ensure that observed concentration trends were not a by-product of changing discharge conditions. The slope calculated by the trend tests is expressed as the annual rate of change in concentration. To allow for ease in interpretation, the slope was also expressed as the annual percent change per year. This was done by dividing the slope by the median of the entire period of record and multiplying by 100. For parameters with censored data, the Regression on Order Statistics (ROS) method was used to calculate the median. As a comparison was desired between multiple datasets, decisions about transformation were made for all datasets, and not on a case-by-case basis. The same rationale was used for flow, where flow-adjusted trend tests were applied across all parameters and sites to provide a consistent baseline for comparison. Results will be more interpretable if a single method is used for all data, and the nonparametric tests used do not require transformations to work well (Helsel et al., 2020). Therefore, no transformations were applied to the data used for this report.

For each WQ parameter both the seasonal and flow-adjusted SMK were performed. This resulted in multiple interpretations of statistical significance being required. To simplify this interpretation, a matrix is provided to explain how the authors interpret the final trend results based on the significance of both tests (Table 2, boxes, A, B, C, D). The simplest of these interpretations occurs when neither test, with or without flow-adjustment (Table 2, box D), was significant and suggests very strongly that there is no trend for the specific parameter. When each test has a significant result, we can conclude that when accounting for the variation of season and flow, there is strong evidence of a trend in concentration over time (Table 2, box A). When concentration trend is not significant but is significant with flow-adjustment, we can infer that the variation resulting from flow was, at least in part, masking evidence of a trend (Table 2, box C). When a significant concentration trend is observed, but when flow adjustment is applied the trend is not significant, we can conclude that the change in concentration is, in part,

Table 2. Matrix of trend results for the concentration seasonal Mann-Kendall and the flow-adjusted seasonal Mann-Kendall. Significant and not significant columns are based on a p value of 0.1. Matrix can be interpreted based on the significance o both trend tests and the description in the corresponding cell.

		Flow-adjusted Seasonal Mann-Kendall	
		Significant	**Not Significant**
Concentration Seasonal Mann-Kendall	**Significant**	After the influence of covariate (flow) is removed, trend is stil significant. Indicate it is likely that changes in concentration are independent of chages in flow.	After the influence of covariate (flow) is removed, trend is no longer significant. Indicates that trend is at least in part related to changes in flow.
	Not Significant	After influence of covariate (flow) is removed, trend becomes significant. Indicates that concentration trend was in part masked by changes in flow.	No trend is likely even when adjusted for season and covariate

due to a change in flow over time (Table 2, box B). Assessing potential drivers of changes in flow was not part of our objective, therefore for this report, we viewed trends with significant results under both methods (concentration and flow-adjusted), or significant results once flow-adjusted (i.e., Table 2, box A&C) as an equivalent result regarding changes in WQ and potential risk to the environment. Flow-adjustment is a valuable tool as it can increase the power of a trend test by removing variability in the data associated with flow (Snelder et al., 2021). However, flow-adjusted slopes are not necessarily representative of the change in water quality that is occurring, as these are values modelled from a regression. For the purposes of this document, trends without flow-adjustment (concentration) and trends with flow-adjustment were reported.

For current trend results, two regional comparisons were selected. The first included a site along the Athabasca River (M9) and two sites from the EGA-LT (M11A, M12). The goal of selecting these sites was to measure and compare the trends that are occurring within and outside of the LAR. The second region included three sites located on the Athabasca River: M3, M7, and M9. These sites were chosen in order to have a comparison for trends upstream and downstream of the OS mining area. For both defined regions of the report (LAR and EGA-LT sites), the decision was made to not include polyaromatic compounds (PACs). This was due to most PAC WQ parameters having highly censored data (i.e. > 80%). There were only a handful of parameters that were able to meet the requirements of the trend analysis, and the methods for these parameters were not consistent between sites, making the desired regional comparisons not valid. Due to these low detection rates in the earlier years of the program, and after consultation and evaluation of options, from 2021 onwards, all WQ PAC samples have been analyzed by AXYS Analytical Services Ltd. (Sidney, BC, Canada). This achieved lower detection limits and consistency with other monitoring programs in the area. For dissolved PACS, the semi-permeable membrane device (SPMD) program has been established and is a better representation of the dissolved PAC concentration at the locations where these devices are deployed (Environment Canada and Alberta Environment, 2011a, 2011b).

To preliminarily assess how the observed trends could potentially impact future aquatic ecosystem health relative to the CCME Water Quality Guidelines for the Protection of Aquatic Life (Freshwater), we estimated future concentrations using the slopes generated by the Seasonal ATS analysis. If significant, the ATS slope for each WQ parameter indicates a change in concentration over the period of record. If we assume this rate of change remains consistent, we estimated the predicted median values over 5- and 10-year periods by multiplying the ATS slope by 5 or 10 and adding the result to the current median concentration. These projections were used only as a screening tool to identify parameters that are already exceeding, or are close to exceeding, guideline values. We also assessed the frequency of guideline exceedances, or excursions, for the current dataset. For each parameter with an existing guideline, all individual WQ samples were compared to the recommended threshold. The number of excursions were divided by the total number of samples for that parameter and multiplied by 100 to calculate the frequency of excursions.

3.3. Correlation Analysis

Correlation analysis was performed using all parameters included in the trend analyses, and comparisons were made within WQ sites. The correlation test selected was Kendall's Tau, which is outlined above as it was also used for the WQ trend analysis. The non-parametric Kendall's Tau test is useful for environmental WQ data as it does not measure only linear relationships, but all monotonic relationships. It also allows for either of the x or y variable to include censored data (Helsel, 2011). Like Spearman's, this method is non-sensitive to outliers in the data. While both Spearman's and Kendall's Tau will produce similar results, Kendall's Tau will generally be 0.2 lower (Helsel, 2011). Correlation heatmaps were produced using the "ggcorrplot" package (Kassambara, 2019).

4. Results

4.1. Comparison of WQSTAT and R Trend Analysis Methods

Each WQ parameter was analyzed using both the WQSTAT and R using identical datasets over two separate time periods: 1989-2014 and 2000-2014 (Table 3-4). There were no instances of a change in significance between either the WQSTAT or the R methods over either the 1989-2014 or the 2000-2014 sampling periods on concentration data (no flow adjustment). Further, there were also no instances where the estimate of the slope had a change in direction (i.e. increasing to decreasing) between the results calculated by either statistical method. A similar finding is observed for the trends that were conducted with a flow-adjustment. No change in significance or change in trend direction was observed over either time period between both statistical tests.

The results of this comparison highlight the similarities of the two approaches to trend analysis. Both programs (WQSTAT and RStudio) use a Seasonal Mann-Kendall to detect monotonic trends in each dataset. The identical results (Table 3-4) in both trend direction and statistical significance ensure that the results obtained using the newer, more efficient approach will not conflict with the results previously reported. Given the results of this comparative study, we proceeded to use the R trend analysis package for all subsequent trend analyses in this report.

4.2. Comparison of Trend Analysis Results Dealing with Censored Data

After confirming the similarity between results from the two statistical packages, we also conducted a comparison between two methods of treating censored data. As mentioned above, using the censeaken or centrendsea R packages, there is no substitution of censored values. Instead, it treats values existing below certain thresholds (i.e. detection limits) as ties for when it estimates the ATS slope, and for the overall Mann-Kendall result. For this comparison the same data set (n=595) as in the comparison above was used to run both the seaken and the censeaken statistical packages. The results were then compared to determine if there were a) differences in significance, and b) differences in the estimated slope. Firstly, there were only minor differences regarding the significance of results (Fig.4). Of the 595 analyses run, only 14 or 2.4% of tests had differences in significance between the methods. There were 8 that were significant with the ½ X DL and not the NADA2, while 6 were significant with NADA2 and not with ½ X DL approach. Of the 14 parameters with differences in trend significance, most (Fig. 4, asterisks in green shaded areas) were with datasets that were highly censored while the others had concentration values close to method detection limits.

We examined the results for differences in slope estimates for those trend analyses where there was at least one significant result (n=126). All slope estimates were similar (Fig. 5), and Spearman's test between the two slope estimates indicated there is a very high, significant correlation (R = 0.96). Considering that minimal differences were found between the two detection methods, and with the advantages gained with the NADA2 approach, all reported trends throughout the remainder of the report were conducted using the updated censeaken and centrendsea packages.

Table 3. Comparison of Seasonal Mann Kendall results generated by WQSTAT and R for WQ parameters sampled from M9 between 1989-2014 without (i.e., No Flow) and with (i.e., Flow) flow-adjustment. Trends are labelled as significantly increasing over time (↑), significantly decreasing over time (↓), or non-significant increase or decrease over time (**-**).

M9 Water Quality 1989-2014				
	p < 0.05 (No Flow)		**p < 0.05 (Flow)**	
	WQSTAT	R	WQSTAT	R
Major Ions				
Alkalinity-T (mg/L)	-		↓	
Bicarbonate (Calc.)	-		↓	
Calcium (mg/l)	-		↓	
Chloride (mg/L)	-		↓	
Fluoride (mg/L)	↑		↑	
Magnesium (mg/L)	-		↓	
Potassium (mg/L)	↑		↑	
Silica (mg/L)	↑		-	
Sodium (mg/L)	-		-	
Sulphate (mg/L)	↑		↑	
Nutrients				
Carbon Dissolved Organic (mg/L)	-		-	
Carbon Particulate Organic (mg/L)	-		↓	
Ammonia-D (mg/L)	-		↓	
Nitrogen Dissolved (mg/L)	-		-	
Nitrogen NO23 (mg/L)	↑		-	
Nitrogen Particulate (mg/L)	-		↓	
Phosphorous Total Dissolved (mg/L)	-		-	
Phosphorous Total (mg/L)	↑		↑	

Table 4. Comparison of Seasonal Mann Kendall results generated by WQSTAT and R for WQ parameters sampled from M9 between 2000-2014 without (i.e., No Flow) and with (i.e., Flow) flow-adjustment. Trends are labelled as significantly increasing over time (↑), significantly decreasing over time (↓), or non-significant increase or decrease over time (**-**).

M9 Water Quality 2000-2014				
	p < 0.05 (No flow)		**p < 0.05 (Flow)**	
	WQSTAT	R	WQSTAT	R
Major Ions				
Alkalinity-T (mg/L)	-		-	
Bicarbonate (Calc.)	-		-	
Calcium (mg/l)	↓		-	
Chloride (mg/L)	↓		-	
Fluoride (mg/L)	↓		↓	
Magnesium (mg/L)	-		↑	
Potassium (mg/L)	↑		↑	
Silica (mg/L)	↑		↑	
Sodium (mg/L)	-		↓	
Sulphate (mg/L)	-		-	
Nutrients				
Carbon Dissolved Organic (mg/L)	-		-	
Carbon Particulate Organic (mg/L)	-		-	
Ammonia-D (mg/L)	↓		↓	
Nitrogen Dissolved (mg/L)	-		-	
Nitrogen NO23 (mg/L)	-		-	
Nitrogen Particulate (mg/L)	-		-	
Phosphorous Total Dissolved (mg/L)	↓		↓	
Phosphorous Total (mg/L)	-		-	
Metals				
Arsenic (mg/L) 2000-2014	↑		↑	
Copper (mg/L) Apr. 2003-2014	-		-	
Iron (mg/L) 2000-2014	-		↑	
Copper (mg/L) 2000-2014	-		-	
Iron (mg/L) 2000-2014	-		-	
Lead (mg/L) Apr. 2003-2014	-		-	
Nickel (mg/L) Apr. 2003-2014	-		-	
Vanadium (mg/L) 2000-2014	-		-	
Zinc (mg/L) 2000-2014	↓		↓	

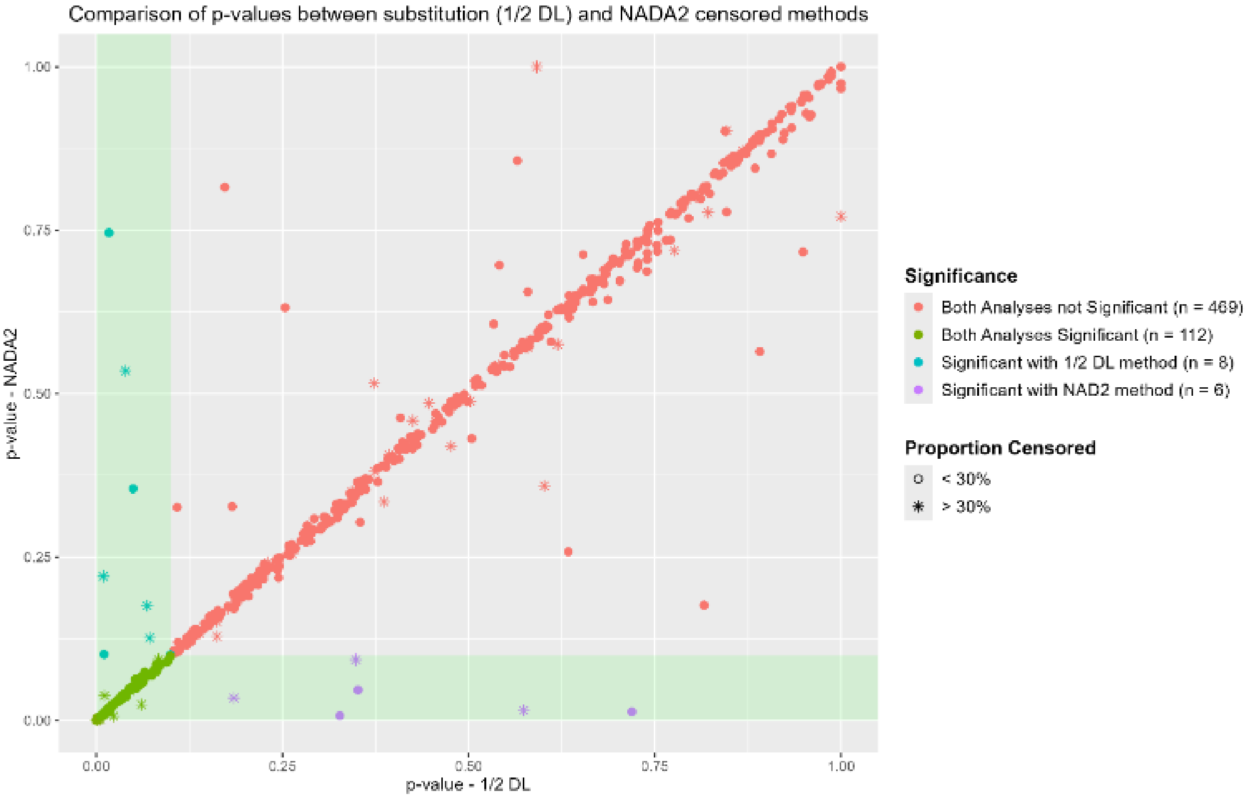

Figure 4. Comparison of the p-value of seasonal Mann-Kendall using separate methods of handling censored data: substitution for ½ of MDL (x-axis), ATS by NADA2 (y-axis). The green shaded areas represent the area on the plot with p values below 0.10. Asterisks highlight values that had greater than 30% total data below MDL. Points are colour-coded based on which method detected, or did not detect, significance, and legend provides total number of parameters.

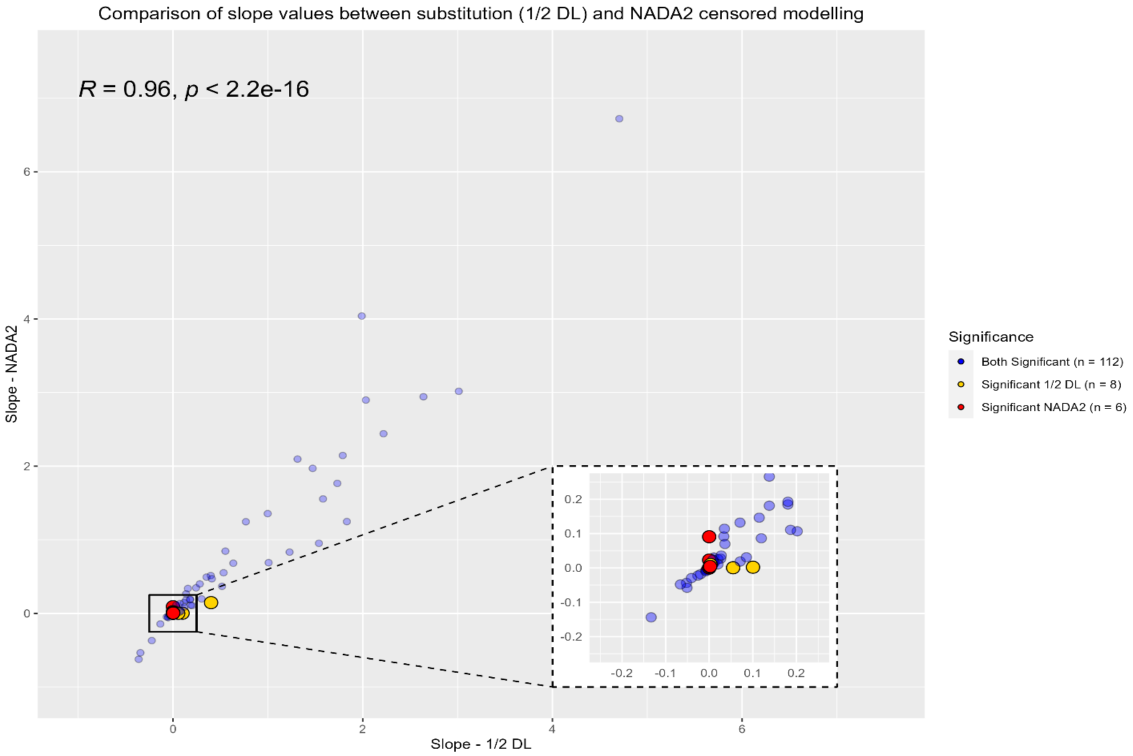

Figure 5. Comparison of the slopes calculated by the seasonal Mann-Kendall using separate methods of handling censored data: substitution for ½ of MDL (x-axis), ATS slope estimate used by NADA2 (y-axis). Points are represented in original units. Points are colour-coded to highlight the significance level resulting from trend analysis using both censored data methods. A Spearman rank correlation test was run between both methods, and the results are displayed in the upper left section of the plot. The inlay is a zoomed in view of the area containing a high concentration of slope values not easily visible in the full plot.

4.3. Trend Results

4.3.1. Proportion of significant trends at all LAR and EGA-LT sites

A total of 500 WQ parameters were analyzed for trends at all five EGA-LT and LAR sampling locations: M3 (102), M7 (101), M9 (106), M11A (96), and M12 (95) (Table 5). The differences in the number of parameters analyzed for trends among locations were typically due to highly censored data (> 50%), or differences in the suite of parameters that were analyzed at a given site. The number and proportion of significant results (significant trend/ total parameters X 100) is presented to indicate which sites had a higher occurrence of significant trends. There was a total of 123 (24.6%) significant ($p < 0.1$) increasing or decreasing concentration trends observed at all five sites (Table 5). This proportion increased substantially after flow-adjustment, with a total of 237 (47.4%). Without flow-adjustment, the majority (80.4%) of concentration trends were increasing with only metals and one nutrient exhibiting decreasing trends. Flow-adjustment reduced the disparity between increasing (60.8%) and decreasing (39.2%) trends. In general, the proportion of significant trends increased from upstream to downstream (M3-M9). Without flow-adjustment, there is also a notable increase in significance between M9 and both EGA-LT sites, but this disparity is reduced substantially once accounting for flow.

Overall, major ions and physicals appear to be increasing moving from M3-M9, especially once trends are flow-adjusted. The EGA-LT sites (M12 and M11A) and M9 appear to have similar proportions of total significance. After flow-adjustment, there appears to be a region-specific decrease in nutrients between the LAR and EGA-LT, as noted by the lack of any significant decreasing trends observed at either M11A or M12. A similar pattern is observed in total metals, as before and after flow-adjustment, there are no instances of significantly increasing trends observed at M11A or M12. These generalized patterns and results are more fully discussed in the two subsequent sections as per the objectives stated previously: comparison of trend results for the three long term sites (M9, M12, M11A), and comparison of trend results for the three sites within the LAR (M3, M7, M9).

Table 5. Proportion of significant WQ trends detected at LAR and EGA-LT sites. WQ measurements are grouped into parameter group and site. Trend results are reported as Concentration (no flow-adjustment) and Flow-Adjusted. The total number ($p < 0.1$) and proportion (Total Sig. %) of significant trends are provided as either concentration (no flow-adjustment) or flow-adjusted. Additionally, the proportion of significant increasing (↑) or decreasing (↓) trends are provided for both trend tests.

			Concentration				Flow-Adjusted			
Group	**Site**	**Total Parameters**	**p < 0.1**	**Total Sig. (%)**	**↑ (%)**	**↓ (%)**	**p < 0.1**	**Total Sig. (%)**	**↑ (%)**	**↓ (%)**
MI and Physicals	M3	17	3	17.6	17.6	0	5	29.4	29.4	0
	M7	16	1	6.3	6.3	0	9	56.3	50.0	6.3
	M9	17	6	35.3	35.3	0	12	70.6	64.7	5.9
	M12	13	8	61.5	61.5	0	10	76.9	76.9	0
	M11A	13	8	61.5	61.5	0	9	69.2	69.2	0
Nutrients	M3	12	0	0	0	0	2	16.7	0	16.7
	M7	12	1	8.3	0	8.3	4	33.3	0	33.3
	M9	14	2	14.3	14.3	0	9	64.3	21.4	42.9
	M12	11	3	27.3	27.3	0	5	45.5	45.5	0
	M11A	12	4	33.3	33.3	0	8	66.7	66.7	0
Metals (Dissolved)	M3	34	10	29.4	29.4	0	9	26.5	20.6	5.9
	M7	34	7	20.6	8.8	11.8	7	20.6	14.7	5.9
	M9	35	10	28.6	17.1	11.4	14	40.0	20.0	20
	M12	31	12	38.7	32.3	6.5	12	38.7	35.5	3.2
	M11A	31	9	29.0	9.7	19.4	9	29.0	19.4	9.7
Metals (Total)	M3	39	3	7.7	5.1	2.6	15	38.5	0	38.5
	M7	39	5	12.8	0	12.8	26	66.7	0	66.7
	M9	40	4	10.0	7.5	2.5	25	62.5	5.0	57.5
	M12	40	11	27.5	27.5	0	19	47.5	47.5	0
	M11A	40	16	40.0	40	0	28	70.0	70.0	0

4.3.2. Temporal Trends at the EGA-LT sites in the Athabasca, Peace and Slave rivers, 2012-2019

In order to directly compare the magnitude of trends between the EGA-LT sites, any parameters that had at least one significant trend, with or without flow-adjustment, were examined in more detail. Parameters that did not show any significance at any sites (n=8) are provided in Appendix A (Table A-1). As the ATS slope estimate calculated by the trend analysis is reported in the WQ parameters original units (i.e. mg/L), displaying these results on one plot is not practical as concentration differences between parameters can be several orders of magnitude. To standardize the annual changes, slopes were divided by the ROS median of the entire sampling period (2012-2019) and then multiplied by 100 to obtain an annual percent change.

One limitation of this method is displaying values with very low concentrations, particularly those close to the method detection limits. Even small changes in concentration can result in a very large percentage change. This result can be amplified after flow-adjustment, as removing the influence of discharge can result in smaller residual concentrations. Scandium dissolved and total, tin dissolved, indium total, and methyl mercury consistently exhibited large percentage increases post-adjustment. Specifically, values such as scandium dissolved at M12 increased from 33% (unadjusted) to 102% (flow-adjusted), and methyl mercury at M11A increased from 8.4% (unadjusted) to 42.6% (flow-adjusted).

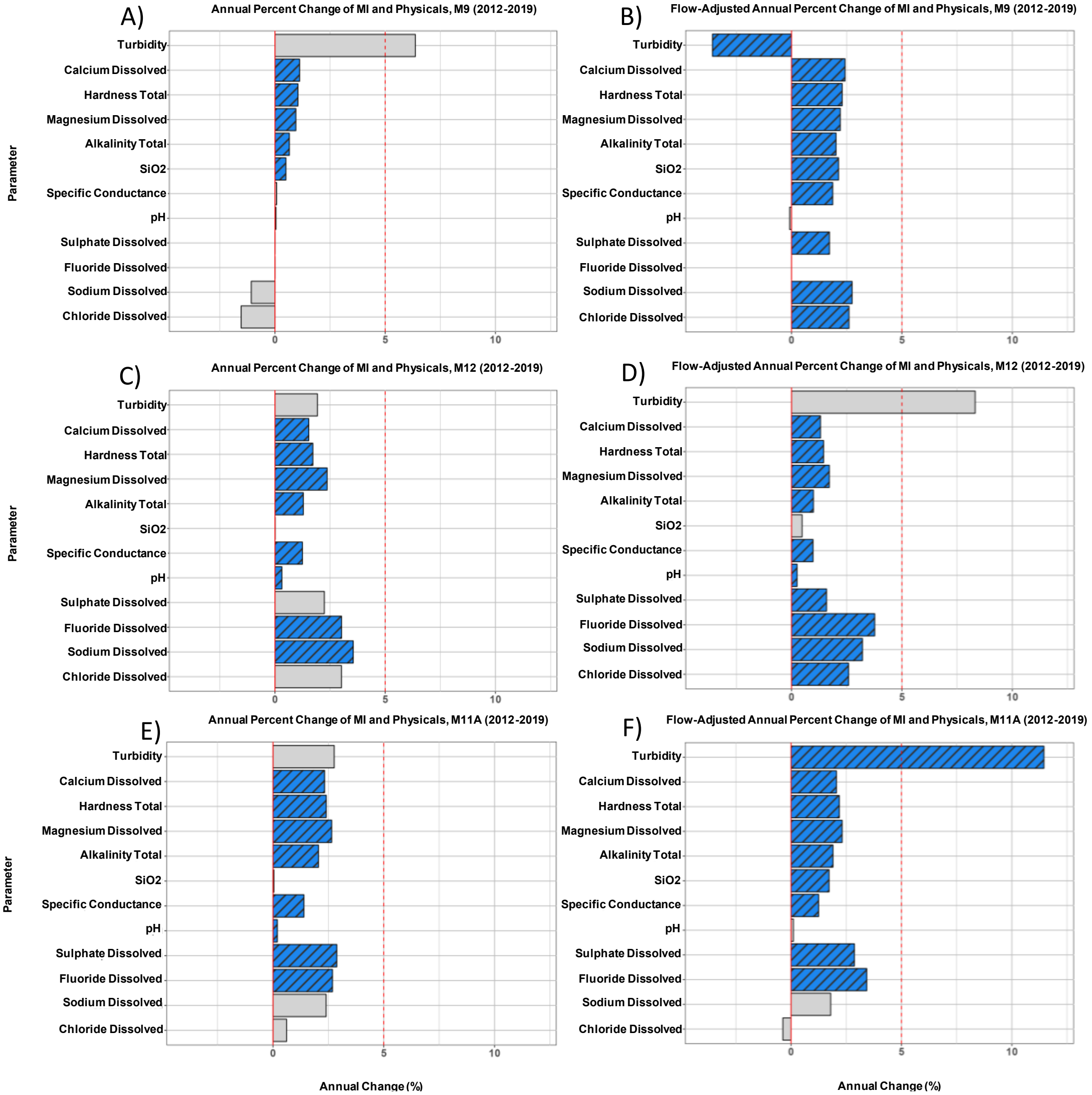

Figure 6. The annual percent change of major ion and physical WQ parameters sampled from M9, M12, and M11A. Trends were calculated with two methods: no flow-adjustment (A, C, E), and flow-adjusted (B, D, F). The percent change is calculated by dividing the concentration slope by the median of the entire sampling period. Parameters are ordered from highest to lowest percent change at the site located on the Athabasca River (M9). The hatched pattern and blue bars highlight significant trends ($p < 0.1$).

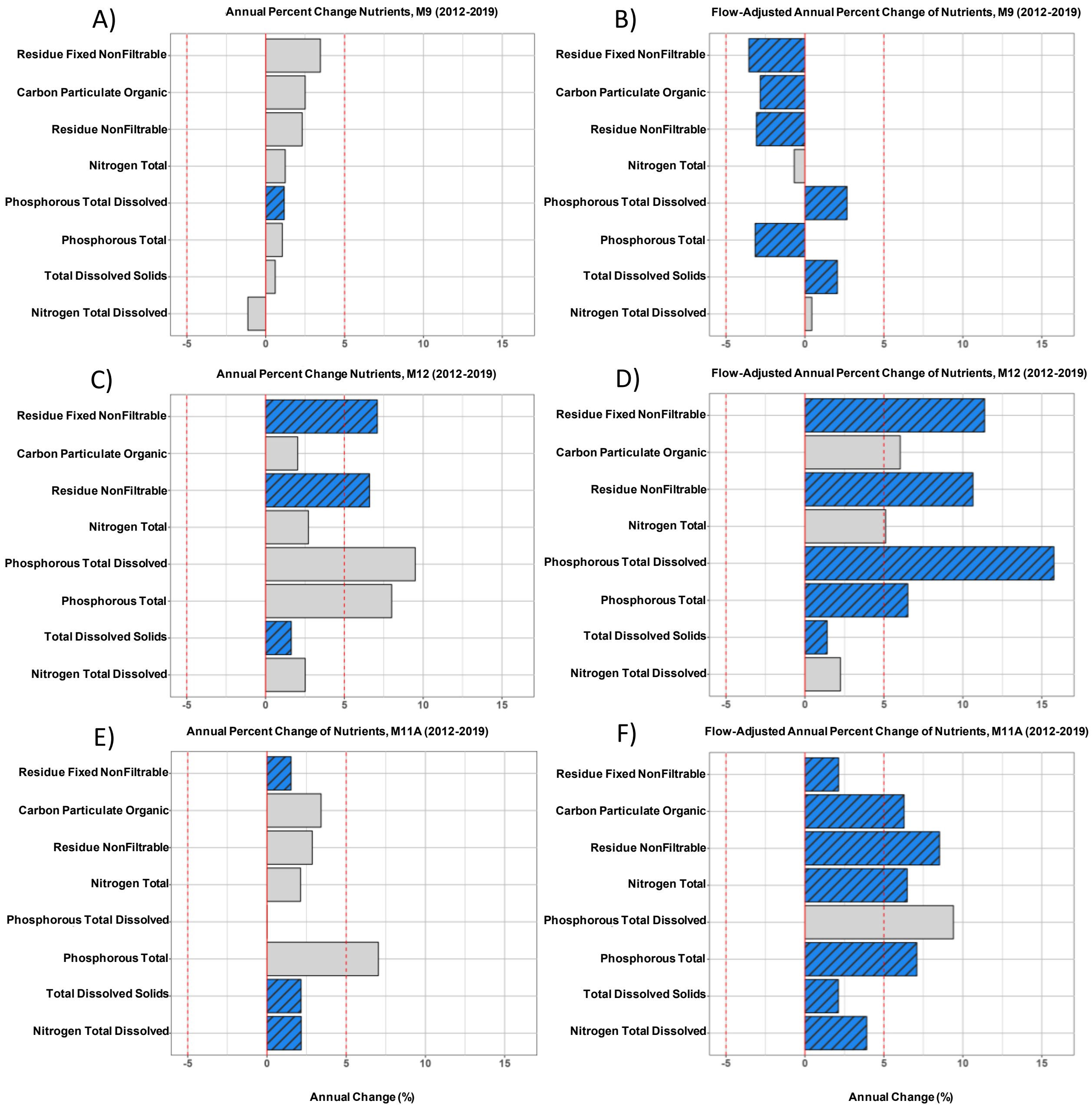

Figure 7. The annual percent change of nutrient WQ parameters sampled from M9, M12, and M11A. Trends were calculated with two methods: no flow-adjustment (A, C, E), and flow-adjusted (B, D, F). The percent change is calculated by dividing the concentration slope by the median of the entire sampling period. Parameters are ordered from highest to lowest percent change at the site located on the Athabasca River (M9). The hatched pattern and blue bars highlight significant trends ($p < 0.1$).

These substantial increases reflect statistical sensitivities associated with extremely low baseline concentrations rather than indicating ecologically meaningful changes. As such, for ease of visual interpretation, any parameters with a percent change due to these statistical sensitives described, were not included in the plots (Fig. 6-13), but are discussed further in text.

For major ions, the results among all three sites was relatively consistent (Fig. 6) After flow-adjusting the data, there were significant increases in alkalinity, calcium, hardness, specific conductance, and sulphate at all three locations. Significant increases in both chloride and sodium were observed at M12 and M9, but not at M11A. Fluoride was significantly increasing at M11A and M12 but not at M9.

There was a notable difference in both the direction and magnitude of trends observed in nutrients between M9 and both M11A and M12 (Fig. 7). Total suspended solids (or residue nonfilterable) and fixed suspended solids (residue fixed nonfilterable) were significant at all three sites. However, both parameters were significantly decreasing at M9, while increasing at M11A and M12. The same pattern was observed for total phosphorus. Turbidity was also decreasing at M9, while there was a strong trend (>10%) observed at M11A. While not significant, there was also a relatively large annual percent change (~8%) observed at M12. There was also a decreasing trend in particulate carbon at M9 that was not observed at either M11A (significant increase) or M12. The strongest trend at any site was a 16% increase in dissolved phosphorus at M12. Total nitrogen was significantly increasing at M11A. While not significant there was a suggestion of an increasing trend at M12.

For the dissolved metal fraction, the only parameter that had a significant trend at all three sites was selenium, which had a significantly increasing trend at M9 (2.0%), M12 (2.4%), and M11A (4.1%) (Fig. 8). There was a significant increase in methyl mercury at both M12 and M11A. Cadmium had a significant decrease at both M12 (-7.1%) and M11A (-8.7%), while no significant trend was observed at M9. There were highly significant increases in several contaminants of concern at M12, including lead, iron, aluminum, chromium, and nickel (Alexander and Chambers, 2016; Kelly et al., 2010). A significant decrease in zinc (9.7%) was observed at M11A, which was a finding not observed at the other locations. The

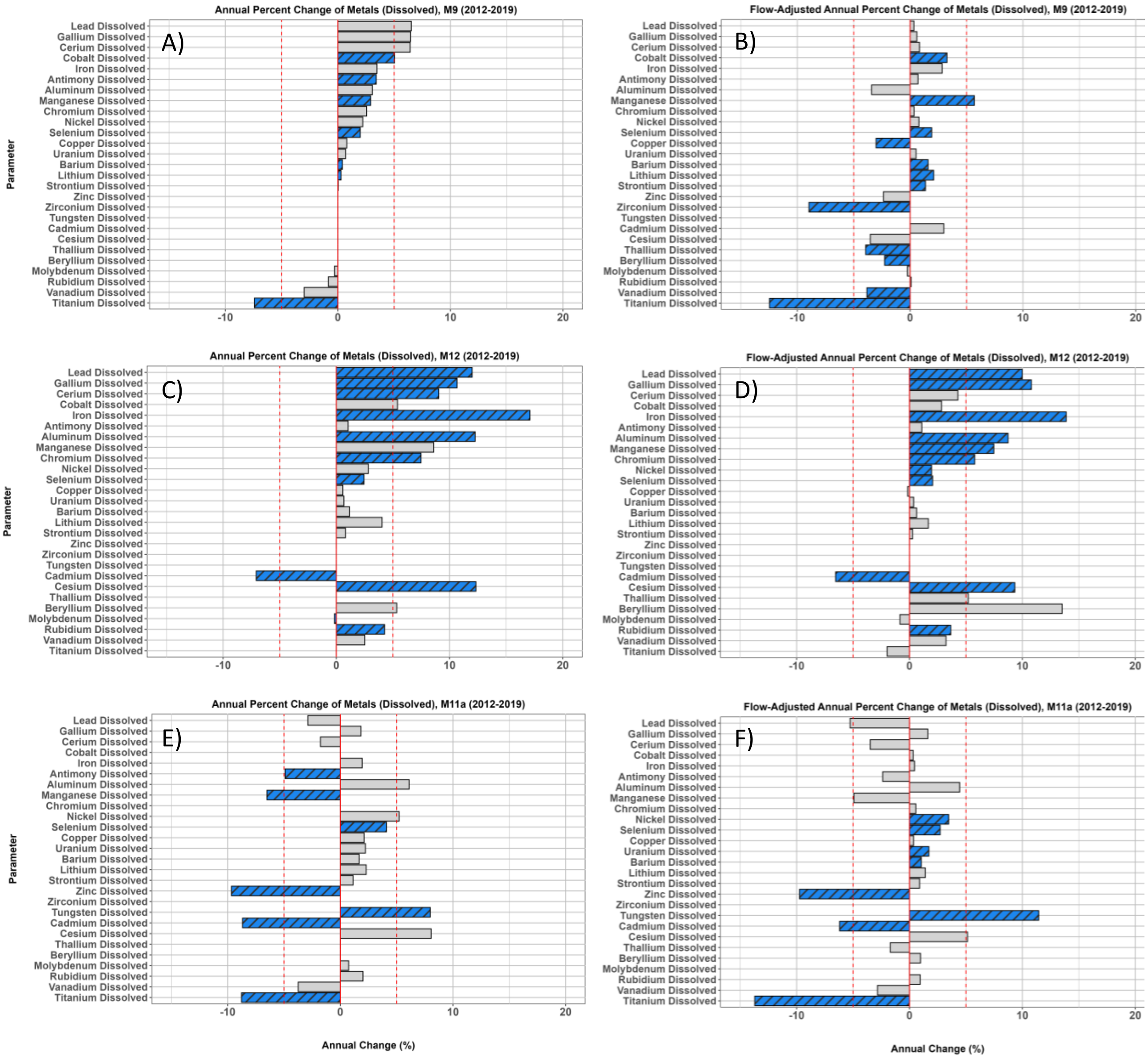

Figure 8. The annual percent change of dissolved metal WQ parameters sampled from M9, M12, and M11A. Trends were calculated with two methods: no flow-adjustment (A, C, E), and flow-adjusted (B, D, F). The percent change is calculated by dividing the concentration slope by the median of the entire sampling period. Parameters are ordered from highest to lowest percent change based on the order they occur at the site located on the Athabasca River (M9). The hatched pattern and blue bars highlight significant trends

only parameter with a difference in significance and direction of trend before and after flow-adjustment was copper at M9 (Fig. 8).

As mentioned previously, the most notable difference among sites for total metals, is the number of decreasing trends observed at M9 after flow-adjustment when compared to both M12 and M11A (Fig. 9). In fact, when comparing similar parameters, neither M12 nor M11A had a single parameter that had a significant decreasing trend before or after flow-adjustment. When compared to M9 after data was flow-adjusted, only boron and strontium had increasing trends, while all other significant results were observed to be decreasing (Fig. 9). This includes several priority contaminants such as aluminum, arsenic, chromium, mercury, and selenium. Conversely, at M12 we observed increasing trends in antimony, cobalt, iron, lead, nickel, selenium, and zinc (Fig. 9). These same parameters were found to have increasing trends at M11A. Additionally, several other priority contaminants sampled at M11A had significantly increasing trends including beryllium, cadmium, chromium, copper, mercury, strontium, and thallium. It is interesting to note that even with the highly significant results for total metals observed at M12 and M11A, this result was not reflected in the dissolved metal trends for the same parameters (Fig. 8-9)).

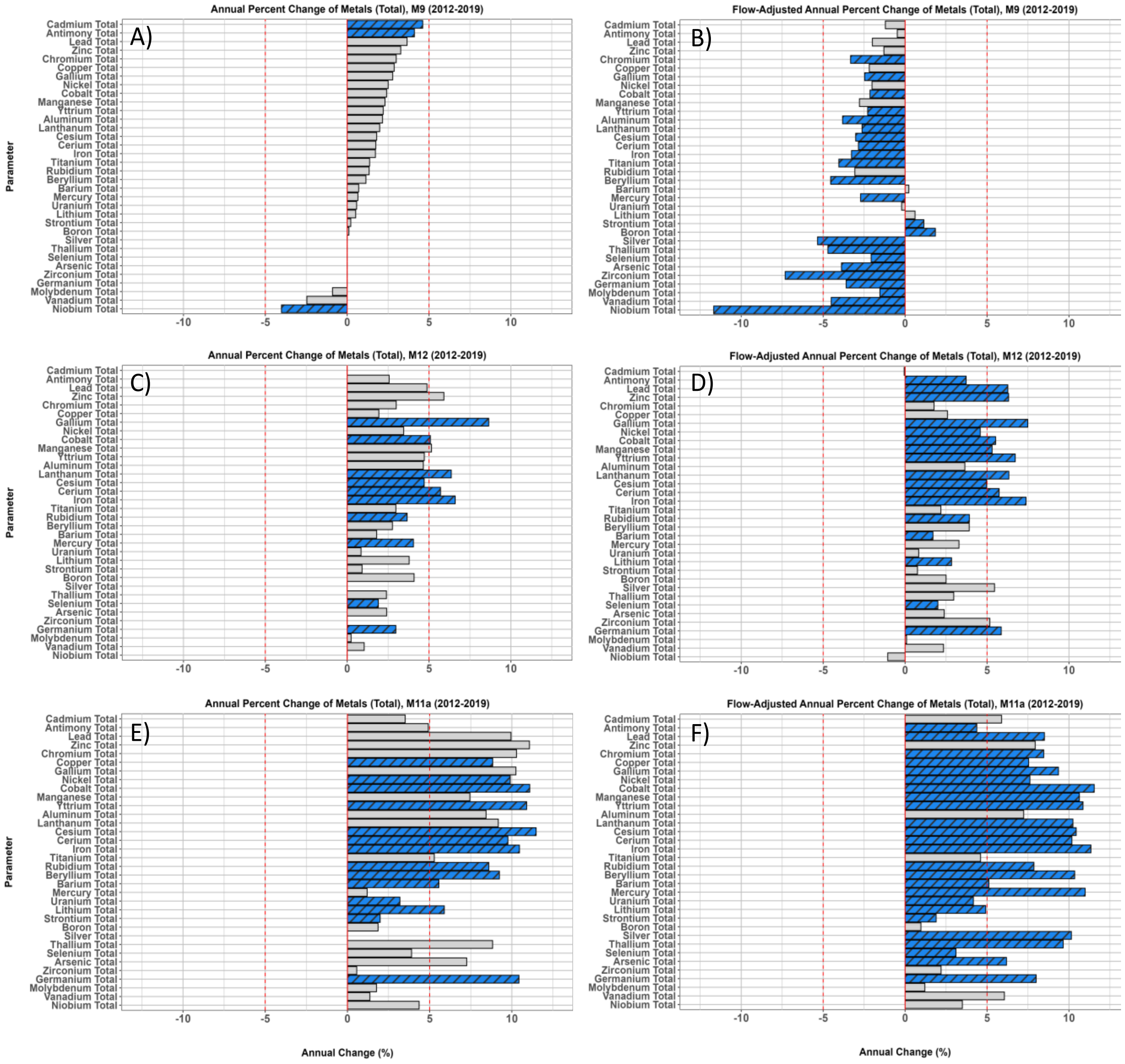

Figure 9. The annual percent change of total metal WQ parameters sampled from M9, M12, and M11A. Trends were calculated with two methods: no flow-adjustment (A, C, E), and flow-adjusted (B, D, F). The percent change is calculated by dividing the concentration slope by the median of the entire sampling period. Parameters are ordered from highest to lowest percent change based on the order they occur at the site located on the Athabasca River (M9). The hatched pattern and blue bars highlight significant trends

4.3.3. Temporal trend results (thalweg) in the Athabasca River (M3-M9) 2012-2019

The previous section addressed comparison of trends observed in the LAR (M9) with trends located in the Peace and Slave rivers (EGA-LT - M11A, M12). To examine trends within the LAR, three sites along the Athabasca River (M3, M7, and M9) were chosen for direct comparison as there are different inputs (tributaries, treatment plants) contributing to the Athabasca River at each site. Additionally, the sites are located at different areas both upstream and downstream of OS mining activities. Examining the WQ data at each of these locations may offer some insight into what is driving differences in observed trends. A total of 325 WQ parameters were analyzed for trends at the three LAR sites: M3 (107), M7 (107), and M9 (111) (Table 5).

As with the previous comparisons among the EGA-LT, to standardize plots among the LAR sites, parameters are ordered on the Y-axis based on the highest to lowest annual percent change values at the most upstream site, M3. For the major ion grouping, there was a significant increase in the annual percentage change of silica (SiO_2) and chloride at all three sites (Fig. 10). The most interesting comparison between the WQ parameters are the dissolved ions (potassium, magnesium, calcium). Regardless of covariate

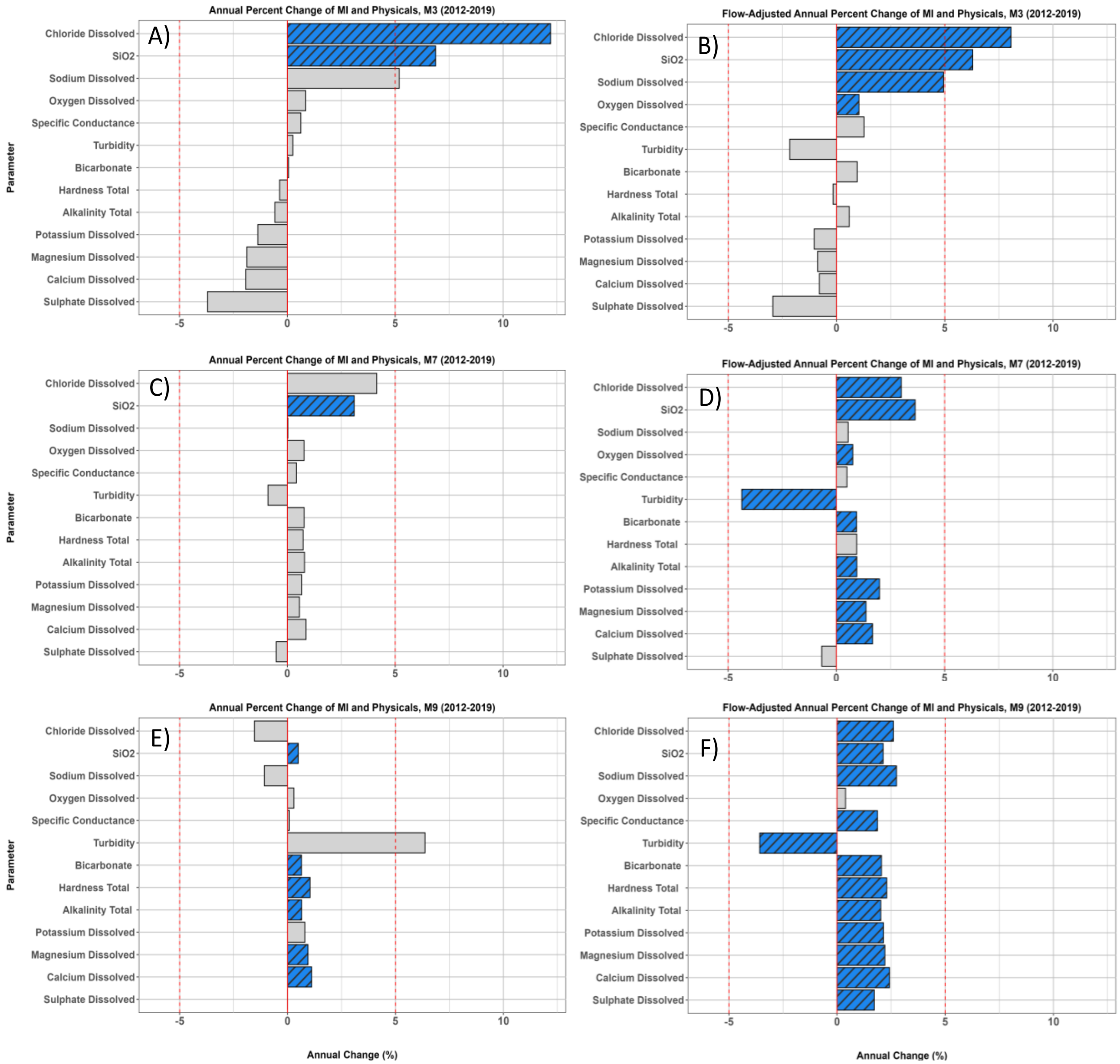

Figure 10. The annual percent change of major ion and physical WQ parameters sampled from M3, M7, and M9. Trends were calculated with two methods: no flow-adjustment (A, C, E), and flow-adjusted (B, D, F). The percent change is calculated by dividing the concentration slope by the median of the entire sampling period. Parameters are ordered from highest to lowest percent change based on the order they occur at the site located furthest upstream on the Athabasca River (M3). The hatched pattern and blue bars highlight significant trends ($p < 0.1$).

adjustment, no significant trends were observed for these ions at M3. This differs for both M7 and M9, where we observed similar increases in potassium, magnesium, calcium, and alkalinity (Fig. 10). Additionally, while not significant, all other statistical results (S, Kendall's Tau, slope estimate) for these same ions were all negative at M3, suggesting a potential decrease. There were significant flow-adjusted trends for decreasing turbidity observed at both M7 and M9. Compared to the previous trend analysis results at M9 (2000-2014), there appears to be an increase in major ions concentration for the most current sampling period (Table 6). After flow-adjustment, Glozier et al., (2018) reported significant increasing trends for 4 major ions parameters, while the current analysis detected 11.

Table 6. Comparison of major ion and nutrient trend results from the OS Technical Report "Surface Water Quality of the Athabasca, Peace, and Slave Rivers and Riverine Waterbodies within the Peace-Athabasca Delta". Results are presented for prior trend analysis (2000-2014) and current sampling period (2012-2019). Seasonal Mann-Kendall results are presented with ("F. Adj.") and without ("Conc.") flow-adjustment. Water quality parameter trends are labelled as either significantly increasing (↑), decreasing (↓), or not significant (↔).

Parameter	**M9**			
	Conc.	**F. Adj.**	**Conc.**	**F. Adj.**
	2000-2014		**2012-2019**	
Major Ions				
pH (pH units)	↑		↔	
Total Suspended Solids (TSS) (mg/L)	↔	↓	↔	↓
Specific Conductance-L (S/m)	↔		↔	↑
Turbidity (NTU)	↓		↔	↓
Alkalinity (mg/L)	↔		↑	↑
Bicarbonate	↔		↑	↑
Calcium (mg/L)	↓	↔	↑	↑
Chloride (mg/L)	↓	↔	↔	↑
Fluoride (mg/L)	↓		↔	
Hardness Total (mg/L)	↔		↑	↑
Magnesium (mg/L)	↔	↑	↑	↑
Potassium (mg/L)	↑		↔	↑
Silica (mg/L)	↑		↑	↑
Sodium (mg/L)	↔	↑	↔	↑
Sulphate (mg/L)	↔		↔	↑
Total Dissolved Solids (mg/L)	↔		↔	↑
Nutrients				
Carbon Dissolved Organic (mg/L)	↔		↔	
Carbon Particulate Organic (mg/L)	↔	↓	↔	↓
Carbon Total Organic (mg/L)	↔		↔	
Ammonia (mg/L)	↓		↔	
Nitrogen Dissolved	↔		↔	
Nitrogen NO_2 & NO_3 (mg/L)	↔	↑	↔	↑
Nitrogen Particulate (mg/L)	↔	↓	↔	↓
Nitrogen Total (mg/L)	↔		↔	
Phosphorous Total Dissolved (mg/L)	↓		↑	
Phosphorous Particulate (mg/L)	↑	↔	↑	↓
Phosphorous Total (mg/L)	↔		↔	↓

For the similar nutrient parameters between all three sites, only total (TSS) and fixed suspended solids (FSS) were significant at all three sites where they were observed to have decreasing trends (Fig. 11). After flow-adjustment, significant decreasing trends in total phosphorus and particulate carbon were observed at M7 and M9 (Fig. 11). There was also a relatively large decrease in nitrogen particulate detected at M9. Compared to the previous trend report, significant decreasing trends in both particulate and total phosphorus were observed that were not reported. Dissolved phosphorus was also observed to have a significantly increasing trend (Fig. 11) over the current sampling period, that was previously reported as a significant decrease (Table 6). The only other parameter that differed from the previous report was dissolved ammonia, which no longer has a significantly decreasing trend.

There were only two parameters with significance observed at all three sites after accounting for flow: titanium and copper (Fig. 12). While all three sites had significant decreasing titanium trends, this was not true for copper. Both M3 and M9 had significant decreasing copper trends, while an increasing trend was observed at M7. A somewhat similar observation was made for lithium

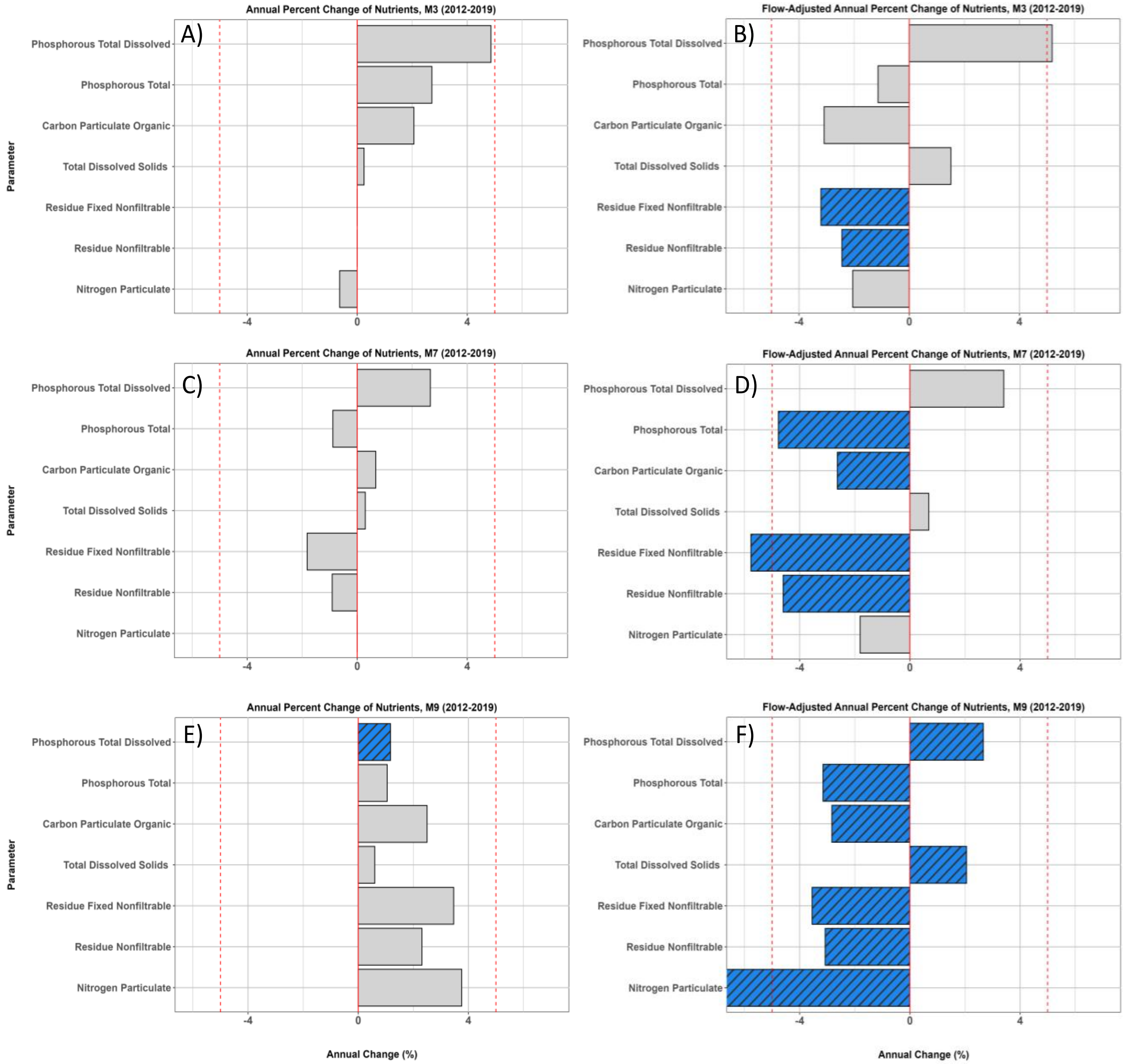

Figure 11. The annual percent change of nutrient WQ parameters sampled from M3, M7, and M9. Trends were calculated with two methods: no flow-adjustment (A, C, E), and flow-adjusted (B, D, F). The percent change is calculated by dividing the concentration slope by the median of the entire sampling period. Parameters are ordered from highest to lowest percent change based on the order they occur at the site located furthest upstream on the Athabasca River (M3). The hatched pattern and blue bars highlight significant trends ($p < 0.1$

concentration, which had increasing trends observed at M3 and M9, but not at M7. The largest increase at M3 was in iron concentration (12%), but this was not reflected at the downstream sites. Both chromium and tungsten had significant increasing trends at M3 and M7, but no significant trend was detected at M9. There were also decreasing trends in beryllium, thallium, and zirconium in WQ samples collected from M9, which were not observed at either M3 or M7 (Fig. 12). The previous trend report detected increasing trends in aluminum, arsenic, and iron that were not detected using the most current dataset (Table 7). They also reported no increase in selenium, which is now significantly increasing regardless of flow-adjustment. Additionally, both copper and vanadium now have significant decreasing flow-adjusted trends.

As mentioned above, the results of the trend analysis suggest that total metal concentrations are decreasing (Table 5). This is made even clearer in the annual percent change graph for M3 – M9 (Fig. 13). At M3, only a single parameter had an increasing concentration trend (germanium), and once flow-adjusted this trend was no longer significant, although the annual percent change increased. In fact, once the data was flow-adjusted the only parameters sampled at any of the LAR sites that had

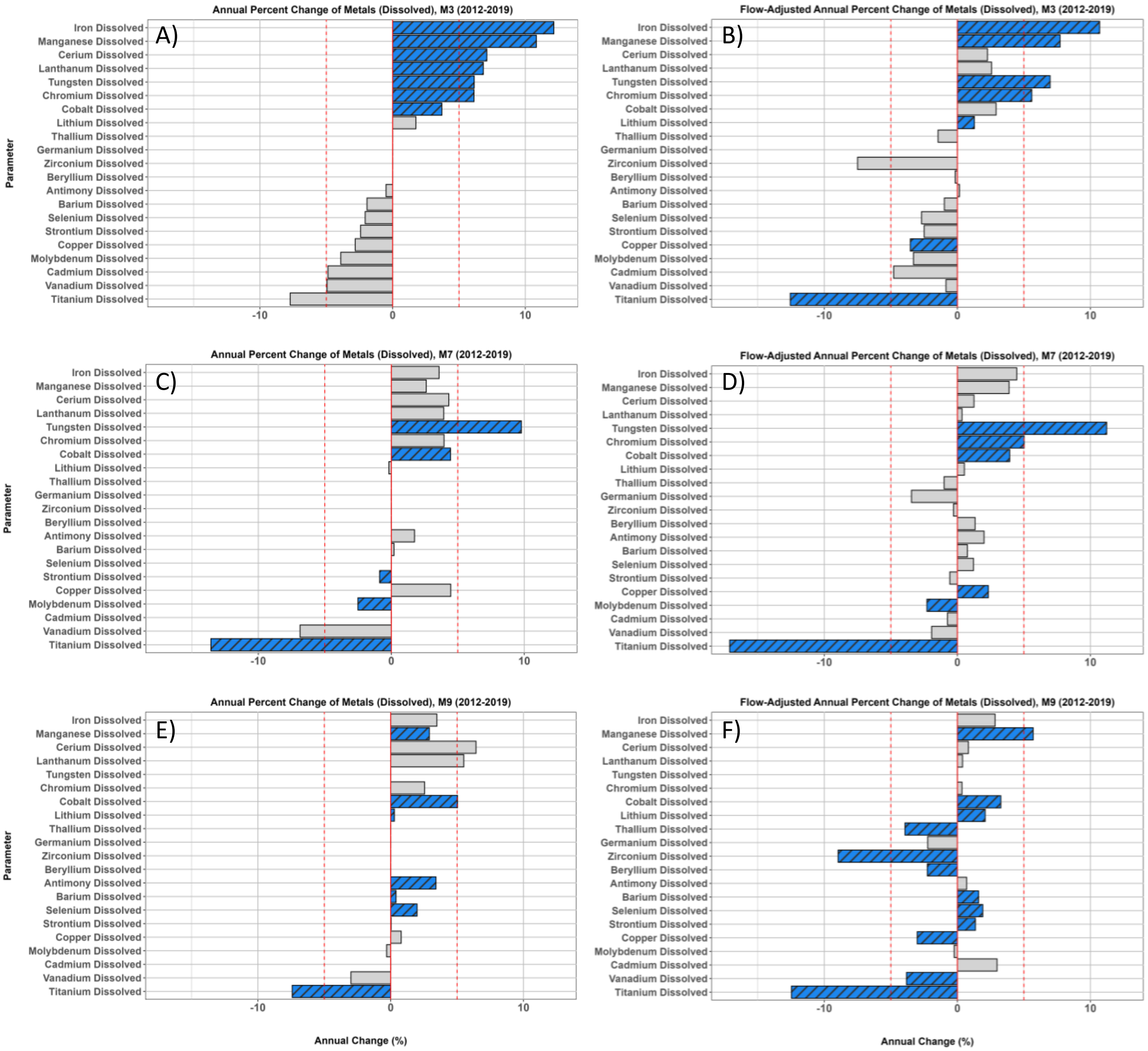

Figure 12. The annual percent change of dissolved metal WQ parameters sampled from M3, M7, and M9. Trends were calculated with two methods: no flow-adjustment (A, C, E), and flow-adjusted (B, D, F). The percent change is calculated by dividing the concentration slope by the median of the entire sampling period. Parameters are ordered from highest to lowest percent change based on the order they occur at the site located furthest upstream on the Athabasca River (M3). The hatched pattern and blue bars highlight significant trends ($p < 0.1$).

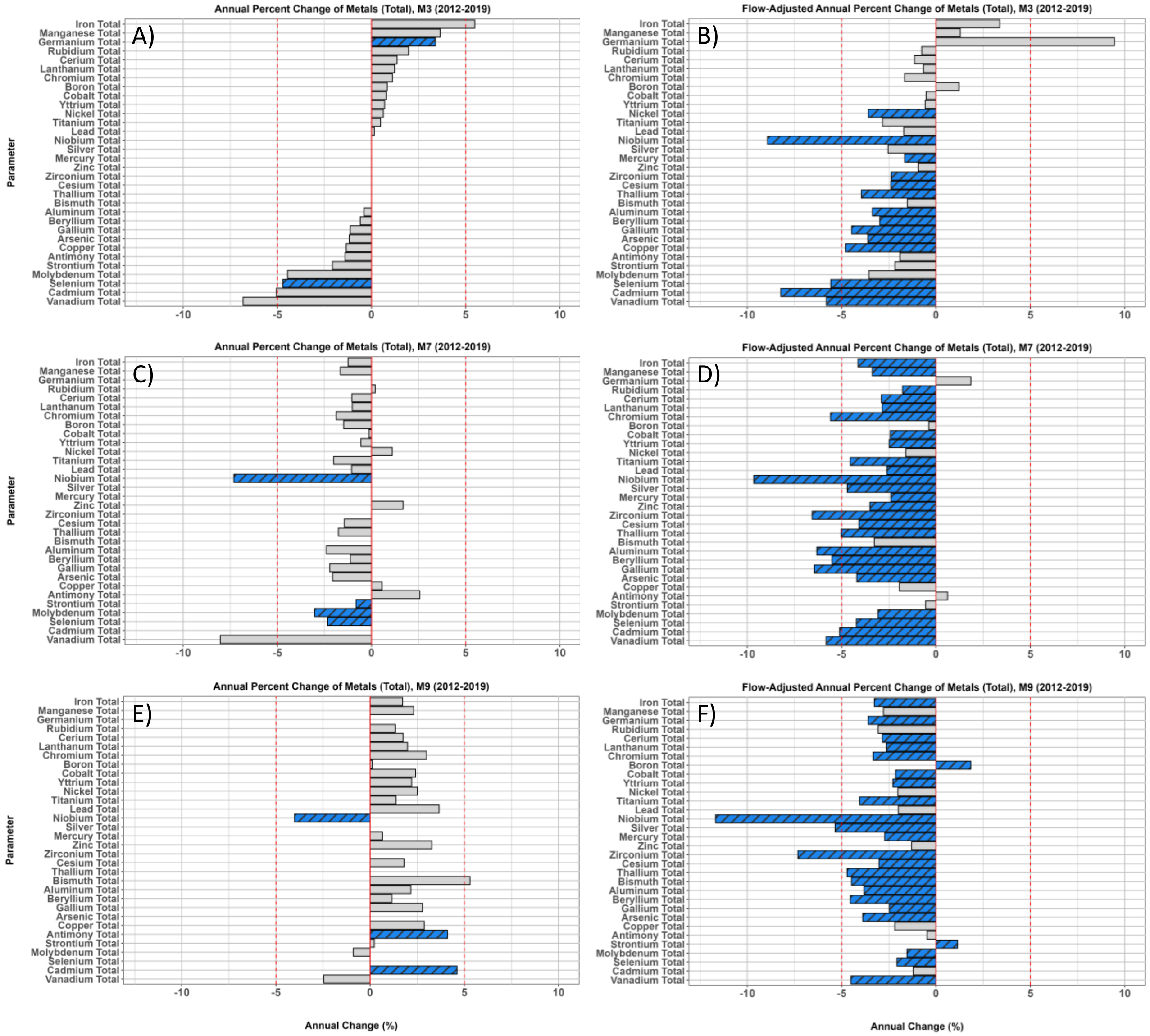

Figure 13. The annual percent change of total metal WQ parameters sampled from M3, M7, and M9. Trends were calculated with two methods: no flow-adjustment (A, C, E), and flow-adjusted (B, D, F). The percent change is calculated by dividing the concentration slope by the median of the entire sampling period. Parameters are ordered from highest to lowest percent change based on the order they occur at the site located furthest upstream on the Athabasca River (M3). The hatched pattern and blue bars highlight significant trends ($p < 0.1$).

an increasing concentration were boron and strontium at M9 (Fig. 13). Unlike with the other parameter groups, there were many total metal parameters that were significant and had the same direction of trend at all sites. Significant decreases in priority contaminants were detected including aluminum, arsenic, beryllium, selenium, thallium, and vanadium. The previous report detected a lone decreasing trend (zinc). While no trend was observed in zinc using the current dataset, four additional decreasing trends were detected (aluminum, iron, selenium, vanadium) that were not previously reported (Table 7). Interestingly, the only significant increasing trend detected by the previous reporting period was total selenium, which is now observed to have a significant decreasing trend.

The previous OS report also touched on WQ trends. While not enough data was present to examine trends at M3 or M7, there was sufficient data to analyze trends at M9. The sampling period for that report was 2000 - 2014. Trend significance and direction were presented, similar to this report, as concentration or flow-adjusted trends. There were several notable differences between the current and earlier reporting period. Based on the comparison, there are a greater number of increasing major ion trends over the most recent period (2012 - 2019) when compared to the previous report (Table 6).

Once flow-adjusted, alkalinity, bicarbonate, calcium, chloride, total hardness, and sulphate all have significant increasing trends that were not detected by the previous report. This seems to suggest an increased input of major ions into the Athabasca River that was not present over the previous sampling period. Unlike major ions, nutrient trends remained relatively consistent between both reports (Table 6). The exception to this was phosphorus. Both total and particulate phosphorus had significant decreasing trends observed over the most recent sampling period, where no trend was detected before. A decreasing trend in dissolved phosphorus, using both unadjusted and flow-adjusted values, was reported over the 2000 - 2014 sampling period. In the current report, increasing concentration and flow-adjusted trends were observed. Increasing trends were previously observed in dissolved arsenic, iron, and aluminum (Table 7). No significant trends were detected in the current report. Decreasing trends are now detected in both copper and vanadium, where no trend was previously reported. Additionally, regardless of flow-adjustment, dissolved selenium has a significantly increasing trend. For total metals, only two WQ parameters had significant trends in the previous report: increasing total selenium and decreasing zinc (Table 7). Additionally, total aluminum, iron, and vanadium now have significantly decreasing trends that were not previously detected.

4.3.4. Potential impact of trends on excursions to CCME Guidelines over 5-10 years

To demonstrate, and preliminary explore, how the trends could potentially impact the health of aquatic ecosystems based on water quality guidelines, we compared the values generated by the trend results to CCME water quality guidelines. The ATS slopes calculated, if significant, indicate a change in concentration over the period of record. If we assume the trend continued at the same rate and in the same direction, we estimated the predicted median values over 5- and 10-year periods (Table A2-A6) post 2019. Interestingly, the only two parameters that exceeded

Table 7. Comparison of total and dissolved metal trend results from the OS Technical Report “Surface Water Quality of the Athabasca, Peace, and Slave Rivers and Riverine Waterbodies within the Peace-Athabasca Delta”. Results are presented for prior trend analysis (2000-2014) and current sampling period (2012-2019). Seasonal Mann-Kendall results are presented with (“F.

Parameter	**M9**			
	Conc.	**F. Adj.**	**Conc.**	**F. Adj.**
	2000-2014		**2012-2019**	
Dissolved Metals (ug/L)				
Arsenic	↑		↔	
Copper	↔		↔	↓
Iron	↔	↑	↔	
Selenium	↔		↑	↑
Aluminum	↑		↔	
Vanadium	↔		↔	↓
Total Metals (ug/l)				
Copper	↔		↔	
Iron	↔		↔	↓
Lead	↔		↔	
Nickel	↔		↔	
Vanadium	↔		↔	↓
Zinc	↓		↔	
Selenium	↑		↔	↓
Aluminum	↔		↔	↓

guideline values consistently were total aluminum and iron and both had slopes that were either not significant or negative. Considering these trend results, and with both parameters having median concentrations higher (or at) the CCME guideline at all sites for the current, 5-year, and 10-year estimates, results would indicate that a change to exceedances for these two parameters, is not expected in the coming decade. Of the four parameters (chloride, fluoride, pH, uranium) at various sites which had significant increasing slopes, none were at a rate of increase that would push the decadal median above the CCME guideline. Total and methyl mercury both displayed significantly increasing slopes at M11A. The slopes for methyl mercury were so small that the predicted median was still orders of magnitude below the guideline. However, for total mercury, while the current median was already slightly above the guideline, with a 63% excursion rate, the five and ten year predicted medians would only be slightly higher. Although we only looked at parameters with CCME guidelines, this exercise was intended to simply demonstrate how the calculated ATS trend slopes could be utilized to identify parameters that have concentrations that may be of concern regarding deteriorating water quality, as evaluated by guideline excursion. This approach could be applied with a broader suite of parameters to other guidelines, concentration triggers or limits of change.

4.3.5. Within site differences in temporal trends M3 and M7 2012-2019

Finally, as previously reported, the water is not fully mixed across the channel at sites downstream of major tributaries (Glozier et al., 2018). Thus, for M3 and M7, we examined if within site differences in the temporal trend results are also evident at different panel locations. At all mainstem river sites, depth integrated samples are collected at the thalweg from the panel with the most flow / depth which is the most consistent representation of WQ conditions. Additional panel sampling at M3 and M7 is ongoing to better capture the inputs from nearby upstream inputs. The original 10 panel sampling was modified and reduced to a three-panel approach with a sample collected from the thalweg and additional samples collected from either panel 1 or 2 (west), and panels 9 and 10 (east). However, the location of the thalweg often moves to different panels depending on the conditions of flow (Fig. 14) and thus can be located at the west or east panels. In cases where the thalweg and east or west panels coincide, sampling was not duplicated.

Similar summary tables indicating the proportion of significant results used for the EGA-LT and LAR sites above were created for the panel sections, and this included all parameters analyzed (Table 8-9). There were many differences in the significance of WQ trends measured between the east and west panels, most notably at M3. There was a large difference in the amount of significantly increasing major ion and physical trends observed between the west panels (57.1%) and the east panels (14.3%) (Table 8). A similar result occurred in dissolved metals as there were more increasing trends near the west shore (45.7%) when compared to the east shore (14.7%) (Table 8). Unlike both major ions and dissolved metals, there was a greater proportion of decreasing nutrient trends observed in west M3 panels (55%) compared to the east panels (14.7%). For total metals, the discrepancy is not as apparent as the number of decreasing trends observed between sampling location remains more consistent.

For M7, it appears that the water in the river becomes more mixed as it flows downstream as the differences in significance are not as large as observed at M3 (Table 9). Similar proportions of significant trends were observed for major ions (east – 43%, west – 48%), total metals (east – 50%, west – 46%), and dissolved metals (east – 33%, west – 34%). Nutrients was the only parameter group that displayed notable discrepancies between panel location, as 33% of parameters sampled from the west panels had significant trends, while no significant trends were observed in the east panels.

The differences in WQ that exist between sampling location can also be highlighted by observing the annual percent change (ATS slope/median of sampling period x 100) of samples collected from both the east and west panels. Any parameter that had a significant concentration or flow-adjusted trend measured from any of the panel sections at M3 or M7 were included. For major ions collected from the panel sections at M3, the suite of similar parameters demonstrates the differences that exist between the trends observed at the west panels, and those observed the east panels (Fig. 15).

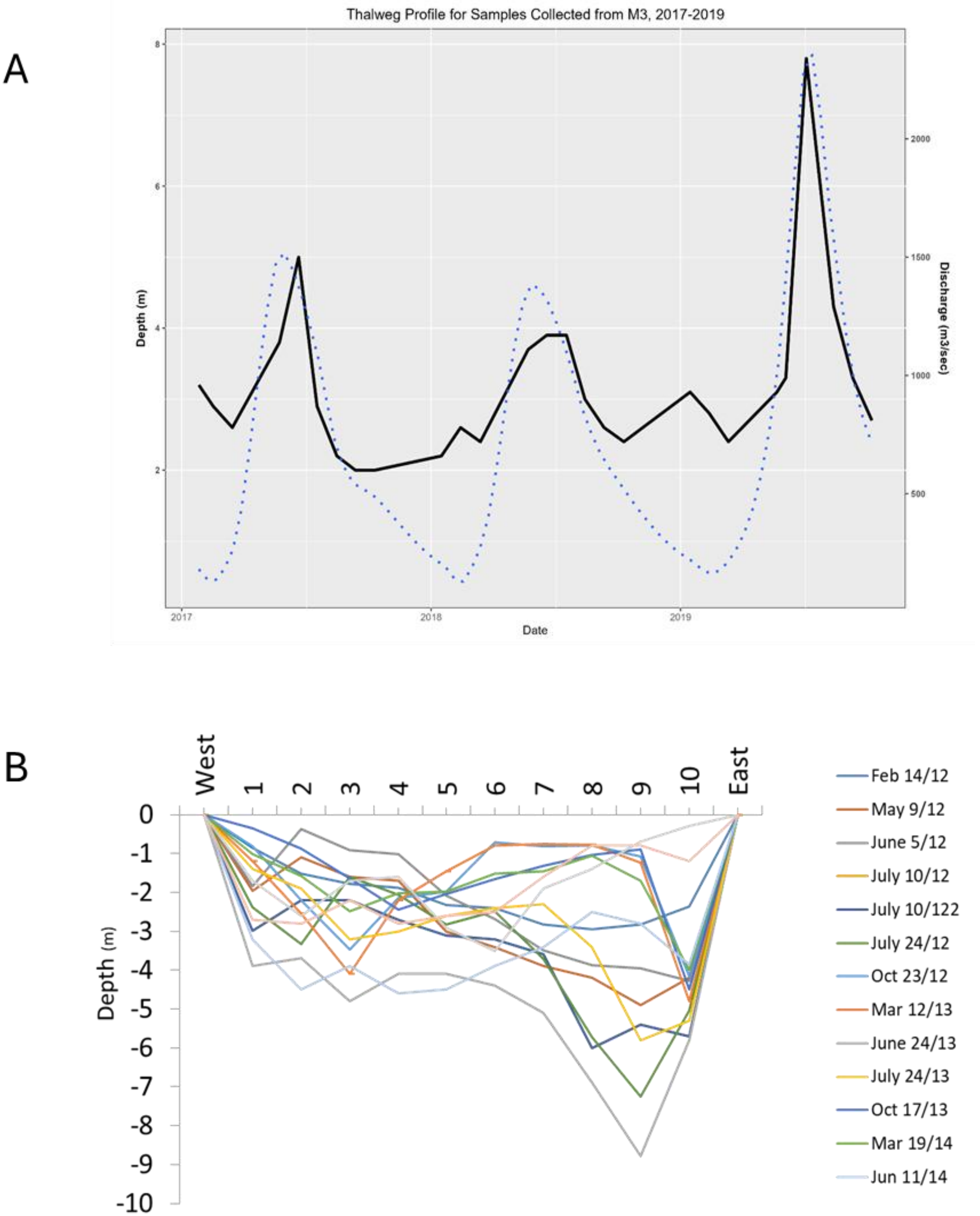

Figure 14. Thalweg depth (metres) and depth cross-section examples at site M3. A) Thalweg depth at time of sample collection from 2017 – 2018. Only one sample was selected per sampling month. The blue dotted line represents the discharge (m^3/sec) at the time of the sample collection. B) Changes in cross-section depth profile from 2012-2017.

Table 8. Proportion of significant WQ trends detected from panel sampling locations at M3. WQ measurements are ordered by parameter group and panel location. Trend results are reported as Concentration (no flow-adjustment) and Flow-Adjusted. The total number ($p < 0.1$) and proportion (Total Sig. %) of significant trends are provided as either concentration (no flow-adjustment) or flow-adjusted. Additionally, the proportion of significant increasing (↑) or decreasing (↓) trends are provided for both trend tests.

				Concentration				Flow-Adjusted			
Group	**Site**	**Panel**	**Total Parameters**	**p < 0.1**	**Total Sig. (%)**	**↑ (%)**	**↓ (%)**	**p < 0.1**	**Total Sig. (%)**	**↑ (%)**	**↓ (%)**
MI and Physicals	M3	East	21	0	0	0	0	4	19.0	14.3	4.8
		West	21	10	47.6	47.6	0	13	61.9	57.1	4.8
Nutrients	M3	East	12	0	0	0	0	4	33.3	0	33.3
		West	12	0	0	0	0	7	58.3	16.7	41.7
Metals (Dissolved)	M3	East	34	7	20.6	14.7	5.9	6	17.6	14.7	2.9
		West	35	8	22.9	22.9	0	16	45.7	45.7	0
Metals (Total)	M3	East	39	1	2.6	2.6	0	13	33.3	2.6	30.8
		West	39	4	10.3	7.7	2.6	15	38.5	5.1	33.3

Table 9. Proportion of significant WQ trends detected from panel sampling locations at M7. WQ measurements are ordered by parameter group and panel location. Trend results are reported as Concentration (no flow-adjustment) and Flow-Adjusted. The total number ($p < 0.1$) and proportion (Total Sig. %) of significant trends are provided as either concentration (no flow-adjustment) or flow-adjusted. Additionally, the proportion of significant increasing (↑) or decreasing (↓) trends are provided for both trend tests.

				Concentration				Flow-Adjusted			
Group	**Site**	**Panel**	**Total Parameters**	**p < 0.1**	**Total Sig. (%)**	**↑ (%)**	**↓ (%)**	**p < 0.1**	**Total Sig. (%)**	**↑ (%)**	**↓ (%)**
MI and Physicals	M7	East	21	8	38.1	38.1	0	9	42.9	42.9	0
		West	21	6	28.6	23.8	4.8	10	47.6	42.9	4.8
Nutrients	M7	East	12	0	0	0	0	0	0	0	0
		West	12	0	0	0	0	4	33.3	0	33.3
Metals (Dissolved)	M7	East	36	4	11.1	11.1	0	12	33.3	30.6	2.8
		West	35	6	17.1	17.1	0	12	34.3	34.3	0
Metals (Total)	M7	East	40	1	2.5	0	2.5	20	50.0	2.5	47.5
		West	39	2	5.1	5.1	0	18	46.2	7.7	38.5

There appears to be a decrease in the magnitude and significance of trends moving from the west to east panels. The major ions from the west panels had the largest annual percentage changes for all major ions and physical parameters. There appears to be a strong influence on the major ions as alkalinity, calcium, conductance, hardness, magnesium, and potassium are all significantly increasing along the west side of the river. These same changes are not observed in samples collected along the east side. At M7, the disparity in trends is not as striking (Fig. 16).

Nutrients measured at M3 had a slightly different pattern as it appears the trends observed along the west and east sides were more closely related than to the thalweg (Fig. 17). FSS, particulate carbon and nitrogen are all significantly decreasing along the west and east sides of the river. Additionally, a decreasing trend in total phosphorus was observed only in samples collected from the west panels. Similarly, increasing dissolved carbon and nitrate/nitrite was detected from the west panels. At M7, there were significant decreasing trends measured in total phosphorus, and both TSS and FSS from the west panels, while there were no significant trends in the east panels (Fig. 18).

Dissolved metal trends at M3 have a similar pattern to the major ions. We observed that the magnitude of percent change and proportion of significance decreases from the west to the east side of the river (Fig. 19). Only one parameter was significant at the east panels that was not significant in the west panels: a decreasing trend in dissolved titanium. Like the major ions, the trends observed at M7 between the west and east panels are more comparable to those measured in the thalweg (Fig. 20). There were six similar increasing trends observed at both shores. For total metals sampled at M3, we observed the same pattern of flow-adjustment resulting in several decreasing trends (Fig. 21). Only two significant increasing trends were observed in any of the panel sections at M3 after accounting for flow: boron and lithium in the west panels. Almost all total metals appear to be decreasing at M7 regardless of sampling location (Fig. 22). Only antimony and barium from the west panels had increasing trends after flow-adjustment.

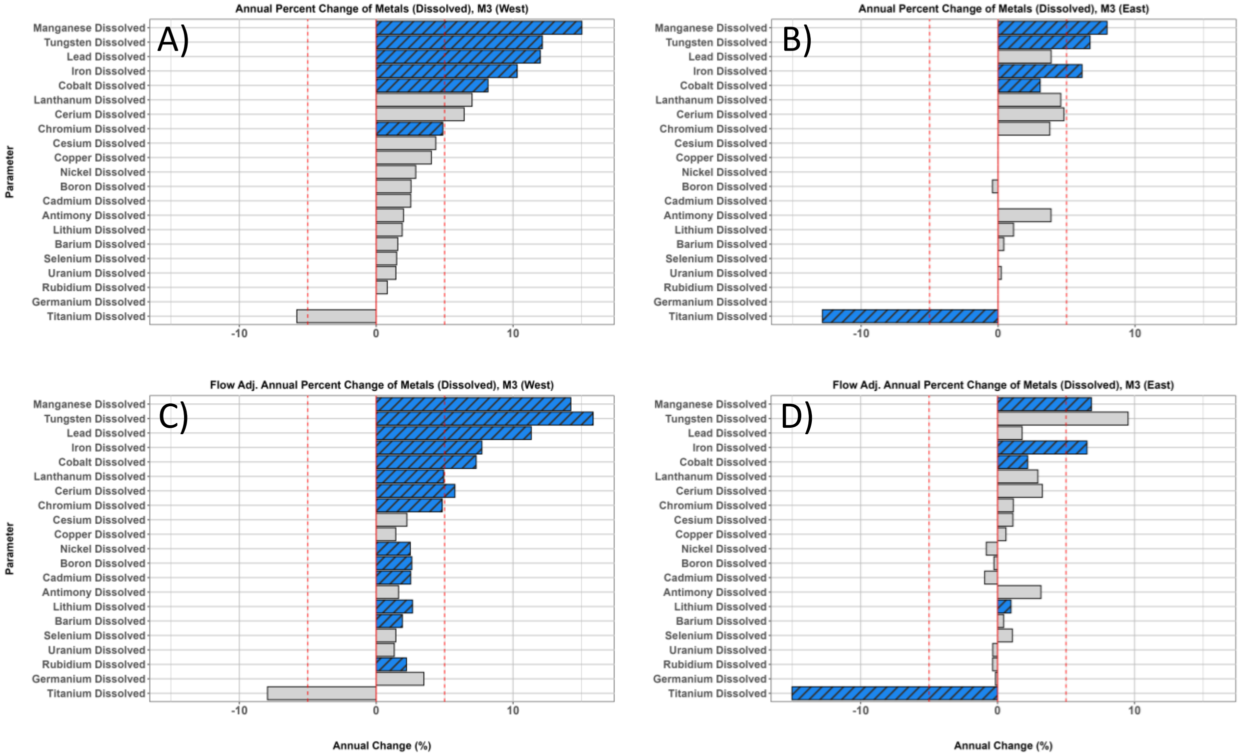

Figure 15. Annual percent change of major ions, physicals, and nutrients measured at M3 from samples collected from: A) West panels, B) East panels , C) West panels (flow adj.), D) East panels (flow adj.). Blue bars with stripes represent a significant trend detected by the statistical test. Parameters are ordered based on the highest and lowest values from the west panel samples.

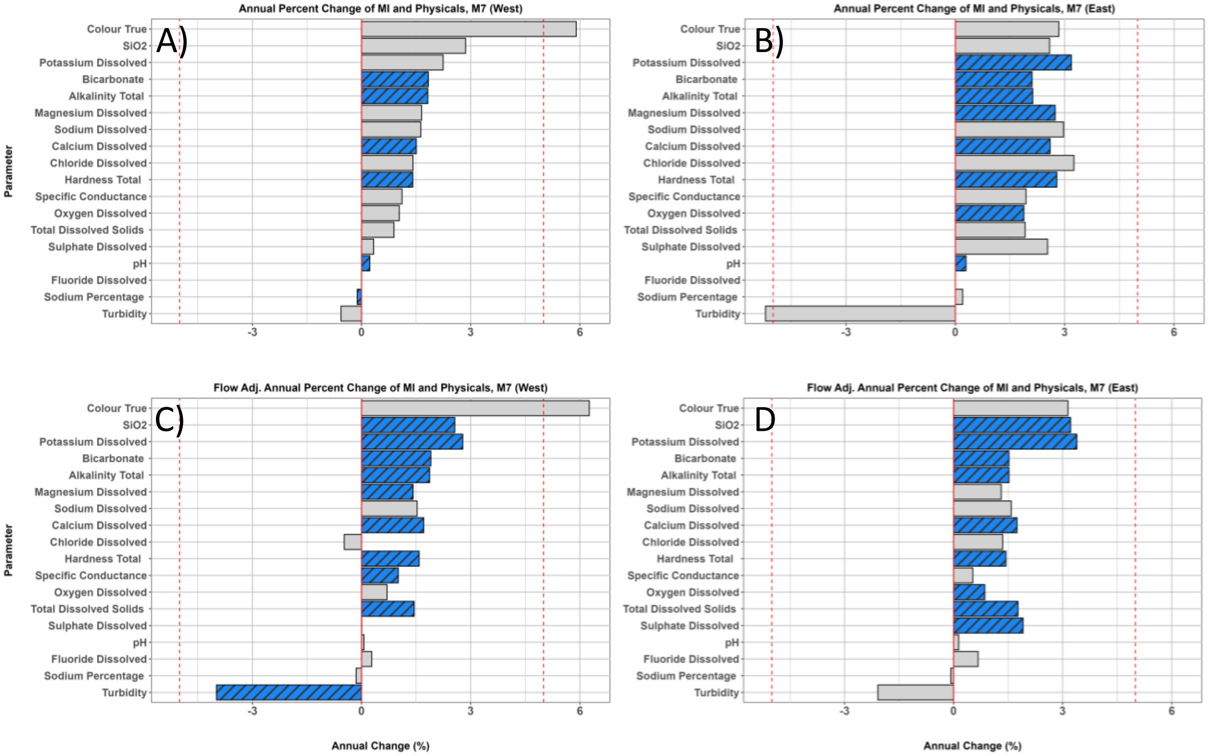

Figure 16. Annual percent change of major ions and physicals measured at M7 from samples collected from: A) West panels, B) East panels , C) West panels (flow adj.), D) East panels (flow adj.). Blue bars with stripes represent a significant trend detected by the statistical test. Parameters are ordered based on the highest and lowest values from the west panel samples.

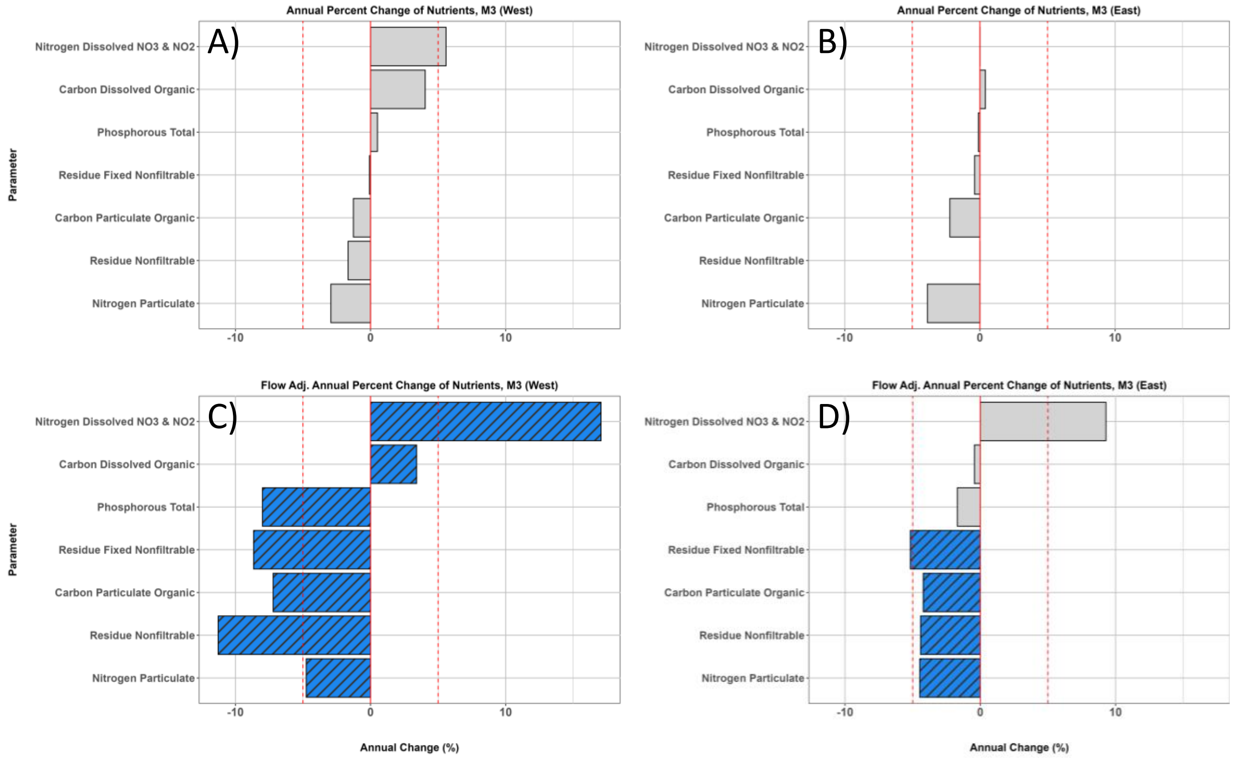

Figure 17. Annual percent change of nutrients measured at M3 from samples collected from: A) West panels, B) East panels , C) West panels (flow adj.), D) East panels (flow adj.). Blue bars with stripes represent a significant trend detected by the statistical test. Parameters are ordered based on the highest and lowest values from the west panel samples.

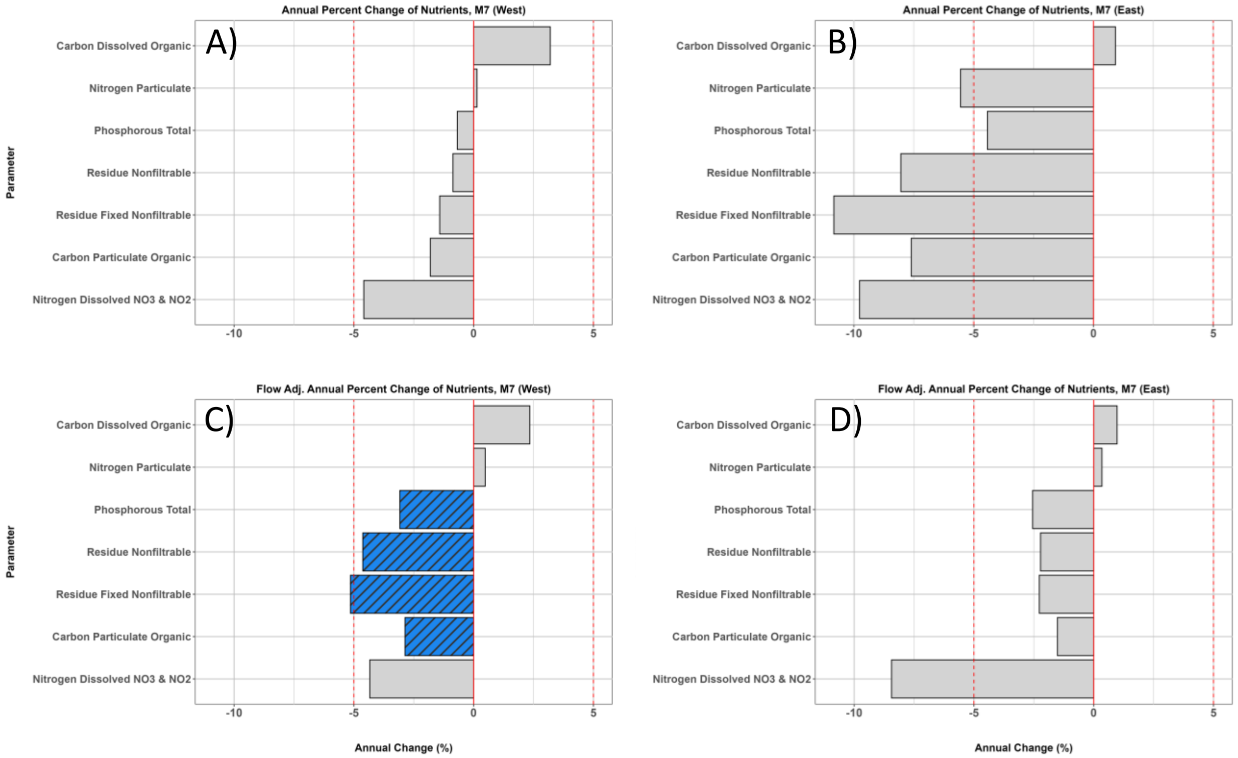

Figure 18. Annual percent change of nutrients measured at M7 from samples collected from: A) West panels, B) East panels , C) West panels (flow adj.), D) East panels (flow adj.). Blue bars with stripes represent a significant trend detected by the statistical test. Parameters are ordered based on the highest and lowest values from the west panel samples.

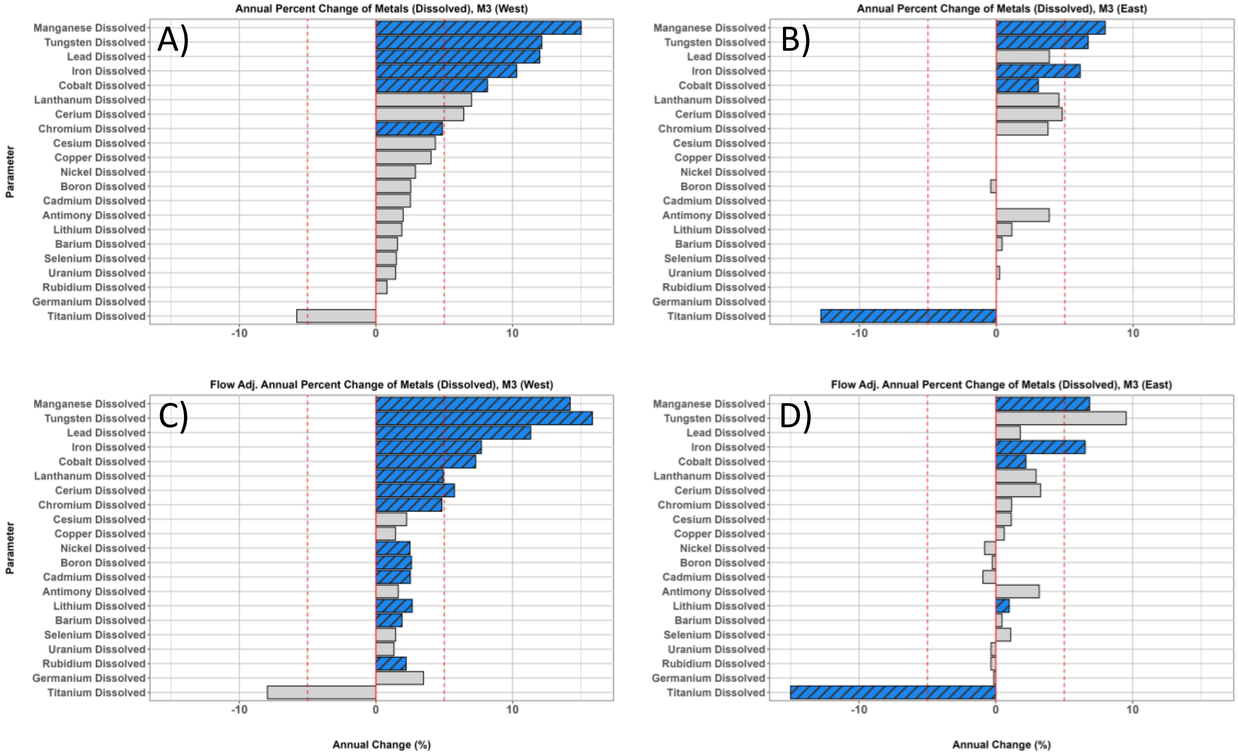

Figure 19. Annual percent change of dissolved metals measured at M3 from samples collected from: A) West panels, B) East panels , C) West panels (flow adj.), D) East panels (flow adj.). Blue bars with stripes represent a significant trend detected by the statistical test. Parameters are ordered based on the highest and lowest values from the west panel samples.

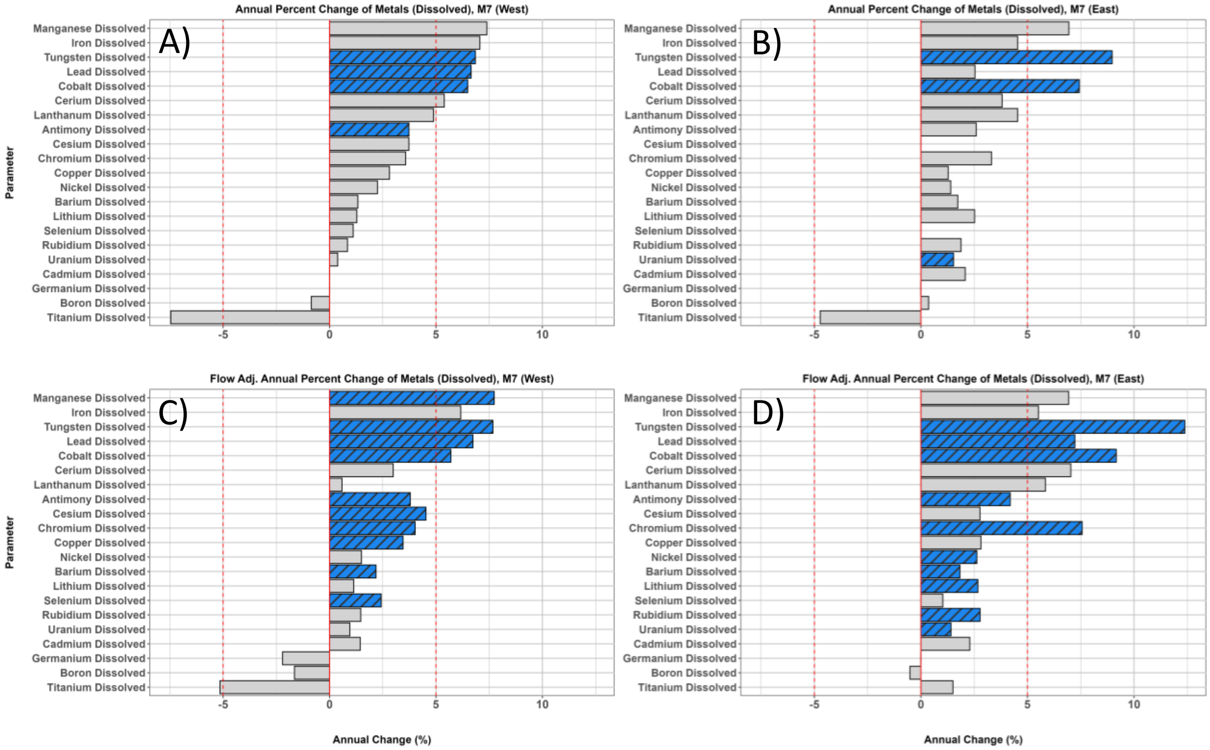

Figure 20. Annual percent change of dissolved metals measured at M7 from samples collected from: A) West panels, B) East panels , C) West panels (flow adj.), D) East panels (flow adj.). Blue bars with stripes represent a significant trend detected by the statistical test. Parameters are ordered based on the highest and lowest values from the west panel samples.

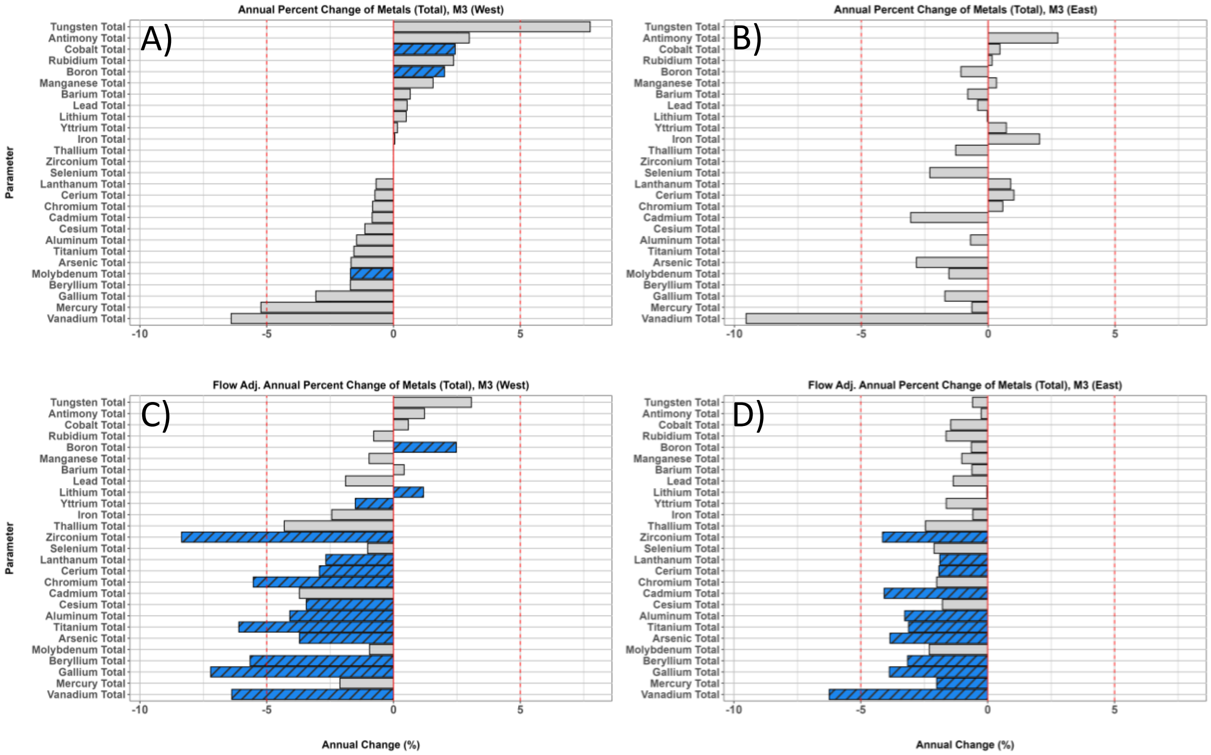

Figure 21. Annual percent change of total metals measured at M3 from samples collected from: A) West panels, B) East panels , C) West panels (flow adj.), D) East panels (flow adj.). Blue bars with stripes represent a significant trend detected by the statistical test. Parameters are ordered based on the highest and lowest values from the west panel samples.

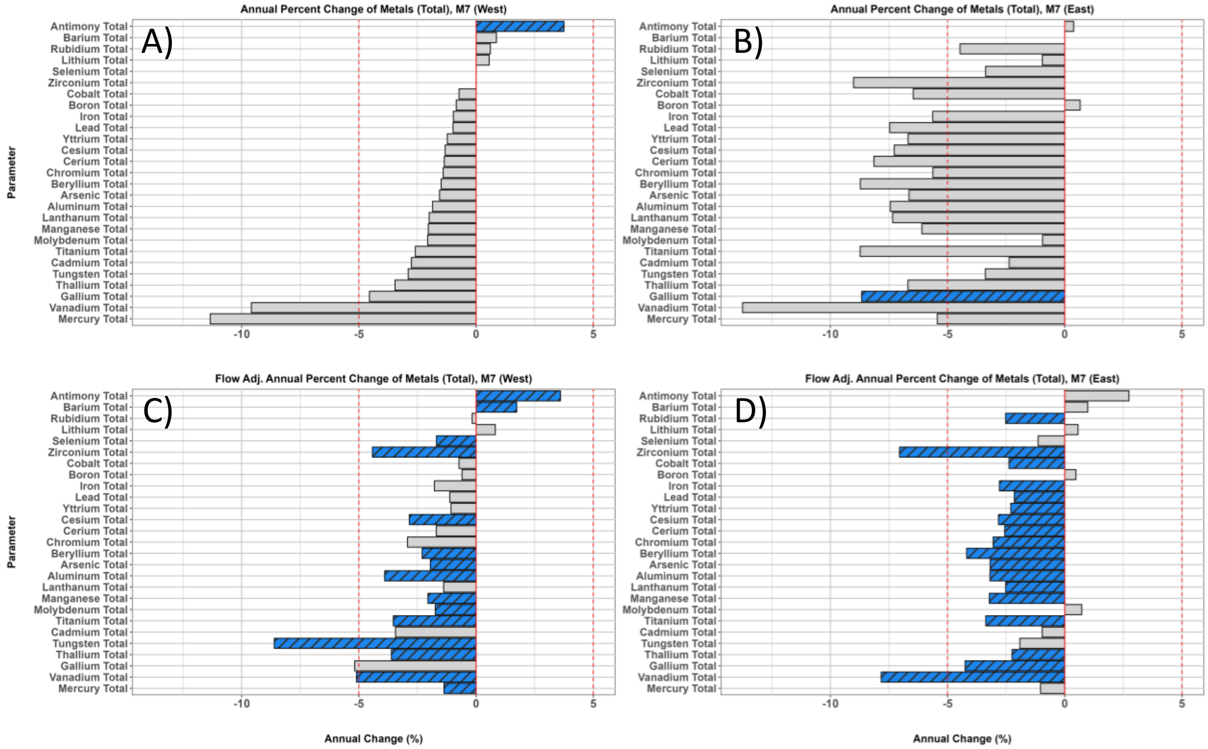

Figure 22. Annual percent change of total metals measured at M7 from samples collected from: A) West panels, B) East panels , C) West panels (flow adj.), D) East panels (flow adj.). Blue bars with stripes represent a significant trend detected by the statistical test. Parameters are ordered based on the highest and lowest values from the west panel samples

5. Discussion

5.1. Comparison of trends results from previous reports

The comparison of trends between the previous sampling period (2000–2014) and the current study (2012–2019) highlights the dynamic nature of WQ conditions in the Athabasca River and underscores the importance of long-term monitoring. Notable differences in the trends of major ions, nutrients, and metals were observed, highlighting potential changes in the sources influencing WQ over time. For instance, the current analysis detected significant increasing trends in flow-adjusted major ions such as alkalinity, bicarbonate, calcium, chloride, and sulphate, which were not present in the previous sampling period. This suggests an increased input of major ions into the river during the most recent sampling period. In contrast, nutrient trends remained relatively consistent between the two periods, with the exception of phosphorus. While decreasing trends in total and particulate phosphorus were observed in the current period, dissolved phosphorus exhibited a shift from a previously decreasing trend to a significant increasing trend. Similarly, trends in dissolved and total metals revealed notable changes, such as a shift from increasing trends in dissolved arsenic, iron, and aluminum to no significant trends in the current analysis, and new decreasing trends for dissolved copper and vanadium. These shifts emphasize how continued monitoring enables the detection of evolving trends that would otherwise go unnoticed if sampling had concluded at the end of the previous period. Such insights are critical for understanding the drivers of WQ variability and adapting monitoring efforts to address emerging challenges effectively.

5.2. EGA-LT sites in the Athabasca, Peace and Slave rivers, 2012-2019

The comparison of the LAR (M9) and the EGA-LT sites (M11A, M12) offers valuable insights into the spatial variability of WQ trends both “within” and outside the areas affected by OS mining activities. The analysis highlights regional similarities and differences and provides a clearer understanding of other background patterns that are occurring in river systems. The major ions, physicals, and nutrient parameters had approximately the same magnitude and direction of trends across all three sites, reflecting overarching regional patterns. The only exception was particulate carbon and total phosphorus, which were decreasing at M9. Another interesting observation included comparisons for the dissolved metals at M9 and M11A (Fig. 8). After accounting for flow, trends at these two sites resemble each other more closely, compared to M12, even though M12 contributes more discharge to the Slave River than the Athabasca River. In contrast, total metal trends exhibited a different dynamic, with M12 and M11A showing similar patterns that were largely opposite to those observed at M9. This is one of the more relevant findings of the trend analysis. Even though the concentrations of total metals may be higher than what is measured at both M12 and M11A, the overall trend observed at M9 is that these metals have been decreasing over time.

5.3. Temporal trend results (thalweg) in the Athabasca River (M3 – M9) 2012-2019

The comparison of trends along the longitudinal course of the LAR sites (M3, M7, M9) reveals significant spatial and temporal variability in WQ parameters. Flow-adjusted trend analysis demonstrated an increasing proportion of significant trends downstream from M3, with M9 exhibiting the highest frequency of significant trends for most parameter groups, including major ions and nutrients. This is true for all ions except chloride and silica at M3. The opposite pattern is observed for nutrient concentrations, as similar parameters have significant decreasing trends over time. There were consistent decreases in total metal trends observed at all three sites. In general, both M7 and M9 had a greater number of decreasing total metal trends when compared to M3, with M7 having the highest proportion of trends observed to be significant. The differences observed between the sites suggests that downstream inputs may play a role in influencing WQ conditions.

One of the goals of analyzing the WQ trends in this region is attempting to account for potential influences of the surrounding OS mining activities. While this report cannot identify the specific causes of these trends, we can highlight parameters that warrant more focused analyses in future reporting. The large number of WQ parameters assessed (~500) can make it challenging to understand the potential drivers of individual trends. To focus on a key list of parameters, we created criteria that would focus on WQ parameters where results suggest a potential linkage to OS activities. As mentioned, M3, M7, and M9 represent areas upstream, within and downstream of the active OS mining region. They are all located sequentially along the Athabasca, so upstream inputs will influence the sites located downstream. We examined whether trends were similar in both significance and direction between M3 and either M7 or M9. If the same significant trend was observed at all LAR sites, it was considered unlikely that oilsands activities were the primary driver. Parameters with significant trends observed only at M3 were also considered unrelated to OS activity. We grouped parameters based on three criteria: 1) similar significant trend observed at all LAR sites, 2) significant trend observed only at M3, and 3) significant trend observed at M7 and/or M9 but not at M3. The full list of grouped parameters is provided in Table 10. Applying these criteria to all assessed parameters provided a reduced list of 45 that may be influenced by oil sands activities, as there are significant trends observed at one or both downstream sites (M7, M9) and not present at M3, the site upstream of OS activity (Table 11).

To further refine this list, we compared trends at M7 and M9 (Athabasca River) to trends observed at M12 (Peace River). This was done to identify trends that were similar in these two large northern rivers. Although river-specific drivers may differ, parameters with similar trends in both rivers were considered more widespread within the broader surrounding area rather than unique to the sites downstream of the Oil Sands Activity area. This screening resulted in a further reduced list of 32 parameters that warranted closer examination (Table 11). Of these 32 parameters, there were 10 that had a significantly increasing trend observed at either M7 or M9 that was not present at M12. These include major ions (potassium), metals (dissolved = antimony, barium, copper, strontium; total = boron, cadmium, strontium) and nutrients (NO3 and NO2). The increasing trends of these parameters may suggest a source that exists within the OS mining region. There were also 10 instances where significantly decreasing trends were observed at M7 and/or M9 while an increasing trend was observed at M12. This included several metals and total phosphorus (Table 11). Finally, there were no USEPA priority contaminants that had similar significant trends across all five sites.

5.4. Within site differences in temporal trends M3 and M7 2012-2019

Panel sampling was continued at M3 and M7 because evidence showed that these two sites are not fully mixed across the channel. In fact, Glozier et al., (2018) reported that concentration of parameters associated with suspended sediments were lower nearer to the shore, while dissolved parameters had higher concentrations. In addition, the patterns in cross section WQ concentration vary by site and time of year. Thus, as there is now sufficient data, we examined whether trend results also differed from east and west bank panels.

The proportional significance (Table 8-9) show that there are differences in trend results based on which panel the WQ sample is collected within the site cross-section. At M3, differences across channel could be due to several sequential upstream influences. The Athabasca River at M2 is upstream of the inputs from both the Horse and Clearwater rivers which both enter the LAR on the east side. The FMWWTP effluent enters the LAR on the west bank, downstream of the Clearwater River and the effluent path often varies with flow and sand bed profile, particularly in low flow. Although it is difficult to isolate the multiple influences at M3, it is recommended that the current panel sampling and evaluation of trends should continue to assess within site differences. If further elucidation of the source of the trend differences at M3 is of interest, an additional site above the WWTP, but below the confluence of the Clearwater may be warranted. Alternatively, if sufficient long-term data is available, additional trend analysis could be conducted at M2, and in both the Clearwater and Horse rivers in relation to trends at M3.

Similarly, at M7, there are differences in trend results depending on cross section location. However, the cross-sectional differences appear to be less pronounced than those observed at M3. The west bank is largely Ells River waters, as the confluence is less than a km upstream (0.8 km). However, for the remainder of the cross section, horizontal mixing of the LAR may generally be greater at this location when compared to M3. Other than the Ells on the west bank, other major tributaries are much further upstream (the MacKay River at 17.5 km; the Muskeg River at 21.6 km and the Steepbank River at 36.7 km). Considering that the water is not fully mixed at this site we recommend the panel sampling continue. However, the addition of a site further downstream could be considered where the river is fully mixed to allow calculations of total loadings prior to the entry of the Firebag River. A site upstream of the Firebag (M8) was sampled in the past by wading from the left and right shore (Glozier et. al., 2018), but access to sample cross sections including the thalweg would be logistically challenging due to the requirement of a boat and the distance downstream. As sampling is currently being reinitiated at site between M3 and M7 (i.e., M4, M5, M6), it is recommended that this is a greater priority than the addition of a fully mixed site downstream of the current M7.

Table 10. WQ quality trends observed at M3 – M9. Trends are identified as: Significant flow-adjusted and concentration (S-S), significant flow-adjusted only (NS-S), significant concentration trend only (S-NS), and no significant trend (NS-NS). A brief explanation of how each trend should be interpreted is provided below each trend label. Significant trends ($p < 0.1$) are presented as increasing (↑), decreasing (↓). Parameters are organized into three groups: 1) same significance and trend direction at all, 2) significant at M3 and M7 or M9, 3) no significance at M3, but significant at M7 and/or M9.

Parameter Group	M3				M7				M9			
	S-S	NS-S	S-NS	NS-NS	S-S	NS-S	S-NS	NS-NS	S-S	NS-S	S-NS	NS-NS
	trend not linked to changes in Q	lack of concentration trend in part masked by changes in Q	trend at least in part linked to changes in Q	no evidence of trend	trend not linked to changes in Q	lack of concentration trend in part masked by changes in Q	trend at least in part linked to changes in Q	no evidence of trend	trend not linked to changes in Q	lack of concentration trend in part masked by changes in Q	trend at least in part linked to changes in Q	no evidence of trend
Sig. Trend and Same Direction at All Sites (*except copper dissolved*) (n = 19)												
Chloride Dissolved	↑					↑				↑		
Sio2	↑				↑				↑			
Tungsten Dissolved	↑				↑					↑		
Aluminum Total		↓				↓				↓		
Arsenic Total		↓				↓				↓		
Beryllium Total		↓				↓				↓		
Cesium Total		↓				↓				↓		
Gallium Total		↓				↓				↓		
Mercury Total		↓				↓				↓		
Niobium Total		↓			↓				↓			
Residue Fixed Nonfiltrable		↓				↓				↓		
Residue Nonfiltrable		↓				↓				↓		
Selenium Total	↓				↓					↓		
Thallium Total		↓				↓				↓		
Tin Total		↓				↓				↓		
Titanium Dissolved		↓			↓				↓			
Vanadium Total		↓				↓				↓		
Zirconium Total		↓				↓				↓		
Copper Dissolved		↓				↑				↓		
Sig. Trend at M3 but No Trend at either M7 or M9 (n = 16)												
Cerium Dissolved			↑					-				-
Iron Dissolved	↑							-				-
Lanthanum Dissolved			↑					-				-
Scandium Total			↑					-				-
Tellurium Total	↑				**N/A**				**N/A**			
Tin Dissolved	↑							-				-
Copper Total		↓						-				-
Nickel Total		↓						-				-
Chromium Dissolved	↑					↑						-
Oxygen Dissolved		↑				↑						-
Scandium Dissolved	↑				↑							-
Lithium Dissolved		↑						-	↑			
Manganese Dissolved	↑							-	↑			
Sodium Dissolved		↑						-		↑		
Germanium Dissolved			↑				↓					-
Cadmium Total		↓				↓					↑	
No Sig. Trend at M3 but Sig. Trend at either M7 and/or M9 (n = 46)												
Alkalinity Total CaCO3				-		↑			↑			
Bicarbonate (Calcd.)				-		↑			↑			
Calcium Dissolved				-		↑			↑			
Magnesium Dissolved				-		↑			↑			
Potassium Dissolved				-		↑				↑		
Antimony Dissolved				-				-			↑	
Antimony Total				-				-			↑	
Barium Dissolved				-				-	↑			
Boron Total				-				-		↑		
Hardness Total (Calcd.) CaCO3				-				-	↑			
Methyl Mercury				-				-			↑	
Phosphorous Total Dissolved				-				-	↑			
Selenium Dissolved				-				-	↑			
Specific Conductance				-				-		↑		
Sulphate Dissolved				-				-		↑		
Total Dissolved Solids (Calcd.)				-				-		↑		
Bismuth Dissolved	**N/A**					↑			**N/A**			
Nitrogen Dissolved NO3 & NO2				-			↓			↑		
Specific Conductance				-				-		↑		
Strontium Dissolved				-			↓			↑		
Strontium Total				-			↓			↑		
Bismuth Total				-				-		↓		
Cadmium Dissolved				-				-			↓	
Nitrogen Particulate				-				-		↓		
Thallium Dissolved				-				-	↓			
Vanadium Dissolved				-				-		↓		
Zirconium Dissolved				-				-		↓		
Lead Total				-		↓						-
Manganese Total				-		↓						-
Molybdenum Dissolved				-	↓							-
Rubidium Total				-		↓						-
Zinc Total				-		↓						-
Carbon Particulate Organic				-		↓				↓		
Cerium Total				-		↓				↓		
Chromium Total				-		↓				↓		
Cobalt Total				-		↓				↓		
Iron Total				-		↓				↓		
Lanthanum Total				-		↓				↓		
Molybdenum Total				-	↓					↓		
Niobium Dissolved	**N/A**				↓				↓			
Phosphorous Total				-		↓				↓		
Silver Total				-		↓				↓		
Titanium Total				-		↓				↓		
Turbidity				-		↓				↓		
Yttrium Total				-		↓				↓		
Cobalt Dissolved			↑		↑				↑			

Table 11. List of significant WQ Trends that are not significant at M3 but are at either M7, M9, or M12. Significant trends ($p < 0.1$) are presented as increasing (↑), decreasing (↓). Arrows highlighted in blue indicate a concentration only trend.

Parameter	M7	M9	M12
Major Ions and Physicals			
Alkalinity Total CaCO3	↑	↑	↑
Calcium Dissolved	↑	↑	↑
Magnesium Dissolved	↑	↑	↑
Bicarbonate (Calcd.)	↑	↑	-
Hardness Total (Calcd.) CaCO3	-	↑	↑
Specific Conductance	-	↑	↑
Sulphate Dissolved	-	↑	↑
Turbidity	↓	↓	-
Nutrients			
Potassium Dissolved	↑	↑	-
Phosphorous Total Dissolved	-	↑	↑
Total Dissolved Solids (Calcd.)	-	↑	↑
Nitrogen Dissolved NO3 & NO2	↓	↑	-
Nitrogen Particulate	-	↓	-
Carbon Particulate Organic	↓	↓	-
Phosphorous Total	↓	↓	↑
Dissolved Metals			
Selenium Dissolved	-	↑	↑
Antimony Dissolved	-	↑	-
Barium Dissolved	-	↑	-
Beryllium Dissolved	-	↓	-
Copper Dissolved	↑	↓	-
Strontium Dissolved	↓	↑	-
Thallium Dissolved	-	↓	-
Vanadium Dissolved	-	↓	-
Zirconium Dissolved	-	↓	-
Cadmium Dissolved	-	↓	↓
Molybdenum Dissolved	↓	-	↓
Total Metals			
Antimony Total	-	↑	↑
Boron Total	-	↑	-
Cadmium Total		↑	-
Lead Total	↓	-	↑
Manganese Total	↓	-	↑
Rubidium Total	↓	-	↑
Zinc Total	↓	-	↑
Strontium Total	↓	↑	-
Bismuth Total	-	↓	-
Chromium Total	↓	↓	-
Molybdenum Total	↓	↓	-
Silver Total	↓	↓	-
Titanium Total	↓	↓	-
Cerium Total	↓	↓	↑
Cobalt Total	↓	↓	↑
Iron Total	↓	↓	↑
Lanthanum Total	↓	↓	↑
Yttrium Total	↓	↓	↑

6. Summary and Recommendations

Long-term water quality monitoring is essential for assessing aquatic ecosystem health and guiding environmental management. This report updates WQ trends for five sites located along the Athabasca, Peace, and Slave Rivers from 2012 to 2019, utilizing improved statistical methods to better handle censored WQ data. The findings of this report revealed significant spatial and temporal variability in WQ trends outside and within the OS mining region.

Comparison of the LAR (M9) with the EGA-LT revealed spatial patterns in WQ trends within and outside of areas influenced by OS activities. Similar trends in major ions, physical parameters, and nutrients were observed across all three sites suggesting broad regional drivers. Exceptions included both total phosphorus and particulate carbon decreasing at M9. Metals displayed interesting patterns, dissolved metal trends were more comparable at M9 and M11A, while total metal trends at M12 and M11A displayed patterns opposite the decreasing trends observed at M9.

Trends across the three LAR sites (M3, M7, M9) showed increasing spatial and temporal variability downstream. Flow-adjusted results revealed that M9 had the highest number of significant trends in major ions and nutrients. Nutrient concentrations generally decreased over time, while total metal concentrations showed consistent decreasing trends at all three sites. M7 and M9 exhibited more significant total metal declines than M3, indicating that downstream inputs may influence observed WQ conditions. Although comparison of trend results to other sites are completed with the thalweg sample, significant within-site variability at M3 and M7 highlighted the importance of continued panel sampling to accurately capture local influences like tributaries and wastewater.

Although we have simplified the trend results and summarized them based on site comparisons to infer potential influence of Oil Sands activities (Table 10 and Table 11), next steps would be to examine all significant trends in more detail for potential sources. For example, a parameter that is increasing at all LAR sites may still be influenced by cumulative downstream inputs, so should not necessarily be dismissed from further investigation. However, by grouping these parameters based on both the significance and direction of the trend, a subset of 45 parameters showed significant trends at one or both LAR sites downstream of OS activity (M7, M9) but not upstream (M3), suggesting potential OS influence. Comparison with M12 further reduced the list to 32 WQ parameters with unique trends near OS activity.

Several general observations can be highlighted for trends in the three LAR sites (M3, M7, and M9):

- There were 18 parameters with similar trends at all LAR sites including chloride (increasing), 12 total metals (decreasing), including vanadium, arsenic and mercury, as well as TSS. All decreasing trends were at least in part related to changes in discharge.

- There were eight parameters with significant trends observed only at M3. These included increasing total (scandium, tellurium) and dissolved (cerium, iron, lanthanum, tin) metals, and a decrease in both total copper and nickel.

- Finally, 45 parameters showed significant trends at either M7 and/or M9 and not at M3. These included increasing trends in eight major ions (e.g. sulphate), two nutrients, five dissolved metals (e.g., antimony, methyl mercury, selenium), and four total metals (including antimony, boron, and strontium). Conversely, numerous parameters showed decreasing trends, including four nutrients and turbidity, seven dissolved metals (e.g., cadmium, chromium, molybdenum, thallium, vanadium), and fifteen total metals (e.g., chromium, iron, molybdenum, cobalt).

Of the 45 parameters that showed significant trends downstream of Oil Sands activities in the LAR, when compared to the results from Peace River (M12), the following highlights emerge:

- There were 10 parameters at M12 that showed trends similar to the downstream LAR sites (M7 and/or M9), including 6 major ions, 1 nutrient, 2 dissolved metals and 1 total metal. These parameters included sulphate, TDS, total dissolved phosphorus, dissolved selenium, and cadmium.

- There were 22 parameters that showed significant trends only at the LAR downstream sites (M7 and/or M9), and not at M12. These included increasing trends in potassium, NO3/NO2, three dissolved metals and three total metals. However, many decreasing trends were observed in the LAR sites that were not present at M12. These included 10 total metals, 6 dissolved metals including vanadium, 3 total or particulate nutrients and turbidity.

Thus, by examining the patterns among sites, next steps can focus on those parameters that are exhibiting unique trends at the downstream LAR sites.

Several recommendations are provided for consideration below:

1. Subsequent analyses with current data set:

   There are several subsequent or additional analyses that could be considered with the current data set (2012-2019), time permitting. These include but are not limited to:

   - The updated approach outlined in this report for handling censored WQ data and trend analysis will be the methods utilized in future WQ reports.
   - An exploration of the season-specific trends (i.e. trends occurring specifically in winter, fall, or summer). Seasonally subdividing the annual trends analyzed in this report may reveal more about timing and thus potential sources contributing to the WQ conditions. This is especially true in winter when ice cover alters the contributions of inputs to the river such as reduced atmospheric deposition and flow from tributaries (Shakibaeinia et al., 2017). This leaves groundwater and anthropogenic sources (wastewater effluent) as major contributors to WQ during the winter.
   - There were very clear differences observed in the trends at each panel section. This was especially true at M3 where the samples taken closest to the west shore had a higher proportion of significant trends, most notably for major ions and physicals, and dissolved metals. This is not surprising given the proximity to upstream inputs, including the FMWWTP and the Clearwater River; however, it remains difficult to isolate their individual contributions. While placing a monitoring site upstream of the FMWWTP but downstream of the Clearwater River confluence may help clarify their respective contributions, the first recommended step is further data exploration and trend analysis at additional sites to better understand the sources of variation in cross-section trends.
   - Similarly, several tributaries (Steepbank, Muskeg, Mackay, Ells, and Firebag rivers) contribute waters upstream of the 3 mainstem LAR sites. As these tributaries represent potential sources of natural and anthropogenic inputs that may influence WQ trends observed at downstream LAR sites, data availability at sites from near their mouths could be explored for complementary data to evaluate linkages to the current trends.

2. Future WQ trend analyses for LAR and EGA-LT sites:

   For future WQ trend analyses there are several recommendations that are derived from the current analysis including:

   - It is recommended that for the next detailed trend reporting period, at a minimum, an additional three years of consistent monthly WQ data be available after the 2020-2021 gap. As previously described, the current trend analysis spanned the time frame of 2012 to 2019. There were several reasons we limited the current analysis to this time frame. First, we initiated the trend analyses in 2022 and ingested the data available at that time. Due to the global pandemic, sampling was suspended in 2020, and only partial sampling was conducted in 2021, leaving a gap in the data, with the next full year of monthly sampling only commencing in spring of 2022. One advantage of the non-parametric seasonal Mann-Kendall test is its ability to handle datasets with missing values; however, several guidelines exist regarding the acceptable size of data gaps. Generally, gaps should not exceed one-third of the total sampling period, and there must be at least two years of complete data available before and after the gap (Snelder et al., 2021). Thus, even if data had been available from 2022, the two-year data gap at the time would not meet these criteria. An additional three years (2022-2024) of WQ data is now largely available (some samples from late 2024/winter 2025 are still being analyzed at laboratories). Having 10 years of consistent seasonal data is regarded as a best practice, allowing for sufficient time to detect trends and minimize short-term variability, thus setting the stage for the next detailed report being sometime after the end of the 2026 sampling period when all data has been received, verified and validated from the analytical laboratories.
   - The focus of this report was a comparison of previous and current trend methods, and an update to the timeframe of the observed trends. As such, there were many hundreds of parameters included in the report. While these trend tests help provide a thorough understanding of WQ conditions at these sites, including 500

parameters in ongoing reporting, it is very time-consuming and unnecessarily complex in terms of interpretability. We reported many significant trends at all sites, but many of these trends are likely to be highly correlated, meaning an increase in one parameter will likewise be observed in another. To assess this, we conducted correlation analyses within each site for over 100 parameters, resulting in large correlation matrixes or heatmaps (Fig. A-1). Parameters with strong Kendall's Tau values (>0.6) were identified and their relationships were mapped to determine the extent of their correlations. An example of this correlation grouping is given in Appendix A (Table A-7). By identifying which parameters are highly correlated (Tau >= 0.6), it would be possible to select a parameter as a representative for other WQ parameters in future statistical analyses. Using these representative parameters is helpful not only by decreasing the amount of work required but also reducing the complexity of interpreting the trend data. Another possibility is identifying how the correlation groups coincide or differ between sampling locations. Parameters that consistently group together across sites suggest shared influences, such as geological, hydrological, or climatic factors. Conversely, differences in grouping may highlight localized inputs, such as point-source pollution or distinct land-use practices. Integrating correlation analysis into future trend analysis would provide a more efficient and focused methodology for understanding complex water quality trends and their underlying drivers. It is recommended that these approaches be considered in future trend analyses.

- This report replaces the substitution method (i.e., using half the detection limit) previously used to handle censored data. The current approach employs the ATS method, which provides a more robust and statistically appropriate analysis of censored data. It is recommended that this method be adopted in future water quality reporting.

- Finally, there are also emerging techniques for detecting trends in environmental data. One of these methods, "Weighted Regressions on Time, Discharge, and Season" (WRTDS), is a flexible approach designed to analyze water quality data (Hirsch et al., 2010). This method has existing documentation (Hirsch & De Cicco, 2015) and is available through the R package EGRET (Explorations and Graphics for River Trends). Some of the major advantages of WRTDS are: 1) It does not assume discharge versus concentration relationships have the same shape over the entire period of sampling, 2) that data does not have to be linear, 3) it does not assume that seasonal patterns remain the same, and 4) it will also account for flow. It was not used in this report as the newer OSM sites (M3, M7) do not currently meet the minimum sample number requirements (>100). However, WRTDS could be used on historical sites (M9, M11A, M12) if additional periods are requested (i.e. before 2012) or in future analyses when sufficient long term trend data is available.

3. Sampling frequency

- After a review of the monitoring program in 2009 (Glozier et al., 2009) sampling frequency at the three EGA-LT sites was established as monthly, with the effective sampling frequency being 9X / year due to unsafe conditions for sampling the thalweg in the shoulder months (i.e., April, Nov, Dec). Based on the current frequency at these, and other sites, sampling at the LAR sites (M0-M9) was also set to monthly (Glozier et al., 2018, Environment Canada and Alberta Environment, 2011a and 2011b). To improve estimates of contaminant loading to downstream receiving environments Cooke et al., (2018) recommended that sampling frequency w be increased to biweekly or twice per month during the high flow open water period (Jun-Aug) at the sites upstream, within and downstream of the OS activity area (M2-M9). Although not the primary objective of this report, with the amount of data that has been collected and the trend results that are available in this and previous reports, it is now possible to evaluate sampling frequency related specifically to trend analyses. As stated, the current sampling frequency of these sites is based on multiple objectives including: 1) improved estimates of loads, 2) comparisons against guidelines, and 3) long-term trend analysis. For trend analysis purposes, maintaining the current monthly (9x/year) sampling frequency is recommended to ensure consistency with both the historical record and other sites within the basin. However, bi-monthly sampling is not a requirement for conducting trend analyses. More critical is the preservation of a consistent seasonal distribution of samples (e.g., three each in summer, fall, and winter).

- However, any reduction in water quality sampling frequency (i.e., less 9X/yr) would necessitate adjustments to future datasets, as prolonged changes, particularly at the beginning or end of a monitoring period, can introduce artificial trends (Helsel et al., 2020). Finally, while the Mann-Kendall test can accommodate missing data, further suspensions in sampling at a given site would compromise the reliability of future trend assessments. To illustrate the impact of reductions in sampling frequency, we conducted a sensitivity analysis and explored alternative sampling frequencies and analyzed how a reduction in sampling would impact our ability to detect significant trends. We chose two alternative scenarios for reduced sampling scenarios: one sample per hydrological season (three samples per year), two samples per hydrological season (six samples per year). Relative to the current sampling frequency, the proportion of significant trends decreased by 41% under the six-sample scenario and by 63% for the three-sample scenario (Table 12). The efficacy of bi-monthly sampling for more accurate loading estimates is currently under review.

Table 12. Comparison of significant WQ trends detected between current frequency (9 per year) and two alternative sampling scenarios. The number of significant trends detected represent results from all sites from the LAR and EGA-LT. Trend detection vs. current sampling (%) represents the proportion of significant trends of both the 3 and 6 per year sampling scenarios vs. the current sampling frequency.

Sampling Scenario	Number of Significant Trends Detected	Trend Detection vs. Current Sampling (%)
Current frequency (9 per year)	144	100%
Bi-Seasonal frequency (6 per year)	85	59%
Seasonal frequency (3 per year)	53	37%

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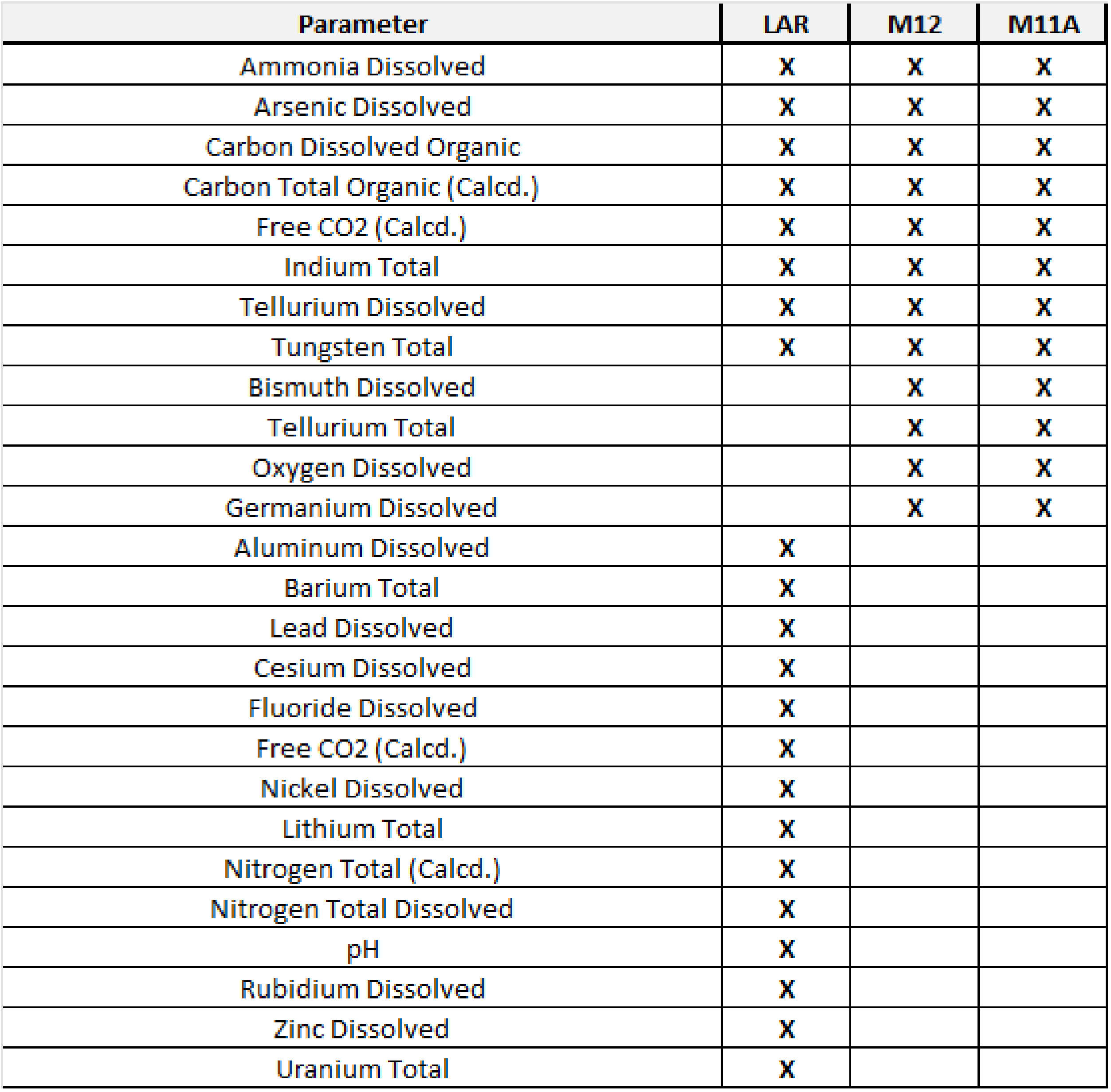
Appendix A

Additional Information

Table A1. List of parameters collected from the LAR and EGA-LT sites. Parameters that had no significant trend are marked with a “X”.



Parameter	LAR	M12	M11A
Ammonia Dissolved	X	X	X
Arsenic Dissolved	X	X	X
Carbon Dissolved Organic	X	X	X
Carbon Total Organic (Calcd.)	X	X	X
Free CO2 (Calcd.)	X	X	X
Indium Total	X	X	X
Tellurium Dissolved	X	X	X
Tungsten Total	X	X	X
Bismuth Dissolved		X	X
Tellurium Total		X	X
Oxygen Dissolved		X	X
Germanium Dissolved		X	X
Aluminum Dissolved	X		
Barium Total	X		
Lead Dissolved	X		
Cesium Dissolved	X		
Fluoride Dissolved	X		
Free CO2 (Calcd.)	X		
Nickel Dissolved	X		
Lithium Total	X		
Nitrogen Total (Calcd.)	X		
Nitrogen Total Dissolved	X		
pH	X		
Rubidium Dissolved	X		
Zinc Dissolved	X		
Uranium Total	X		

Table A2. Comparison of current and predicted concentrations of WQ parameters sampled at M9 against the CCME Water Quality Guidelines for the Protection of Aquatic Life (Freshwater). Excursion (%) represents any instance of a sample measuring over the guideline value. Predictions are calculated using the slope from the seasonal Mann-Kendall test to estimate concentrations over a 5- and 10-year period. Any exceedances of the CCME values are bolded and italicized.

	CCME Guideline						
	Guideline	**Excursion (%)**	**Median**	**Slope**	**p Value**	**5 Year**	**10 Year**
Major Ions and Physicals							
CHLORIDE DISSOLVED (mg/L)	120	0	10.10	0.26	1.3E-05	11.42	12.73
FLOURIDE DISSOLVED (mg/L)	120*	0	0.09	0.0E+00	1.00	0.09	0.09
PH	9	0	7.91	-0.01	0.66	7.88	7.84
Metals (µg/L)							
ALUMINUM TOTAL	100[D]	69.23	***400.00***	-15.26	4.3E-04	***323.68***	***247.36***
ARSENIC TOTAL	5	3.08	0.76	-0.02	0.00	0.66	0.56
BORON TOTAL	1500[LT]	0	26.60	0.49	0.01	29.06	31.51
	29,000[ST]	0	26.60	0.49	0.01		
CADMIUM TOTAL	2.6[ST+WH]	0	0.02	-2.7E-04	0.48	0.02	0.02
	0.19[LT+WH]	3.17	0.02	-2.7E-04	0.48	0.02	0.02
CHROMIUM TOTAL	8.9[E]	6.15	0.67	-0.02	0.01	0.56	0.45
COBALT TOTAL[ABSWQ]	2.5	13.85	0.36	0.00	0.15	0.34	0.33
COPPER TOTAL	2.86[WH]	30.77	1.33	-0.01	0.45	1.27	1.20
IRON TOTAL	300	100.00	***770.00***	-11.21	0.21	***713.96***	***657.93***
LEAD TOTAL	4.23[WH]	9.23	0.49	-0.01	0.21	0.44	0.39
MERCURY TOTAL	0.026	3.17	2.77E-03	-7.5E-05	0.00	0.00	0.00
METHYL MERCURY	0.004*	0	8.0E-05	1.0E-06	0.40	1.1E-04	1.3E-04
MOLYBENUM TOTAL	73*	0	0.74	-0.01	0.02	0.69	0.63
NICKEL TOTAL	113.24[WH]	0	1.54	-0.02	0.33	1.45	1.35
SELENIUM TOTAL	1	0	0.16	0.00	0.03	0.14	0.13
SILVER TOTAL	0.25	0	0.01	-3.2E-04	0.00	0.00	0.00
THALLIUM TOTAL	0.8	0	0.01	-5.7E-04	2.0E-04	0.01	0.01
URANIUM TOTAL	15[LT]	0	0.43	5.5E-04	0.83	0.43	0.43
	33[ST]	0	0.43	5.5E-04	0.83	0.43	0.43
ZINC TOTAL	30	4.62	3.00	-0.04	0.30	2.81	2.61

* Interim Guideline

[D] At pH >6.5

[E] Guidle for trivalent chromium (fuideline for hexavalent chromium = 1 µg/L)

[ST] Guideline for short term concentration

[LT] Guideline for long term concentration

[WH] Guideline varies with water hardness (equation)

[ABSWQ] Alberta surface water quality guideline

Table A3. Comparison of current and predicted concentrations of WQ parameters sampled at M12 against the CCME Water Quality Guidelines for the Protection of Aquatic Life (Freshwater). Excursion (%) represents any instance of a sample measuring over the guideline value. Predictions are calculated using the slope from the seasonal Mann-Kendall test to estimate concentrations over a 5- and 10-year period. Any exceedances of the CCME values are bolded and italicized.

	CCME Guideline						
	Guideline	**Excursion (%)**	**Median**	**Slope**	**p Value**	**5 Year**	**10 Year**
Major Ions and Physicals							
CHLORIDE DISSOLVED (mg/L)	120	0	1.09	0.03	0.04	1.23	1.37
FLOURIDE DISSOLVED (mg/L)	120*	0	0.06	0.00	1.6E-04	0.07	0.08
PH	9	0	8.10	0.02	2.3E-04	8.20	8.31
Metals (µg/L)							
ALUMINUM TOTAL	100^{D}	95.38	***456.00***	16.63	0.17	***539.15***	***622.29***
ARSENIC TOTAL	5	4.62	0.65	0.02	0.33	0.73	0.81
BORON TOTAL	1500^{LT}	0	9.40	0.23	0.14	10.57	11.75
	$29{,}000^{ST}$	0	9.40	0.23	0.14	10.57	11.75
CADMIUM TOTAL	2.4^{ST+WH}	0	0.05	-2.6E-05	0.99	0.05	0.05
	0.18^{LT+WH}	12.90	0.05	-2.6E-05	0.99	0.05	0.05
CHROMIUM TOTAL	8.9^{E}	7.69	0.76	0.01	0.40	0.83	0.89
COBALT TOTAL^{ABSWQ}	2.5	16.92	0.35	0.02	0.04	0.44	0.54
COPPER TOTAL	2.66^{WH}	40.00	1.78	0.05	0.23	2.01	2.24
IRON TOTAL	300	80.00	***738.00***	54.45	0.04	***1010.26***	***1282.53***
LEAD TOTAL	3.80^{WH}	15.38	0.48	0.03	0.06	0.64	0.79
MERCURY TOTAL	0.026	4.76	4.3E-03	1.4E-04	0.20	0.01	0.01
METHYL MERCURY	0.004*	0	5.0E-05	1.7E-05	0.02	0.00	0.00
MOLYBENUM TOTAL	73*	0	1.02	8.9E-04	0.91	1.02	1.03
NICKEL TOTAL	106.29^{WH}	0	1.78	0.08	0.04	2.19	2.60
SELENIUM TOTAL	1	1.54	0.35	0.01	0.02	0.38	0.42
SILVER TOTAL	0.25	1.54	0.01	4.4E-04	0.24	0.01	0.01
THALLIUM TOTAL	0.8	0	0.02	5.0E-04	0.21	0.02	0.02
URANIUM TOTAL	15^{LT}	0	0.58	0.00	0.27	0.61	0.63
	33^{ST}	0	0.58	0.00	0.27	0.61	0.63
ZINC TOTAL	30	16.92	3.90	0.25	0.07	5.13	6.36

* Interim Guideline

^{D} At pH >6.5

^{E} Guidle for trivalent chromium (fuideline for hexavalent chromium = 1 µg/L)

ST Guideline for short term concentration

^{LT} Guideline for long term concentration

^{WH} Guideline varies with water hardness (equation)

^{ABSWQ} Alberta surface water quality guideline

Table A4. Comparison of current and predicted concentrations of WQ parameters sampled at M11A against the CCME Water Quality Guidelines for the Protection of Aquatic Life (Freshwater). Excursion (%) represents any instance of a sample measuring over the guideline value. Predictions are calculated using the slope from the seasonal Mann-Kendall test to estimate concentrations over a 5- and 10-year period. Any exceedances of the CCME values are bolded and italicized.

	CCME Guideline						
	Guideline	**Excursion (%)**	**Median**	**Slope**	**p Value**	**5 Year**	**10 Year**
Major Ions and Physicals							
CHLORIDE DISSOLVED (mg/L)	120	0	4.07	-0.02	0.76	3.99	3.91
FLOURIDE DISSOLVED (mg/L)	120*	0	0.07	0.00	0.00	0.08	0.09
PH	9	0	8.04	0.01	0.10	8.10	8.17
Metals (µg/L)							
ALUMINUM TOTAL	100[D]	96.43	***1205.00***	87.19	0.13	***1640.97***	***2076.95***
ARSENIC TOTAL	5	7.14	1.29	0.08	0.03	1.68	2.08
BORON TOTAL	1500[LT]	0	16.55	0.16	0.51	17.35	18.15
	29,000[ST]	0	16.55	0.16	0.51		
CADMIUM TOTAL	2.2[ST+WH]	0	0.06	0.00	0.12	0.07	0.09
	0.16[LT+WH]	16.98	0.06	0.00	0.12	0.07	0.09
CHROMIUM TOTAL	8.9[E]	10.71	1.80	0.15	0.07	2.56	3.32
COBALT TOTAL[ABSWQ]	2.5	21.43	0.83	0.10	0.03	1.30	1.78
COPPER TOTAL	2.43[WH]	58.93	3.01	0.23	0.01	4.14	5.27
IRON TOTAL	300	94.64	***2060.00***	233.59	0.03	***3227.97***	***4395.94***
LEAD TOTAL	3.30[WH]	16.07	1.10	0.09	0.05	1.57	2.04
MERCURY TOTAL	0.026	10.76	0.01	7.1E-04	0.01	0.01	0.01
METHYL MERCURY	0.004*	0	7.0E-05	3.0E-05	0.00	2.3E-04	3.9E-04
MOLYBENUM TOTAL	73*	0	0.82	0.01	0.22	0.87	0.91
NICKEL TOTAL	97.75[WH]	1.79	3.42	0.26	0.04	4.72	6.02
SELENIUM TOTAL	1	1.79	0.29	0.01	0.03	0.33	0.38
SILVER TOTAL	0.25	1.79	0.02	0.00	0.03	0.02	0.03
THALLIUM TOTAL	0.8	0	0.03	0.00	0.02	0.05	0.07
URANIUM TOTAL	15[LT]	0	0.49	0.02	0.01	0.59	0.69
	33[ST]	0	0.49	0.02	0.01	0.59	0.69
ZINC TOTAL	30	17.86	7.90	0.63	0.11	11.04	14.17

* Interim Guideline

[D] At pH >6.5

[E] Guidle for trivalent chromium (fuideline for hexavalent chromium = 1 µg/L)

[ST] Guideline for short term concentration

[LT] Guideline for long term concentration

[WH] Guideline varies with water hardness (equation)

[ABSWQ] Alberta surface water quality guideline

Table A5. Comparison of current and predicted concentrations of WQ parameters sampled at M3 against the CCME Water Quality Guidelines for the Protection of Aquatic Life (Freshwater). Excursion (%) represents any instance of a sample measuring over the guideline value. Predictions are calculated using the slope from the seasonal Mann-Kendall test to estimate concentrations over a 5- and 10-year period. Any exceedances of the CCME values are bolded and italicized.

	CCME Guideline						
	Guideline	**Excursion (%)**	**Median**	**Slope**	**p Value**	**5 Year**	**10 Year**
Major Ions and Physicals							
CHLORIDE DISSOLVED (mg/L)	120	0	11.10	0.89	0.01	15.57	20.05
FLUORIDE DISSOLVED (mg/L)	120*	0	0.09	8.2E-04	0.15	0.09	0.10
PH	9	0	8.07	0.00	0.56	8.09	8.10
Metals (µg/L)							
ALUMINUM TOTAL	100^{D}	70.69	***565.00***	-19.03	0.01	***469.85***	***374.70***
ARSENIC TOTAL	5	1.72	0.79	-0.03	0.04	0.65	0.50
BORON TOTAL	1500^{LT}	0	30.10	0.37	0.36	31.93	33.76
	29,000ST	0	30.10	0.37	0.36	31.93	33.76
CADMIUM TOTAL	2.3^{ST+WH}	0	0.02	0.00	0.01	0.01	0.00
	0.17^{LT+WH}	1.82	0.02	0.00	0.01	0.01	0.00
CHROMIUM TOTAL	8.9^{E}	3.45	0.88	-0.01	0.18	0.81	0.73
COBALT TOTAL^{ABSWQ}	2.5	5.17	0.44	0.00	0.54	0.42	0.41
COPPER TOTAL	2.57^{WH}	27.59	1.13	-0.05	0.07	0.86	0.59
IRON TOTAL	300	87.93	***1280.00***	43.22	0.32	***1496.09***	***1712.19***
LEAD TOTAL	3.59^{WH}	5.17	0.45	-0.01	0.23	0.41	0.38
MERCURY TOTAL	0.026	0.00	0.00	-4.5E-05	0.04	2.5E-03	2.2E-03
METHYL MERCURY	0.004*	0	6.0E-05	0.01	0.75	1.6E-04	1.8E-04
MOLYBDENUM TOTAL	73*	0	0.56	-0.02	0.19	0.46	0.36
NICKEL TOTAL	102.76^{WH}	0	1.49	-0.05	0.08	1.22	0.95
SELENIUM TOTAL	1	0	0.15	-0.01	0.04	0.11	0.07
SILVER TOTAL	0.25	0	0.00	-1.1E-04	0.16	0.00	0.00
THALLIUM TOTAL	0.8	0	0.01	-5.1E-04	0.09	0.01	0.01
URANIUM TOTAL	15^{LT}	0	0.34	-0.01	0.45	0.30	0.25
	33ST	0	0.34	-0.01	0.45	0.30	0.25
ZINC TOTAL	30	5.17	3.50	-0.03	0.65	3.34	3.17

* Interim Guideline

^{D} At pH >6.5

^{E} Guidle for trivalent chromium (fuideline for hexavalent chromium = 1 µg/L)

ST Guideline for short term concentration

^{LT} Guideline for long term concentration

^{WH} Guideline varies with water hardness (equation)

^{ABSWQ} Alberta surface water quality guideline

Table A6. Comparison of current and predicted concentrations of WQ parameters sampled at M7 against the CCME Water Quality Guidelines for the Protection of Aquatic Life (Freshwater). Excursion (%) represents any instance of a sample measuring over the guideline value. Predictions are calculated using the slope from the seasonal Mann-Kendall test to estimate concentrations over a 5- and 10-year period. Any exceedances of the CCME values are bolded and italicized.

	CCME Guideline						
	Guideline	**Excursion (%)**	**Median**	**Slope**	**p Value**	**5 Year**	**10 Year**
Major Ions and Physicals							
CHLORIDE DISSOLVED (mg/L)	120	0	7.70	0.23	0.03	8.85	10.00
FLOURIDE DISSOLVED (mg/L)	120*	0	0.10	1.35E-04	0.71	0.10	0.10
PH	9	0	8.07	0.00	0.74	8.08	8.09
Metals (µg/L)							
ALUMINUM TOTAL	100[D]	69.64	***268.50***	-16.96	2.7E-04	***183.72***	98.94
ARSENIC TOTAL	5	1.79	0.68	-0.03	1.6E-04	0.53	0.39
BORON TOTAL	1500[LT]	0	26.20	-0.10	0.68	25.70	25.20
	29,000[ST]	0	26.20	-0.10	0.68	25.70	25.20
CADMIUM TOTAL	2.7[ST+WH]	0	0.02	0.00	0.05	0.02	0.01
	0.19[LT+WH]	1.85	0.02	0.00	0.05	0.02	0.01
CHROMIUM TOTAL	8.9[E]	1.79	0.46	-0.03	0.01	0.33	0.20
COBALT TOTAL[ABSWQ]	2.5	12.50	0.30	-0.01	0.06	0.27	0.23
COPPER TOTAL	2.90[WH]	28.57	1.03	-0.02	0.43	0.93	0.83
IRON TOTAL	300	98.21	***663.50***	-27.40	0.01	***526.50***	***389.50***
LEAD TOTAL	4.31[WH]	7.14	0.29	-0.01	0.06	0.25	0.21
MERCURY TOTAL	0.026	3.64	0.00	-4.6E-05	0.01	0.00	0.00
METHYL MERCURY	0.004*	0	5.0E-05	2.5E-07	0.68	8.0E-05	8.0E-05
MOLYBENUM TOTAL	73*	0	0.74	-0.02	0.00	0.63	0.52
NICKEL TOTAL	114.62[WH]	0	1.37	-0.02	0.41	1.26	1.15
SELENIUM TOTAL	1	0	0.17	-0.01	0.00	0.13	0.10
SILVER TOTAL	0.25	0	0.00	-1.9E-04	0.04	0.00	2.1E-03
THALLIUM TOTAL	0.8	0	0.01	-5.0E-04	0.00	0.01	0.00
URANIUM TOTAL	15[LT]	0	0.43	0.00	0.77	0.43	0.42
	33[ST]	0	0.43	0.00	0.77	0.43	0.42
ZINC TOTAL	30	3.57	1.90	-0.07	0.07	1.57	1.23

* Interim Guideline

[D] At pH >6.5

[E] Guidle for trivalent chromium (fuideline for hexavalent chromium = 1 µg/L)

[ST] Guideline for short term concentration

[LT] Guideline for long term concentration

[WH] Guideline varies with water hardness (equation)

[ABSWQ] Alberta surface water quality guideline

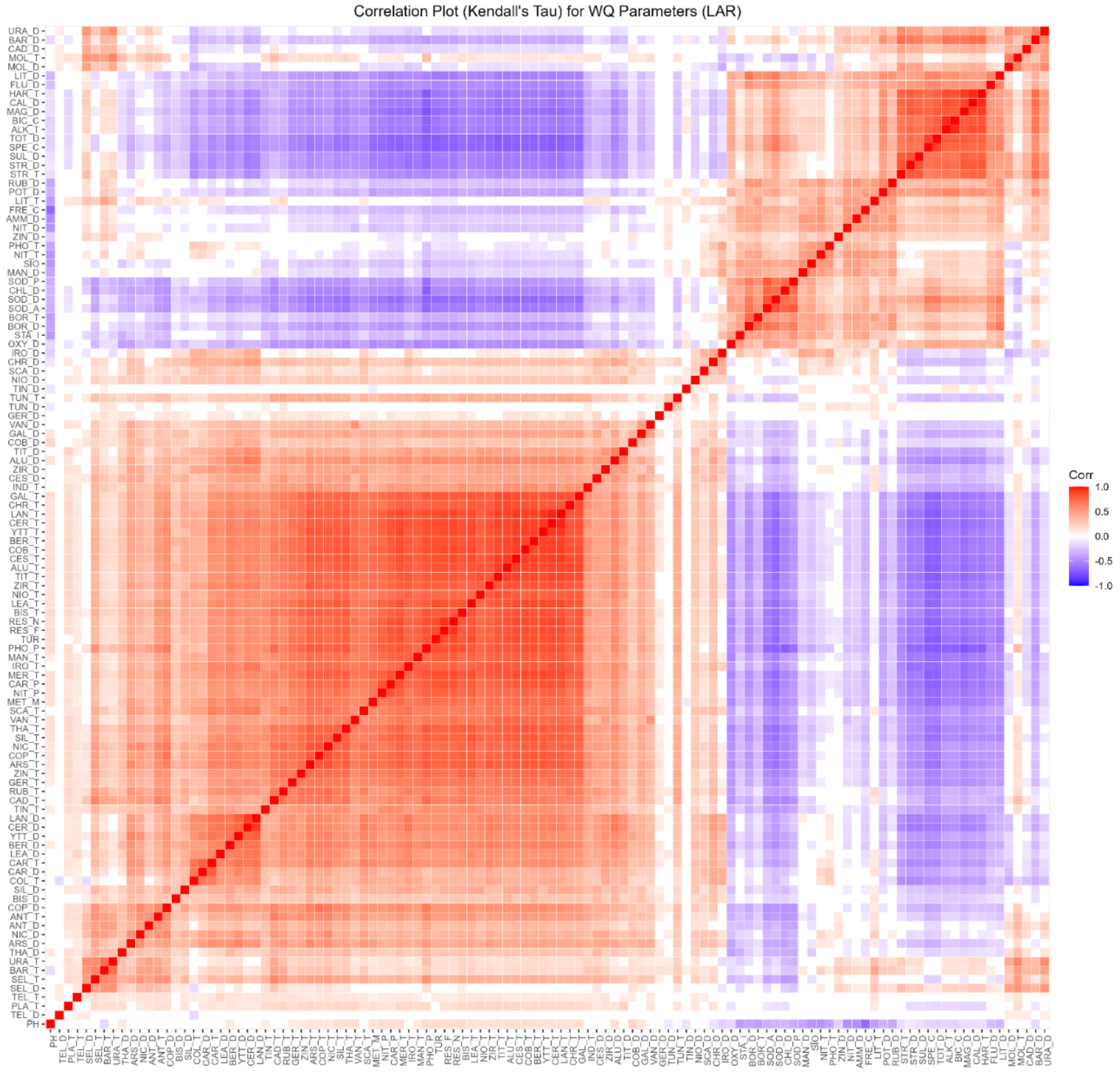


Figure A-1. Example heatmap of correlation values for WQ parameters collected from the LAR (M3-M9). The colour of the square within the matrix indicates if it is significantly positively (red) or negatively (blue) correlated. White squares indicate no significant ($p < 0.1$) correlation.

Table A-7. Example table of the count of correlations between WQ parameters sampled from the LAR (M3-M9). Columns include counts for total significant correlations ($p < 0.1$), highly positively correlated (Kendall’s Tau > 0.6), and highly negatively correlated (Kendall’s Tau < -0.6).

Parameter	Total	Positive	Negative
Phosphorous Particulate	51	38	13
Titanium Total	46	38	8
Cerium Total	46	38	8
Zirconium Total	44	40	4
Arsenic Total	44	42	2
Yttrium Total	44	40	4
Iron Total	44	39	5
Lanthanum Total	44	38	6
Beryllium Total	43	39	4
Copper Total	42	41	1
Cesium Total	42	38	4
Aluminum Total	42	38	4
Phosphorous Total	42	37	5
Cobalt Total	41	37	4
Mercury Total	41	37	4
Turbidity	41	34	7
Nickel Total	40	40	0
Carbon Particulate Organic	40	34	6
Bismuth Total	39	36	3
Chromium Total	39	35	4
Gallium Total	39	35	4
Specific Conductance	39	11	28
Scandium Total	38	38	0
Lead Total	38	35	3
Silver Total	38	35	3
Thallium Total	38	35	3
Niobium Total	38	35	3
Residue Fixed Nonfiltrable	38	34	4
Residue Nonfiltrable	38	34	4
Total Dissolved Solids	38	11	27
Manganese Total	37	34	3
Methyl Mercury	36	34	2
Germanium Total	34	34	0
Zinc Total	34	34	0
Nitrogen Particulate	34	32	2
Magnesium Dissolved Ml	31	10	21
Sodium Dissolved Ml	30	7	23
Cadmium Total	29	29	0
Rubidium Total	28	28	0
Vanadium Total	27	27	0
Beryllium Dissolved	25	25	0
Cerium Dissolved	21	21	0
Lanthanum Dissolved	20	20	0
Strontium Dissolved	17	10	7
Carbon Total Organic	16	16	0
Hardness Total CaCO3	16	10	6
Alkalinity Total CaCO3	15	11	4
Sulphate Dissolved	15	10	5
Yttrium- Dissolved	13	13	0
Bicarbonate	13	11	2
Calcium Dissolved Ml	11	10	1
Strontium Total	10	10	0
Barium Dissolved	9	9	0
Lead Dissolved	7	7	0
Lithium Dissolved	5	5	0
Boron Dissolved	5	5	0
Sodium Adsorption Ratio	5	4	1
Sodium Percentage	5	4	1
Aluminum Dissolved	5	5	0
Copper Dissolved	5	5	0
Carbon Dissolved Organic	4	4	0
Chloride Dissolved	4	3	1
Colour True	3	3	0
Antimony Total	3	3	0
Potassium Dissolved Ml	3	3	0
Barium Total	2	2	0
Molybdenum Dissolved	2	2	0
Molybdenum Total	2	2	0
Uranium Dissolved	2	2	0
Uranium Total	2	2	0
Selenium Total	2	2	0
Fluoride Dissolved	1	1	0
Arsenic Dissolved	1	1	0
Boron Total	1	1	0
Rubidium Dissolved	1	1	0
Titanium Dissolved	1	1	0
Nickel Dissolved	1	1	0
Free CO2	1	0	1
Ph	1	0	1
Indium Total	0	0	0

Appendix B
Summary Statistics

Table B1-1. Statistical Summaries – Major Ions and Physicals

M3	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Alkalinity Total CaCO3	↔	-5.6E-01	-5.8E-01	↔	5.6E-01	5.9E-01
Bicarbonate	↔	6.1E-02	5.4E-02	↔	1.1E+00	9.5E-01
Calcium Dissolved	↔	-5.7E-01	-1.9E+00	↔	-2.4E-01	-8.0E-01
Chloride Dissolved	↑	1.4E+00	1.2E+01	↑	8.9E-01	8.1E+00
Colour True	↑	3.4E+00	9.6E+00	↑	2.4E+00	6.8E+00
Fluoride Dissolved	↔	-9.3E-08	-1.0E-04	↔	8.2E-04	9.1E-01
Free CO2	↔	7.0E-03	4.9E-01	↔	2.2E-02	1.6E+00
Hardness Total CaCO3	↔	-3.8E-01	-3.6E-01	↔	-1.7E-01	-1.6E-01
Magnesium Dissolved	↔	-1.5E-01	-1.9E+00	↔	-7.1E-02	-8.7E-01
Oxygen Dissolved	↔	8.8E-02	8.5E-01	↑	1.1E-01	1.0E+00
Ph	↔	6.3E-08	7.8E-07	↔	-4.7E-03	-5.8E-02
Potassium Dissolved	↔	-1.7E-02	-1.4E+00	↔	-1.3E-02	-1.0E+00
Sio2	↑	4.7E-01	6.9E+00	↑	4.3E-01	6.3E+00
Sodium Dissolved	↔	8.5E-01	5.2E+00	↑	8.0E-01	4.9E+00
Specific Conductance	↔	1.6E+00	6.3E-01	↔	3.2E+00	1.3E+00
Sulphate Dissolved	↔	-6.9E-01	-3.7E+00	↔	-5.4E-01	-2.9E+00
Total Dissolved Solids	↔	3.6E-01	2.5E-01	↔	2.2E+00	1.5E+00

M7	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Alkalinity Total CaCO3	↔	8.7E-01	8.0E-01	↑	1.0E+00	9.4E-01
Bicarbonate	↔	1.0E+00	7.8E-01	↑	1.2E+00	9.3E-01
Calcium Dissolved	↔	2.9E-01	8.7E-01	↑	5.6E-01	1.7E+00
Chloride Dissolved	↔	3.2E-01	4.1E+00	↑	2.3E-01	3.0E+00
Fluoride Dissolved	↔	2.2E-08	2.3E-05	↔	1.3E-04	1.4E-01
Free CO2	↔	-1.9E-02	-1.3E+00	↔	-5.3E-03	-3.4E-01
Hardness Total CaCO3	↔	9.0E-01	7.3E-01	↔	1.2E+00	9.4E-01
Magnesium Dissolved	↔	5.3E-02	5.6E-01	↑	1.3E-01	1.4E+00
Oxygen Dissolved	↔	8.2E-02	7.7E-01	↑	8.0E-02	7.6E-01
Ph	↔	1.1E-02	1.3E-01	↔	1.8E-03	2.2E-02
Potassium Dissolved	↔	9.3E-03	6.6E-01	↑	2.8E-02	2.0E+00
Sio2	↑	1.9E-01	3.1E+00	↑	2.3E-01	3.6E+00
Sodium Dissolved	↔	2.8E-03	2.2E-02	↔	6.7E-02	5.4E-01
Specific Conductance	↔	1.2E+00	4.2E-01	↔	1.4E+00	4.9E-01
Sulphate Dissolved	↔	-1.4E-01	-5.2E-01	↔	-1.8E-01	-6.8E-01
Total Dissolved Solids	↔	4.7E-01	2.9E-01	↔	1.1E+00	6.9E-01

M9	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Alkalinity Total CaCO3	↑	6.9E-01	6.5E-01	↑	2.1E+00	2.0E+00
Bicarbonate	↑	8.3E-01	6.5E-01	↑	2.6E+00	2.1E+00
Calcium Dissolved	↑	3.7E-01	1.1E+00	↑	8.0E-01	2.4E+00
Chloride Dissolved	↔	-1.6E-01	-1.5E+00	↑	2.6E-01	2.6E+00
Colour True	↔	1.3E+00	4.3E+00	↔	2.7E-01	8.6E-01
Fluoride Dissolved	↔	-7.5E-08	-8.3E-05	↔	0.0E+00	0.0E+00
Free CO2	↔	-5.5E-02	-3.5E+00	↔	-1.1E-02	-7.1E-01
Hardness Total CaCO3	↑	1.2E+00	1.0E+00	↑	2.8E+00	2.3E+00
Magnesium Dissolved	↑	8.6E-02	9.5E-01	↑	2.0E-01	2.2E+00
Oxygen Dissolved	↔	2.8E-02	2.9E-01	↔	3.8E-02	3.9E-01
Ph	↔	3.6E-03	4.5E-02	↔	-6.6E-03	-8.4E-02
Potassium Dissolved	↔	1.0E-02	8.0E-01	↑	2.8E-02	2.1E+00
Sio2	↑	3.1E-02	5.0E-01	↑	1.3E-01	2.1E+00
Sodium Dissolved	↔	-1.4E-01	-1.1E+00	↑	3.7E-01	2.7E+00
Specific Conductance	↔	2.1E-01	7.6E-02	↑	5.1E+00	1.9E+00
Sulphate Dissolved	↔	2.3E-08	9.2E-08	↑	4.2E-01	1.7E+00
Total Dissolved Solids	↔	9.5E-01	6.0E-01	↑	3.3E+00	2.1E+00

M11A	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Alkalinity Total CaCO3	↑	1.8E+00	2.1E+00	↑	1.6E+00	1.9E+00
Calcium Dissolved	↑	6.8E-01	2.3E+00	↑	6.0E-01	2.1E+00
Chloride Dissolved	↔	2.5E-02	6.1E-01	↔	-1.5E-02	-3.7E-01
Fluoride Dissolved	↑	1.9E-03	2.7E+00	↑	2.4E-03	3.4E+00
Hardness Total CaCO3	↑	2.4E+00	2.4E+00	↑	2.2E+00	2.2E+00
Magnesium Dissolved	↑	1.8E-01	2.6E+00	↑	1.6E-01	2.3E+00
Oxygen Dissolved	↔	2.9E-02	2.8E-01	↔	-2.9E-02	-2.8E-01
SiO2	↔	1.9E-03	4.0E-02	↑	8.3E-02	1.7E+00
Sodium Dissolved	↔	1.5E-01	2.4E+00	↔	1.1E-01	1.8E+00
Specific Conductance	↑	3.0E+00	1.4E+00	↑	2.7E+00	1.2E+00
Sulphate Dissolved	↑	5.5E-01	2.9E+00	↑	5.5E-01	2.9E+00

M12	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Alkalinity Total CaCO3	↑	1.2E+00	9.9E-01	↑	9.6E-01	9.9E-01
Calcium Dissolved	↑	5.1E-01	1.3E+00	↑	4.4E-01	1.3E+00
Chloride Dissolved	↔	3.3E-02	2.6E+00	↑	2.8E-02	2.6E+00
Fluoride Dissolved	↑	1.8E-03	3.8E+00	↑	2.3E-03	3.8E+00
Hardness Total CaCO3	↑	2.0E+00	1.5E+00	↑	1.7E+00	1.5E+00
Magnesium Dissolved	↑	1.8E-01	1.7E+00	↑	1.3E-01	1.7E+00
Oxygen Dissolved	↔	-2.3E-02	-5.6E-01	↔	-6.2E-02	-5.6E-01
Ph	↑	2.5E-02	2.5E-01	↑	2.1E-02	2.5E-01
SiO2	↔	3.9E-04	4.8E-01	↔	2.1E-02	4.8E-01
Sodium Dissolved	↑	1.3E-01	3.2E+00	↑	1.2E-01	3.2E+00
Specific Conductance	↑	2.9E+00	9.8E-01	↑	2.3E+00	9.8E-01
Sulphate Dissolved	↔	4.9E-01	1.6E+00	↑	3.5E-01	1.6E+00
Total Dissolved Solids	↑	2.1E+00	1.4E+00	↑	1.9E+00	1.4E+00

Table B1-2. Statistical Summaries – Nutrients

M3	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Ammonia Dissolved	↔	7.9E-08	6.6E-04	↔	7.7E-04	6.4E+00
Carbon Dissolved Organic	↔	3.5E-01	3.8E+00	↔	2.3E-01	2.5E+00
Carbon Particulate Organic	↔	2.4E-02	2.1E+00	↔	-3.6E-02	-3.1E+00
Carbon Total Organic	↔	3.8E-01	3.6E+00	↔	1.2E-01	1.2E+00
Nitrogen Dissolved NO3 & NO2	↔	4.4E-08	1.7E-04	↔	1.7E-03	6.7E+00
Nitrogen Particulate	↔	-7.0E-04	-6.4E-01	↔	-2.3E-03	-2.1E+00
Nitrogen Total	↔	-1.7E-03	-3.1E-01	↔	-5.4E-03	-9.6E-01
Phosphorous Total	↔	1.7E-03	2.7E+00	↔	-7.1E-04	-1.1E+00
Phosphorous Total Dissolved	↔	8.8E-04	4.9E+00	↔	9.3E-04	5.2E+00
Residue Fixed Nonfiltrable	↔	6.3E-08	2.1E-07	↓	-9.5E-01	-3.2E+00
Residue Nonfiltrable	↔	7.2E-08	2.0E-07	↓	-8.7E-01	-2.4E+00

M7	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Ammonia Dissolved	↔	-1.5E-08	-1.1E-04	↔	7.0E-04	5.0E+00
Carbon Dissolved Organic	↔	1.7E-01	2.1E+00	↔	1.9E-01	2.3E+00
Carbon Particulate Organic	↔	6.3E-03	6.7E-01	↓	-2.5E-02	-2.6E+00
Carbon Total Organic	↔	1.4E-01	1.5E+00	↔	7.7E-02	8.2E-01
Nitrogen Dissolved NO3 & NO2	↓	-2.5E-03	-8.5E+00	↔	-3.8E-03	-1.3E+01
Nitrogen Particulate	↔	-4.0E-08	-3.8E-05	↔	-1.9E-03	-1.8E+00
Nitrogen Total	↔	-2.9E-03	-5.4E-01	↔	-2.1E-03	-4.0E-01
Phosphorous Total	↔	-4.3E-04	-8.9E-01	↓	-2.3E-03	-4.8E+00
Phosphorous Total Dissolved	↔	4.0E-04	2.7E+00	↔	5.1E-04	3.4E+00
Residue Fixed Nonfiltrable	↔	-3.7E-01	-1.8E+00	↓	-1.2E+00	-5.8E+00
Residue Nonfiltrable	↔	-2.1E-01	-9.1E-01	↓	-1.1E+00	-4.6E+00

M9	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Ammonia Dissolved	↔	-9.7E-04	-6.4E+00	↔	-1.2E-04	-7.9E-01
Carbon Dissolved Organic	↔	9.3E-02	1.1E+00	↔	1.8E-02	2.2E-01
Carbon Particulate Organic	↔	2.7E-02	2.5E+00	↓	-3.1E-02	-2.8E+00
Carbon Total Organic	↔	2.0E-01	1.9E+00	↔	-4.0E-02	-3.8E-01
Nitrogen Dissolved NO3 & NO2	↔	-6.2E-04	-1.8E+00	↑	1.9E-03	5.7E+00
Nitrogen Particulate	↔	3.6E-03	3.8E+00	↓	-6.6E-03	-6.8E+00
Nitrogen Total	↔	7.3E-03	1.2E+00	↔	-4.0E-03	-6.8E-01
Nitrogen Total Dissolved	↔	-5.3E-03	-1.1E+00	↔	2.0E-03	4.4E-01
Phosphorous Particulate	↑	4.1E-08	8.5E-05	↓	-3.0E-03	-6.2E+00
Phosphorous Total	↔	6.0E-04	1.1E+00	↓	-1.8E-03	-3.2E+00
Phosphorous Total Dissolved	↑	1.8E-04	1.2E+00	↑	4.2E-04	2.7E+00
Residue Fixed Nonfiltrable	↔	1.0E+00	3.5E+00	↓	-1.0E+00	-3.5E+00
Residue Nonfiltrable	↔	7.9E-01	2.3E+00	↓	-1.0E+00	-3.1E+00

M11A	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Ammonia Dissolved	↔	3.1E-08	5.1E-04	↔	4.7E-04	7.8E+00
Carbon Dissolved Organic	↔	-1.3E-01	-2.1E+00	↔	7.2E-02	1.2E+00
Carbon Particulate Organic	↔	7.6E-02	3.4E+00	↑	1.4E-01	6.3E+00
Nitrogen NO3	↑	2.7E-02	1.7E+01	↑	2.7E-02	1.7E+01
Nitrogen Particulate	↔	-1.2E-02	-3.0E+00	↔	-7.9E-03	-2.0E+00
Nitrogen Total Dissolved	↑	6.7E-03	2.2E+00	↑	1.2E-02	3.9E+00
Phosphorous Total	↔	6.3E-03	7.0E+00	↑	6.3E-03	7.1E+00
Phosphorous Total Dissolved	↔	6.2E-07	1.2E-02	↔	4.7E-04	9.4E+00

M12	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Ammonia Dissolved	↔	-6.1E-08	-1.3E+00	↔	-1.1E-04	-1.3E+00
Carbon Dissolved Organic	↔	1.3E-01	2.7E+00	↔	9.8E-02	2.7E+00
Carbon Particulate Organic	↔	1.8E-02	6.0E+00	↔	5.3E-02	6.0E+00
Nitrogen Total	↔	7.0E-03	5.1E+00	↔	1.3E-02	5.1E+00
Nitrogen Total Dissolved	↔	4.7E-03	2.3E+00	↔	4.2E-03	2.3E+00
Phosphorous Particulate	↔	3.7E-03	1.6E+01	↔	6.9E-03	1.6E+01
Phosphorous Total	↔	3.8E-03	6.5E+00	↑	3.1E-03	6.5E+00
Phosphorous Total Dissolved	↔	3.8E-04	1.6E+01	↑	6.3E-04	1.6E+01

Table B1-3. Statistical Summaries – Metals (Dissolved)

M3	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Aluminum Dissolved	↔	1.5E-01	7.9E-01	↔	-5.3E-01	-2.7E+00
Antimony Dissolved	↔	-2.5E-04	-5.0E-01	↔	8.1E-05	1.6E-01
Arsenic Dissolved	↔	4.2E-03	8.3E-01	↔	1.8E-03	3.6E-01
Barium Dissolved	↔	-8.8E-01	-1.9E+00	↔	-4.5E-01	-9.8E-01
Beryllium Dissolved	↔	-8.0E-08	-1.6E-03	↔	-8.1E-06	-1.6E-01
Bismuth Dissolved	↔	5.1E-07	7.9E-02	↔	5.0E-04	7.8E+01
Boron Dissolved	↔	4.8E-01	1.7E+00	↔	4.7E-01	1.7E+00
Cadmium Dissolved	↔	-4.4E-04	-4.9E+00	↔	-4.3E-04	-4.8E+00
Cerium Dissolved	↑	7.4E-03	7.1E+00	↔	2.4E-03	2.3E+00
Cesium Dissolved	↔	-1.0E-07	-2.5E-03	↔	5.0E-05	1.2E+00
Chromium Dissolved	↑	5.5E-03	6.1E+00	↑	5.0E-03	5.6E+00
Cobalt Dissolved	↑	2.5E-03	3.7E+00	↔	2.0E-03	2.9E+00
Copper Dissolved	↔	-1.9E-02	-2.8E+00	↓	-2.3E-02	-3.5E+00
Gallium Dissolved	↔	-1.7E-08	-1.5E-04	↔	7.4E-05	6.7E-01
Germanium Dissolved	↑	6.2E-08	6.2E-04	↔	-1.7E-07	-1.7E-03
Iron Dissolved	↑	3.4E+01	1.2E+01	↑	3.0E+01	1.1E+01
Lanthanum Dissolved	↑	3.8E-03	6.8E+00	↔	1.4E-03	2.6E+00
Lead Dissolved	↔	3.8E-03	6.4E+00	↔	2.1E-03	3.5E+00
Lithium Dissolved	↔	1.2E-01	1.8E+00	↑	8.5E-02	1.3E+00
Manganese Dissolved	↑	4.0E-01	1.1E+01	↑	2.8E-01	7.7E+00
Molybdenum Dissolved	↔	-2.1E-02	-3.9E+00	↔	-1.8E-02	-3.3E+00
Nickel Dissolved	↔	-2.0E-02	-2.0E+00	↔	-1.4E-02	-1.4E+00
Niobium Dissolved	↔	-2.7E-07	-3.5E-02	↔	-4.4E-04	-5.8E+01
Rubidium Dissolved	↔	6.0E-03	6.3E-01	↔	1.0E-02	1.1E+00
Scandium Dissolved	↑	2.5E-03	1.7E+01	↑	8.4E-03	5.6E+01
Selenium Dissolved	↔	-2.5E-03	-2.1E+00	↔	-3.2E-03	-2.7E+00
Strontium Dissolved	↔	-4.6E+00	-2.4E+00	↔	-4.7E+00	-2.5E+00
Thallium Dissolved	↔	3.1E-08	7.8E-04	↔	-5.8E-05	-1.4E+00
Tin Dissolved	↑	1.2E-03	2.4E+01	↑	4.5E-03	8.9E+01
Titanium Dissolved	↔	-3.1E-02	-7.7E+00	↓	-5.0E-02	-1.3E+01
Tungsten Dissolved	↑	1.8E-04	6.1E+00	↑	2.1E-04	7.0E+00
Uranium Dissolved	↔	-1.1E-02	-3.8E+00	↔	-8.3E-03	-2.8E+00
Vanadium Dissolved	↔	-1.3E-02	-4.9E+00	↔	-2.3E-03	-8.5E-01
Yttrium Dissolved	↔	2.5E-03	2.7E+00	↔	7.9E-04	8.6E-01
Zinc Dissolved	↔	-4.3E-08	-7.2E-06	↔	1.0E-02	1.7E+00
Zirconium Dissolved	↔	5.2E-08	5.2E-05	↔	-7.5E-03	-7.5E+00

M7	Concentration			Flow-Adjusted		
Parameter	Trend	ATS Slope	APC (%)	Trend	ATS Slope	APC (%)
Aluminum Dissolved	↔	-2.8E-01	-1.8E+00	↔	-7.2E-01	-4.5E+00
Antimony Dissolved	↔	1.0E-03	1.7E+00	↔	1.2E-03	2.0E+00
Arsenic Dissolved	↔	-3.5E-08	-7.1E-06	↔	-4.2E-04	-8.6E-02
Barium Dissolved	↔	1.0E-01	2.0E-01	↔	3.8E-01	7.6E-01
Beryllium Dissolved	↔	-1.8E-08	-4.6E-04	↔	5.3E-05	1.3E+00
Bismuth Dissolved	↔	4.0E-07	5.1E-02	↑	5.9E-04	7.6E+01
Boron Dissolved	↔	-2.8E-01	-1.1E+00	↔	-6.8E-02	-2.7E-01
Cadmium Dissolved	↔	-3.4E-08	-3.0E-04	↔	-8.2E-05	-7.5E-01
Cerium Dissolved	↔	3.1E-03	4.3E+00	↔	8.9E-04	1.2E+00
Cesium Dissolved	↔	-8.1E-08	-2.0E-03	↔	-1.9E-05	-4.7E-01
Chromium Dissolved	↔	3.2E-03	4.0E+00	↑	4.0E-03	5.0E+00
Cobalt Dissolved	↑	3.2E-03	4.5E+00	↑	2.9E-03	3.9E+00
Copper Dissolved	↔	3.9E-02	4.5E+00	↑	2.0E-02	2.3E+00
Gallium Dissolved	↔	4.0E-08	3.6E-04	↔	-2.2E-05	-2.0E-01
Germanium Dissolved	↓	-4.4E-08	-4.4E-04	↔	-3.4E-04	-3.4E+00
Iron Dissolved	↔	7.6E+00	3.6E+00	↔	9.4E+00	4.5E+00
Lanthanum Dissolved	↔	1.7E-03	3.9E+00	↔	1.5E-04	3.5E-01
Lead Dissolved	↔	2.1E-03	4.3E+00	↔	1.6E-03	3.4E+00
Lithium Dissolved	↔	-1.2E-02	-1.8E-01	↔	3.4E-02	5.3E-01
Manganese Dissolved	↔	9.6E-02	2.6E+00	↔	1.4E-01	3.9E+00
Molybdenum Dissolved	↓	-1.8E-02	-2.5E+00	↓	-1.7E-02	-2.3E+00
Nickel Dissolved	↔	1.1E-02	1.0E+00	↔	3.9E-03	3.7E-01
Niobium Dissolved	↓	-4.6E-04	-5.8E+01	↓	-1.4E-03	-1.8E+02
Rubidium Dissolved	↔	1.5E-08	1.6E-06	↔	8.7E-03	9.4E-01
Scandium Dissolved	↑	3.9E-06	3.8E-02	↑	6.4E-03	6.4E+01
Selenium Dissolved	↔	-6.0E-09	-4.0E-06	↔	1.8E-03	1.2E+00
Strontium Dissolved	↓	-2.0E+00	-8.8E-01	↔	-1.3E+00	-5.7E-01
Tellurium Dissolved	↔	3.8E-06	8.3E-02	↔	8.1E-08	1.8E-03
Thallium Dissolved	↔	5.9E-09	1.2E-04	↔	-5.0E-05	-9.9E-01
Tin Dissolved	↔	8.4E-04	1.7E+01	↔	2.5E-03	5.1E+01
Titanium Dissolved	↓	-4.8E-02	-1.4E+01	↓	-6.1E-02	-1.7E+01
Tungsten Dissolved	↑	2.9E-04	9.8E+00	↑	3.4E-04	1.1E+01
Uranium Dissolved	↔	-2.0E-03	-5.3E-01	↔	-1.0E-03	-2.7E-01
Vanadium Dissolved	↔	-1.8E-02	-6.9E+00	↔	-5.1E-03	-1.9E+00
Yttrium Dissolved	↔	2.5E-03	2.8E+00	↔	8.0E-04	8.9E-01
Zinc Dissolved	↔	2.0E-02	2.5E+00	↔	2.3E-02	2.9E+00
Zirconium Dissolved	↔	-4.1E-08	-4.1E-05	↔	-2.9E-04	-2.9E-01

M9	Concentration			Flow-Adjusted		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Aluminum Dissolved	↔	4.7E-01	3.1E+00	↔	-5.2E-01	-3.4E+00
Antimony Dissolved	↑	2.0E-03	3.4E+00	↔	4.2E-04	7.0E-01
Arsenic Dissolved	↔	9.0E-03	1.8E+00	↔	2.1E-04	4.2E-02
Barium Dissolved	↑	2.0E-01	4.0E-01	↑	7.8E-01	1.6E+00
Beryllium Dissolved	↔	-5.7E-08	-1.4E-03	↓	-9.0E-05	-2.3E+00
Bismuth Dissolved	↔	6.6E-05	8.0E+00	↔	1.4E-04	1.8E+01
Boron Dissolved	↔	-5.2E-01	-2.1E+00	↔	2.7E-01	1.1E+00
Cadmium Dissolved	↓	-1.6E-08	-1.6E-04	↔	3.0E-04	3.0E+00
Cerium Dissolved	↔	4.9E-03	6.4E+00	↔	6.3E-04	8.3E-01
Cesium Dissolved	↔	-6.9E-09	-1.7E-04	↔	-1.4E-04	-3.5E+00
Chromium Dissolved	↔	2.0E-03	2.6E+00	↔	2.8E-04	3.5E-01
Cobalt Dissolved	↑	3.7E-03	5.0E+00	↑	2.4E-03	3.3E+00
Copper Dissolved	↔	7.1E-03	7.9E-01	↓	-2.7E-02	-3.0E+00
Gallium Dissolved	↔	7.1E-04	6.5E+00	↔	6.6E-05	6.0E-01
Germanium Dissolved	↔	-2.7E-08	-2.7E-04	↔	-2.2E-04	-2.2E+00
Iron Dissolved	↔	7.4E+00	3.5E+00	↔	6.0E+00	2.8E+00
Lanthanum Dissolved	↔	2.4E-03	5.5E+00	↔	1.7E-04	3.9E-01
Lead Dissolved	↔	3.6E-03	6.5E+00	↔	1.8E-04	3.3E-01
Lithium Dissolved	↑	1.9E-02	2.8E-01	↑	1.4E-01	2.1E+00
Manganese Dissolved	↑	1.1E-01	2.9E+00	↑	2.1E-01	5.7E+00
Molybdenum Dissolved	↔	-2.2E-03	-3.1E-01	↔	-1.7E-03	-2.4E-01
Nickel Dissolved	↔	2.5E-02	2.2E+00	↔	8.8E-03	7.8E-01
Niobium Dissolved	↓	-4.9E-04	-4.9E+01	↓	-2.0E-03	-2.0E+02
Rubidium Dissolved	↔	-7.9E-03	-8.5E-01	↔	8.3E-04	8.9E-02
Scandium Dissolved	↔	2.0E-06	2.0E-02	↔	4.4E-04	4.4E+00
Selenium Dissolved	↑	2.8E-03	2.0E+00	↑	2.7E-03	1.9E+00
Strontium Dissolved	↔	6.8E-02	3.1E-02	↑	3.0E+00	1.4E+00
Tellurium Dissolved	↔	-2.1E-06	-6.1E-02	↔	-6.2E-03	-1.8E+02
Thallium Dissolved	↓	-5.6E-08	-1.1E-03	↓	-2.0E-04	-3.9E+00
Tin Dissolved	↔	-6.2E-04	-8.9E+00	↔	-2.8E-03	-4.0E+01
Titanium Dissolved	↓	-3.0E-02	-7.4E+00	↓	-5.0E-02	-1.2E+01
Tungsten Dissolved	↔	-2.5E-09	-8.5E-05	↑	1.9E-08	6.4E-04
Uranium Dissolved	↔	2.7E-03	6.8E-01	↔	2.1E-03	5.3E-01
Vanadium Dissolved	↔	-9.2E-03	-3.0E+00	↓	-1.2E-02	-3.8E+00
Yttrium Dissolved	↔	3.3E-03	3.5E+00	↔	5.8E-04	6.2E-01
Zinc Dissolved	↔	-4.3E-08	-6.1E-06	↔	-1.7E-02	-2.4E+00
Zirconium Dissolved	↔	-2.6E-08	-2.6E-05	↓	-9.0E-03	-9.0E+00

M11A	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Aluminum Dissolved	↔	1.3E+00	6.1E+00	↔	9.2E-01	4.4E+00
Antimony Dissolved	↓	-5.2E-03	-4.9E+00	↔	-2.5E-03	-2.4E+00
Arsenic Dissolved	↔	9.8E-03	2.4E+00	↔	1.3E-03	3.2E-01
Barium Dissolved	↔	7.7E-01	1.7E+00	↑	4.8E-01	1.0E+00
Beryllium Dissolved	↔	7.8E-08	2.0E-03	↔	3.9E-05	9.8E-01
Bismuth Dissolved	↔	2.9E-08	4.3E-03	↔	2.8E-04	4.2E+01
Boron Dissolved	↔	1.1E-01	8.1E-01	↔	-3.2E-02	-2.4E-01
Cadmium Dissolved	↓	-1.4E-03	-8.7E+00	↓	-9.9E-04	-6.2E+00
Cerium Dissolved	↔	-1.8E-03	-1.8E+00	↔	-3.5E-03	-3.5E+00
Cesium Dissolved	↔	4.8E-04	8.1E+00	↔	3.1E-04	5.1E+00
Chromium Dissolved	↔	-7.9E-08	-7.5E-05	↔	5.8E-04	5.6E-01
Cobalt Dissolved	↔	-9.0E-09	-1.7E-05	↔	1.7E-04	3.3E-01
Copper Dissolved	↔	2.8E-02	2.1E+00	↔	4.9E-03	3.7E-01
Gallium Dissolved	↔	2.8E-04	1.8E+00	↔	2.4E-04	1.6E+00
Germanium Dissolved	↔	-5.7E-08	-7.2E-04	↔	6.4E-05	8.1E-01
Iron Dissolved	↔	1.3E+00	1.9E+00	↔	3.1E-01	4.5E-01
Lanthanum Dissolved	↔	-3.2E-08	-6.6E-05	↔	-9.2E-04	-1.9E+00
Lead Dissolved	↔	-1.8E-03	-2.9E+00	↔	-3.3E-03	-5.3E+00
Lithium Dissolved	↔	1.0E-01	2.3E+00	↔	6.2E-02	1.4E+00
Manganese Dissolved	↓	-1.4E-01	-6.5E+00	↔	-1.1E-01	-4.9E+00
Molybdenum Dissolved	↔	5.6E-03	7.4E-01	↔	-6.0E-05	-7.9E-03
Nickel Dissolved	↔	5.3E-02	5.2E+00	↑	3.5E-02	3.5E+00
Niobium Dissolved	↓	-2.2E-04	-2.8E+01	↓	-1.3E-03	-1.6E+02
Rubidium Dissolved	↔	1.3E-02	2.0E+00	↔	5.9E-03	9.5E-01
Scandium Dissolved	↑	2.0E-05	2.0E-01	↑	5.6E-03	5.6E+01
Selenium Dissolved	↑	9.8E-03	4.1E+00	↑	6.5E-03	2.7E+00
Strontium Dissolved	↔	1.6E+00	1.1E+00	↔	1.2E+00	9.0E-01
Thallium Dissolved	↓	-3.7E-08	-6.2E-04	↔	-1.0E-04	-1.7E+00
Tin Dissolved	↑	1.9E-03	1.5E+02	↑	3.1E-02	2.4E+03
Titanium Dissolved	↓	-4.4E-02	-8.8E+00	↓	-6.9E-02	-1.4E+01
Tungsten Dissolved	↑	1.6E-04	8.0E+00	↑	2.3E-04	1.1E+01
Uranium Dissolved	↔	9.3E-03	2.2E+00	↑	7.2E-03	1.7E+00
Vanadium Dissolved	↔	-1.1E-02	-3.7E+00	↔	-8.3E-03	-2.8E+00
Yttrium Dissolved	↔	1.2E-03	1.4E+00	↔	-1.2E-03	-1.4E+00
Zinc Dissolved	↓	-5.8E-02	-9.7E+00	↓	-5.8E-02	-9.7E+00
Zirconium Dissolved	↔	-1.2E-05	-1.5E-02	↔	6.5E-04	7.9E-01

M12	Concentration			Flow-Adjusted		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Aluminum Dissolved	↑	2.1E+00	8.7E+00	↑	1.5E+00	8.7E+00
Antimony Dissolved	↔	1.0E-03	1.1E+00	↔	1.1E-03	1.1E+00
Arsenic Dissolved	↔	1.1E-02	2.2E+00	↔	7.3E-03	2.2E+00
Barium Dissolved	↔	5.9E-01	6.3E-01	↔	3.2E-01	6.3E-01
Beryllium Dissolved	↔	1.6E-04	1.4E+01	↔	4.1E-04	1.4E+01
Bismuth Dissolved	↔	2.8E-04	1.1E+00	↔	7.1E-06	1.1E+00
Boron Dissolved	↔	-6.5E-08	-6.7E-02	↔	-5.6E-03	-6.7E-02
Cadmium Dissolved	↓	-1.3E-03	-6.5E+00	↓	-1.2E-03	-6.5E+00
Cerium Dissolved	↑	3.7E-03	4.3E+00	↔	1.8E-03	4.3E+00
Cesium Dissolved	↑	6.2E-04	9.3E+00	↑	4.7E-04	9.3E+00
Chromium Dissolved	↑	7.5E-03	5.8E+00	↑	5.8E-03	5.8E+00
Cobalt Dissolved	↔	2.1E-03	2.8E+00	↔	1.1E-03	2.8E+00
Copper Dissolved	↔	5.9E-03	-1.6E-01	↔	-1.6E-03	-1.6E-01
Gallium Dissolved	↑	1.8E-03	1.1E+01	↑	1.8E-03	1.1E+01
Germanium Dissolved	↔	-7.1E-08	3.0E-01	↔	2.1E-05	3.0E-01
Iron Dissolved	↑	6.7E+00	1.4E+01	↑	5.5E+00	1.4E+01
Lanthanum Dissolved	↔	1.6E-03	2.8E+00	↔	7.1E-04	2.8E+00
Lead Dissolved	↑	4.2E-03	1.0E+01	↑	3.5E-03	1.0E+01
Lithium Dissolved	↔	1.3E-01	1.7E+00	↔	5.2E-02	1.7E+00
Manganese Dissolved	↔	1.1E-01	7.5E+00	↑	9.3E-02	7.5E+00
Molybdenum Dissolved	↓	-1.6E-03	-8.4E-01	↔	-7.8E-03	-8.4E-01
Nickel Dissolved	↔	2.6E-02	2.0E+00	↑	1.8E-02	2.0E+00
Niobium Dissolved	↓	-4.6E-04	-3.8E+02	↓	-3.0E-03	-3.8E+02
Rubidium Dissolved	↑	1.6E-02	3.7E+00	↑	1.4E-02	3.7E+00
Scandium Dissolved	↑	3.5E-03	1.0E+02	↑	1.1E-02	1.0E+02
Selenium Dissolved	↑	7.8E-03	2.0E+00	↑	6.5E-03	2.0E+00
Strontium Dissolved	↔	1.1E+00	2.8E-01	↔	3.8E-01	2.8E-01
Thallium Dissolved	↔	-8.1E-09	5.2E+00	↔	2.6E-04	5.2E+00
Tin Dissolved	↔	3.5E-08	9.4E+00	↔	4.5E-04	9.4E+00
Titanium Dissolved	↔	-4.7E-08	-2.0E+00	↔	-5.9E-03	-2.0E+00
Tungsten Dissolved	↔	-4.5E-08	-1.0E-03	↔	-2.0E-08	-1.0E-03
Uranium Dissolved	↔	3.6E-03	3.7E-01	↔	2.0E-03	3.7E-01
Vanadium Dissolved	↔	7.2E-03	3.2E+00	↔	9.2E-03	3.2E+00
Yttrium Dissolved	↔	1.8E-03	1.5E+00	↔	8.4E-04	1.5E+00
Zinc Dissolved	↔	4.4E-08	-5.0E-03	↔	-2.5E-05	-5.0E-03
Zirconium Dissolved	↔	3.7E-08	0.0E+00	↔	0.0E+00	0.0E+00

Table B1-4. Statistical Summaries – Metals (Total)

M3	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Aluminum Total	↔	-2.3E+00	-4.1E-01	↓	-1.9E+01	-3.4E+00
Antimony Total	↔	-9.0E-04	-1.4E+00	↔	-1.2E-03	-1.9E+00
Arsenic Total	↔	-9.3E-03	-1.2E+00	↓	-2.9E-02	-3.6E+00
Barium Total	↔	-1.6E+00	-2.8E+00	↔	-6.8E-01	-1.2E+00
Beryllium Total	↔	-2.0E-04	-6.0E-01	↓	-1.0E-03	-3.0E+00
Bismuth Total	↔	-7.1E-08	-8.9E-04	↔	-1.2E-04	-1.5E+00
Boron Total	↔	2.5E-01	8.3E-01	↔	3.7E-01	1.2E+00
Cadmium Total	↔	-1.1E-03	-5.0E+00	↓	-1.7E-03	-8.2E+00
Cerium Total	↔	1.8E-02	1.4E+00	↔	-1.5E-02	-1.1E+00
Cesium Total	↔	-2.5E-08	-2.3E-05	↓	-2.6E-03	-2.4E+00
Chromium Total	↔	9.8E-03	1.1E+00	↔	-1.5E-02	-1.7E+00
Cobalt Total	↔	3.4E-03	7.9E-01	↔	-2.3E-03	-5.2E-01
Copper Total	↔	-1.5E-02	-1.3E+00	↓	-5.4E-02	-4.8E+00
Gallium Total	↔	-2.2E-03	-1.1E+00	↓	-8.5E-03	-4.5E+00
Germanium Total	↑	6.8E-04	3.4E+00	↔	1.9E-03	9.5E+00
Indium Total	↔	1.8E-04	1.8E+01	↔	3.8E-04	3.8E+01
Iron Total	↔	7.0E+01	5.5E+00	↔	4.3E+01	3.4E+00
Lanthanum Total	↔	7.5E-03	1.2E+00	↔	-4.0E-03	-6.6E-01
Lead Total	↔	6.7E-04	1.5E-01	↔	-7.7E-03	-1.7E+00
Lithium Total	↔	2.0E-02	2.5E-01	↔	4.7E-02	6.0E-01
Manganese Total	↔	1.8E+00	3.6E+00	↔	6.4E-01	1.3E+00
Mercury Total	↔	3.2E-08	1.2E-06	↓	-4.5E-02	-1.7E+00
Methyl Mercury	↔	4.1E-08	6.9E-05	↔	8.5E-03	1.4E+01
Molybdenum Total	↔	-2.5E-02	-4.5E+00	↔	-2.0E-02	-3.6E+00
Nickel Total	↔	9.3E-03	6.3E-01	↓	-5.3E-02	-3.6E+00
Niobium Total	↔	5.3E-08	2.6E-04	↓	-1.8E-03	-8.9E+00
Rubidium Total	↔	3.9E-02	2.0E+00	↔	-1.5E-02	-7.6E-01
Scandium Total	↑	2.4E-02	2.1E+01	↔	5.4E-02	4.9E+01
Selenium Total	↓	-7.1E-03	-4.7E+00	↓	-8.4E-03	-5.6E+00
Silver Total	↔	2.4E-09	5.3E-05	↔	-1.1E-04	-2.5E+00
Strontium Total	↔	-4.1E+00	-2.1E+00	↔	-4.3E+00	-2.2E+00
Tellurium Total	↑	5.7E-05	1.5E+00	↑	1.7E-05	4.4E-01
Thallium Total	↔	-4.7E-09	-3.6E-05	↓	-5.1E-04	-4.0E+00
Tin Total	↔	-6.4E-04	-2.0E+00	↓	-5.2E-03	-1.6E+01
Titanium Total	↔	4.9E-02	4.8E-01	↔	-2.9E-01	-2.8E+00
Tungsten Total	↔	1.9E-04	3.5E+00	↔	8.7E-05	1.6E+00
Uranium Total	↔	-1.7E-02	-5.0E+00	↔	-8.9E-03	-2.6E+00
Vanadium Total	↔	-7.1E-02	-6.8E+00	↓	-6.0E-02	-5.8E+00
Yttrium Total	↔	3.6E-03	7.0E-01	↔	-3.0E-03	-5.7E-01
Zinc Total	↔	3.4E-08	9.7E-07	↔	-3.3E-02	-9.3E-01
Zirconium Total	↔	-2.0E-08	-3.5E-06	↓	-1.3E-02	-2.4E+00

M7	Concentration			Flow-Adjusted		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Aluminum Total	↔	-6.4E+00	-2.4E+00	↓	-1.7E+01	-6.3E+00
Antimony Total	↔	1.6E-03	2.6E+00	↔	3.9E-04	6.1E-01
Arsenic Total	↔	-1.4E-02	-2.1E+00	↓	-2.8E-02	-4.2E+00
Barium Total	↔	4.0E-01	6.0E-01	↔	-1.3E-02	-2.0E-02
Beryllium Total	↔	-2.3E-04	-1.1E+00	↓	-1.1E-03	-5.5E+00
Bismuth Total	↔	4.6E-08	9.2E-04	↔	-1.6E-04	-3.3E+00
Boron Total	↔	-3.9E-01	-1.5E+00	↔	-1.0E-01	-3.8E-01
Cadmium Total	↔	7.7E-08	3.3E-04	↓	-1.2E-03	-5.1E+00
Cerium Total	↔	-7.3E-03	-1.0E+00	↓	-2.0E-02	-2.9E+00
Cesium Total	↔	-8.9E-04	-1.4E+00	↓	-2.5E-03	-4.1E+00
Chromium Total	↔	-8.5E-03	-1.9E+00	↓	-2.5E-02	-5.6E+00
Cobalt Total	↔	-4.3E-04	-1.4E-01	↓	-7.4E-03	-2.4E+00
Copper Total	↔	5.7E-03	5.5E-01	↔	-2.0E-02	-1.9E+00
Gallium Total	↔	-2.2E-03	-2.2E+00	↓	-6.3E-03	-6.4E+00
Germanium Total	↓	-5.3E-08	-2.6E-04	↔	3.7E-04	1.9E+00
Indium Total	↔	-2.3E-04	-2.3E+01	↔	-8.1E-04	-8.1E+01
Iron Total	↔	-8.2E+00	-1.2E+00	↓	-2.7E+01	-4.1E+00
Lanthanum Total	↔	-3.4E-03	-1.0E+00	↓	-9.5E-03	-2.9E+00
Lead Total	↔	-3.0E-03	-1.1E+00	↓	-7.5E-03	-2.6E+00
Lithium Total	↔	-5.5E-02	-6.7E-01	↔	-3.7E-02	-4.6E-01
Manganese Total	↔	-6.4E-01	-1.7E+00	↓	-1.3E+00	-3.4E+00
Mercury Total	↔	-5.2E-08	-2.7E-06	↓	-4.6E-02	-2.4E+00
Molybdenum Total	↓	-2.2E-02	-3.0E+00	↓	-2.3E-02	-3.1E+00
Nickel Total	↔	1.5E-02	1.1E+00	↔	-2.2E-02	-1.6E+00
Niobium Total	↓	-7.7E-04	-7.3E+00	↓	-1.0E-03	-9.7E+00
Rubidium Total	↔	3.1E-03	2.0E-01	↓	-2.8E-02	-1.8E+00
Scandium Total	↔	5.0E-03	7.2E+00	↔	2.6E-03	3.7E+00
Selenium Total	↓	-4.0E-03	-2.3E+00	↓	-7.2E-03	-4.2E+00
Silver Total	↔	-1.5E-08	-3.8E-04	↓	-1.9E-04	-4.7E+00
Strontium Total	↓	-1.9E+00	-8.2E-01	↔	-1.3E+00	-5.5E-01
Tellurium Total	↔	1.7E-05	2.3E-01	↔	5.2E-03	6.9E+01
Thallium Total	↔	-1.8E-04	-1.8E+00	↓	-5.0E-04	-5.0E+00
Tin Total	↔	-5.1E-08	-1.6E-04	↓	-5.7E-03	-1.8E+01
Titanium Total	↔	-9.1E-02	-2.0E+00	↓	-2.1E-01	-4.6E+00
Tungsten Total	↔	1.9E-08	3.2E-04	↔	-2.3E-04	-3.8E+00
Uranium Total	↔	-7.8E-04	-1.8E-01	↔	-1.1E-03	-2.6E-01
Vanadium Total	↔	-7.1E-02	-8.0E+00	↓	-5.1E-02	-5.8E+00
Yttrium Total	↔	-1.8E-03	-5.6E-01	↓	-7.9E-03	-2.5E+00
Zinc Total	↔	3.2E-02	1.7E+00	↓	-6.7E-02	-3.5E+00
Zirconium Total	↔	7.3E-08	2.4E-05	↓	-2.0E-02	-6.6E+00
Methyl Mercury	↔	-3.1E-03	-6.3E+00	↔	2.5E-04	5.1E-01

M9	Concentration			Flow-Adjusted		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Aluminum Total	↔	8.6E+00	2.2E+00	↓	-1.5E+01	-3.8E+00
Antimony Total	↑	2.8E-03	4.1E+00	↔	-3.2E-04	-4.8E-01
Arsenic Total	↔	4.8E-08	5.9E-06	↓	-3.1E-02	-3.9E+00
Barium Total	↔	4.7E-01	7.0E-01	↔	1.5E-01	2.3E-01
Beryllium Total	↔	3.3E-04	1.1E+00	↓	-1.3E-03	-4.5E+00
Bismuth Total	↔	3.2E-04	5.3E+00	↓	-2.7E-04	-4.5E+00
Boron Total	↔	2.8E-02	1.0E-01	↑	4.9E-01	1.8E+00
Cadmium Total	↑	1.0E-03	4.6E+00	↔	-2.7E-04	-1.2E+00
Cerium Total	↔	1.9E-02	1.8E+00	↓	-3.1E-02	-2.8E+00
Cesium Total	↔	1.7E-03	1.8E+00	↓	-2.8E-03	-3.0E+00
Chromium Total	↔	2.0E-02	3.0E+00	↓	-2.2E-02	-3.3E+00
Cobalt Total	↔	1.0E-02	2.4E+00	↓	-8.9E-03	-2.1E+00
Copper Total	↔	3.9E-02	2.9E+00	↔	-3.0E-02	-2.2E+00
Gallium Total	↔	4.4E-03	2.8E+00	↓	-4.0E-03	-2.5E+00
Germanium Total	↔	-6.9E-08	-2.3E-04	↓	-1.1E-03	-3.6E+00
Indium Total	↔	2.2E-08	2.1E-03	↔	-1.7E-03	-1.7E+02
Iron Total	↔	1.6E+01	1.7E+00	↓	-3.1E+01	-3.3E+00
Lanthanum Total	↔	1.0E-02	2.0E+00	↓	-1.4E-02	-2.6E+00
Lead Total	↔	1.8E-02	3.7E+00	↔	-9.7E-03	-2.0E+00
Lithium Total	↔	4.5E-02	5.2E-01	↔	5.2E-02	6.1E-01
Manganese Total	↔	1.1E+00	2.3E+00	↔	-1.3E+00	-2.8E+00
Mercury Total	↔	1.8E-02	6.5E-01	↓	-7.5E-02	-2.7E+00
Methyl Mercury	↑	4.9E-03	6.1E+00	↔	1.0E-03	1.3E+00
Molybdenum Total	↔	-6.7E-03	-9.0E-01	↓	-1.1E-02	-1.5E+00
Nickel Total	↔	4.4E-02	2.5E+00	↔	-3.6E-02	-2.0E+00
Niobium Total	↓	-6.8E-04	-4.0E+00	↓	-2.0E-03	-1.2E+01
Platinum Total	↓	-1.5E-04	-2.9E+01	↓	-1.1E-19	-2.1E-14
Rubidium Total	↔	2.2E-02	1.3E+00	↔	-5.1E-02	-3.1E+00
Scandium Total	↔	1.3E-02	1.0E+01	↔	-1.1E-03	-8.4E-01
Selenium Total	↔	5.8E-08	3.6E-05	↓	-3.3E-03	-2.1E+00
Silver Total	↔	2.5E-08	4.1E-04	↓	-3.2E-04	-5.3E+00
Strontium Total	↔	5.1E-01	2.2E-01	↑	2.6E+00	1.1E+00
Tellurium Total	↔	1.8E-06	3.9E-02	↔	2.6E-04	5.8E+00
Thallium Total	↔	3.1E-08	2.6E-04	↓	-5.7E-04	-4.7E+00
Tin Total	↔	-2.2E-03	-6.1E+00	↓	-8.2E-03	-2.3E+01
Titanium Total	↔	1.0E-01	1.4E+00	↓	-3.0E-01	-4.0E+00
Tungsten Total	↔	2.0E-04	3.9E+00	↔	-1.2E-05	-2.5E-01
Uranium Total	↔	2.4E-03	5.8E-01	↔	-8.9E-04	-2.1E-01
Vanadium Total	↔	-3.2E-02	-2.5E+00	↓	-5.9E-02	-4.5E+00
Yttrium Total	↔	1.0E-02	2.2E+00	↓	-1.0E-02	-2.3E+00
Zinc Total	↔	9.8E-02	3.3E+00	↔	-3.9E-02	-1.3E+00
Zirconium Total	↔	-3.4E-09	-8.4E-07	↓	-2.9E-02	-7.3E+00

M11A	**Concentration**			**Flow-Adjusted**		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Aluminum Total	↔	1.0E+02	8.4E+00	↔	8.7E+01	7.2E+00
Antimony Total	↔	5.7E-03	4.9E+00	↑	5.0E-03	4.4E+00
Arsenic Total	↔	9.3E-02	7.3E+00	↑	7.9E-02	6.2E+00
Barium Total	↑	4.0E+00	5.6E+00	↑	3.7E+00	5.1E+00
Beryllium Total	↑	6.7E-03	9.2E+00	↑	7.6E-03	1.0E+01
Bismuth Total	↔	2.0E-03	1.1E+01	↑	1.8E-03	1.0E+01
Boron Total	↔	3.1E-01	1.9E+00	↔	1.6E-01	9.7E-01
Cadmium Total	↔	2.0E-03	3.5E+00	↔	3.3E-03	5.9E+00
Cerium Total	↑	2.3E-01	9.8E+00	↑	2.4E-01	1.0E+01
Cesium Total	↑	3.0E-02	1.1E+01	↑	2.7E-02	1.0E+01
Chromium Total	↔	1.9E-01	1.0E+01	↑	1.5E-01	8.5E+00
Cobalt Total	↑	9.2E-02	1.1E+01	↑	9.5E-02	1.2E+01
Copper Total	↑	2.7E-01	8.8E+00	↑	2.3E-01	7.5E+00
Gallium Total	↔	3.9E-02	1.0E+01	↑	3.5E-02	9.4E+00
Germanium Total	↑	5.2E-03	1.0E+01	↑	4.0E-03	8.0E+00
Indium Total	↔	4.3E-04	2.2E+01	↔	1.4E-03	6.9E+01
Iron Total	↑	2.2E+02	1.0E+01	↑	2.3E+02	1.1E+01
Lanthanum Total	↔	1.0E-01	9.2E+00	↑	1.1E-01	1.0E+01
Lead Total	↔	1.1E-01	9.9E+00	↑	9.4E-02	8.5E+00
Lithium Total	↑	3.5E-01	5.9E+00	↑	2.9E-01	4.9E+00
Manganese Total	↔	3.7E+00	7.4E+00	↑	5.2E+00	1.1E+01
Mercury Total	↔	7.7E-02	1.2E+00	↑	7.1E-01	1.1E+01
Methyl Mercury	↑	5.9E-03	8.4E+00	↑	3.0E-02	4.3E+01
Molybdenum Total	↔	1.4E-02	1.8E+00	↔	9.8E-03	1.2E+00
Nickel Total	↑	3.4E-01	9.9E+00	↑	2.6E-01	7.6E+00
Niobium Total	↔	1.8E-03	4.4E+00	↔	1.4E-03	3.5E+00
Rubidium Total	↑	2.8E-01	8.6E+00	↑	2.5E-01	7.9E+00
Scandium Total	↑	7.0E-02	2.0E+01	↑	2.1E-01	6.2E+01
Selenium Total	↔	1.1E-02	3.9E+00	↑	9.0E-03	3.1E+00
Silver Total	↔	7.5E-08	4.5E-04	↑	1.7E-03	1.0E+01
Strontium Total	↑	2.9E+00	2.0E+00	↑	2.8E+00	1.9E+00
Tellurium Total	↔	7.0E-06	7.8E-02	↔	5.1E-03	5.7E+01
Thallium Total	↔	3.0E-03	8.8E+00	↑	3.3E-03	9.6E+00
Tin Total	↔	2.4E-03	5.6E+00	↔	3.5E-03	8.4E+00
Titanium Total	↔	9.7E-01	5.3E+00	↔	8.4E-01	4.6E+00
Tungsten Total	↔	2.3E-09	4.7E-05	↔	-1.5E-05	-3.1E-01
Uranium Total	↑	1.6E-02	3.2E+00	↑	2.0E-02	4.2E+00
Vanadium Total	↔	4.5E-02	1.4E+00	↔	2.0E-01	6.1E+00
Yttrium Total	↑	1.1E-01	1.1E+01	↑	1.1E-01	1.1E+01
Zinc Total	↔	8.7E-01	1.1E+01	↔	6.3E-01	7.9E+00
Zirconium Total	↔	4.0E-03	5.7E-01	↔	1.5E-02	2.2E+00

M12	Concentration			Flow-Adjusted		
Parameter	**Trend**	**ATS Slope**	**APC (%)**	**Trend**	**ATS Slope**	**APC (%)**
Aluminum Total	↔	2.1E+01	3.6E+00	↔	1.7E+01	3.6E+00
Antimony Total	↔	2.9E-03	3.7E+00	↑	4.2E-03	3.7E+00
Arsenic Total	↔	1.6E-02	2.4E+00	↔	1.6E-02	2.4E+00
Barium Total	↔	1.3E+00	1.7E+00	↑	1.2E+00	1.7E+00
Beryllium Total	↔	8.6E-04	3.9E+00	↔	1.2E-03	3.9E+00
Bismuth Total	↔	3.4E-04	2.0E+01	↔	1.6E-03	2.0E+01
Boron Total	↔	3.8E-01	2.5E+00	↔	2.3E-01	2.5E+00
Cadmium Total	↔	-6.9E-08	-5.7E-02	↔	-2.6E-05	-5.7E-02
Cerium Total	↑	4.7E-02	5.7E+00	↑	4.7E-02	5.7E+00
Cesium Total	↑	5.3E-03	5.0E+00	↑	5.6E-03	5.0E+00
Chromium Total	↔	2.3E-02	1.8E+00	↔	1.3E-02	1.8E+00
Cobalt Total	↑	1.8E-02	5.5E+00	↑	1.9E-02	5.5E+00
Copper Total	↔	3.4E-02	2.6E+00	↔	4.6E-02	2.6E+00
Gallium Total	↑	1.3E-02	7.5E+00	↑	1.2E-02	7.5E+00
Germanium Total	↑	8.9E-04	5.9E+00	↑	1.8E-03	5.9E+00
Indium Total	↔	1.8E-06	1.5E+02	↔	1.5E-03	1.5E+02
Iron Total	↑	4.9E+01	7.4E+00	↑	5.4E+01	7.4E+00
Lanthanum Total	↑	2.3E-02	6.3E+00	↑	2.3E-02	6.3E+00
Lead Total	↔	2.4E-02	6.3E+00	↑	3.0E-02	6.3E+00
Lithium Total	↔	1.6E-01	2.8E+00	↑	1.2E-01	2.8E+00
Manganese Total	↔	1.3E+00	5.3E+00	↑	1.4E+00	5.3E+00
Mercury Total	↑	1.7E-01	3.3E+00	↔	1.4E-01	3.3E+00
Methyl Mercury	↔	6.9E-03	3.5E+01	↑	1.7E-02	3.5E+01
Molybdenum Total	↔	2.4E-03	8.8E-02	↔	8.9E-04	8.8E-02
Nickel Total	↔	6.1E-02	4.6E+00	↑	8.2E-02	4.6E+00
Niobium Total	↔	1.1E-09	-1.1E+00	↔	-2.0E-04	-1.1E+00
Rubidium Total	↑	5.5E-02	3.9E+00	↑	5.8E-02	3.9E+00
Scandium Total	↑	2.4E-02	8.2E+01	↑	9.0E-02	8.2E+01
Selenium Total	↑	6.7E-03	2.0E+00	↑	7.0E-03	2.0E+00
Silver Total	↔	-3.6E-08	5.5E+00	↔	4.4E-04	5.5E+00
Strontium Total	↔	1.3E+00	7.5E-01	↔	1.1E+00	7.5E-01
Tellurium Total	↔	7.2E-09	-2.5E+01	↔	-1.2E-03	-2.5E+01
Thallium Total	↔	4.1E-04	3.0E+00	↔	5.0E-04	3.0E+00
Tin Total	↔	1.6E-03	4.2E+00	↔	1.8E-03	4.2E+00
Titanium Total	↔	2.2E-01	2.2E+00	↔	1.6E-01	2.2E+00
Tungsten Total	↔	3.9E-08	-3.1E+00	↔	-1.5E-04	-3.1E+00
Uranium Total	↔	4.9E-03	8.3E-01	↔	4.8E-03	8.3E-01
Vanadium Total	↔	1.8E-02	2.3E+00	↔	4.0E-02	2.3E+00
Yttrium Total	↔	2.0E-02	6.7E+00	↑	2.8E-02	6.7E+00
Zinc Total	↔	2.3E-01	6.3E+00	↑	2.5E-01	6.3E+00
Zirconium Total	↔	-1.2E-08	5.2E+00	↔	1.6E-02	5.2E+00