



2022 Status of surface water quality, Upper Athabasca Region, Alberta

Reporting on the Surface Water Quality Management
Framework for the Upper Athabasca River for
November 2019 to October 2022

2022 Status of Surface Water Quality, Upper Athabasca Region, Alberta

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Alberta's Environmental Science Program

The Chief Scientist has a legislated responsibility for developing and implementing Alberta's environmental science program for monitoring, evaluation and reporting on the condition of the environment in Alberta. The program seeks to meet the environmental information needs of multiple users in order to inform policy and decision-making processes. Two independent advisory panels, the Science Advisory Panel and the Indigenous Wisdom Advisory Panel, periodically review the integrity of the program and provide strategic advice on the respectful braiding of Indigenous Knowledge with conventional scientific knowledge.

Alberta's environmental science program is grounded in the principles of:

- *Openness and Transparency.* Appropriate standards, procedures and methodologies are employed, and findings are reported in an open, honest and accountable manner.
- *Credibility.* Quality in the data and information are upheld through a comprehensive Quality Assurance, Quality Control program that invokes peer review processes when needed.
- *Scientific Integrity.* Standards, professional values, and practices of the scientific community are adopted to produce objective and reproducible investigation.
- *Accessible Monitoring Data and Science.* Scientifically-informed decision making is enabled through the public reporting of monitoring data and scientific findings in a timely, accessible, unaltered and unfettered manner.
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Acronyms and Abbreviations

EPA	Alberta Environment and Protected Areas
GL	Guideline
GOA	Government of Alberta
LTRN	Long Term River Network
PAL	Protection of Aquatic Life
SWQMF	Surface Water Quality Management Framework
TMN	Tributary Monitoring Network
UAR	Upper Athabasca Region
UAR SWQMF	Upper Athabasca Region Surface Water Quality Management Framework for the Upper Athabasca River

Executive Summary

Background

This report was prepared by Alberta Environment and Protected Areas (EPA) to fulfill reporting requirements outlined in the Upper Athabasca Region Surface Water Quality Management Framework for the Upper Athabasca River (UAR SWQMF, 2022).

This is the first annual report for the Upper Athabasca Region (UAR), communicating changes in the central tendency (median) and peak (90th percentile) values for 29 primary and 3 secondary water quality indicators at 1 primary monitoring station (Athabasca River at the Town of Athabasca) from November 1, 2019, to October 31, 2022. Furthermore, this report identifies relevant water quality limits or guidelines that were exceeded from November 1, 2021, to October 31, 2022, at 1 primary station and 9 secondary stations in the Upper Athabasca Region, where applicable. For primary indicators, significant median trigger, peak trigger and/or limit exceedances at the primary station will initiate a management response as per the UAR SWQMF.

Methodology

Primary indicators are monitored monthly during the winter (November–March) and open water (April–October) seasons. Following the methodology outlined in the UAR SWQMF, seasonal reporting data from November 1, 2019, to October 31, 2022, for the primary monitoring station, were compared to the baseline dataset for primary indicators to determine whether the median and peak values deviate from baseline median or peak triggers. The starting date for the baseline period varied for different indicators from 1987 to 2007, while the end date for all indicators was 2018. Values for primary indicators of the reporting period that deviate from baseline triggers at the primary station were statistically assessed for significant median and/or peak changes. Median seasonal values for primary indicators at the primary station from November 1, 2021, to October 31, 2022, were also compared to surface water quality guidelines for the Protection of Aquatic Life (PAL), Irrigation, Livestock, and Recreation and Aesthetics for all indicators included in the UAR SWQMF. Since indicators can have multiple guidelines for different uses, the most stringent guideline was predominantly used to define the ambient water quality limit for each primary indicator under the UAR SWQMF.

Secondary indicators are generally monitored monthly and assessed for any significant deviations from baseline, median, or peak values. Importantly there are no triggers or limits assigned to secondary indicators or primary indicators at secondary stations. Reporting data from the primary and secondary stations were also compared to surface water quality guidelines as defined in the UAR SWQMF.

Results

For the 29 primary indicators that were measured at the one primary monitoring station (Athabasca River at the Town of Athabasca), there are a total of 58 potential season/primary indicator combinations (29 primary indicators across two seasons) that were assessed for median and peak trigger exceedances. There were 8 (14%) indicator/season combinations for primary indicators that were found to be significantly exceeding trigger values. For the one primary station, 6 primary indicators exceeded the median and/or peak trigger, in either the winter or the open water season.

The key results for the primary indicators are:

- Median triggers were exceeded for dissolved cobalt (winter), dissolved nickel (open and winter), potassium (winter), total suspended solids (winter), sulphate (open), and dissolved uranium (open and winter).
- Peak triggers were exceeded for sulphate (open) and dissolved uranium (winter).

- No indicators exceeded surface water quality limits.

For the 3 secondary indicators that resulted in 6 season/indicator combinations, there were 2 indicators with a significant change from baseline values. Those secondary indicators were total mercury (winter) and total recoverable cobalt (winter).

There were 14 primary and secondary indicators assessed for potential exceedance of five surface water quality guidelines (i.e., Irrigation, Livestock, Recreation and Aesthetics, Protection of Aquatic Life Chronic, and Protection of Aquatic Life Acute). In total, 646 individual measurements from primary and secondary stations were assessed against the five potential guidelines with 20 (3%) values exceeding a surface water quality guideline.

Conclusion

The main objective of this annual condition report was to outline instances where primary indicators exceeded a water quality median or peak trigger, or a surface water quality limit as outlined in the UAR SWQMF. In total, 6 (21%) primary indicators exceeded the median and/or peak trigger in either the winter or the open water season. Additionally, there were no water quality limit exceedances for the primary indicators at the primary station. Results from this assessment will inform a management response as per the UAR SWQMF (GOA, 2022).



Introduction

The Government of Alberta (GOA) is committed to the management of cumulative effects on the environment. This commitment, articulated in the Land-use Framework (GOA, 2008), is supported by regional and sub-regional planning and other initiatives from Alberta's Integrated Resource Management System. Environmental management frameworks are a fundamental component of Alberta's approach to both assessing and managing cumulative effects, that have been developed for multiple media, including air quality, groundwater, surface water quality, surface water quantity, and tailings management.

Surface water quality management frameworks (SWQMFs) have been in place for the Lower Athabasca region since 2012 (GOA, 2012) and the South Saskatchewan regions since 2014 (GOA, 2014). To complement these frameworks, the GOA introduced SWQMFs for the North Saskatchewan and Upper Athabasca regions in 2022 with the intent to eventually have SWQMFs in place for all of Alberta's major river systems.

The Upper Athabasca Region Surface Water Quality Management Framework for the Upper Athabasca River (UAR SWQMF) applies to the mainstem of the Athabasca River, within the boundary of the Upper Athabasca Region (Figure 1). The UAR SWQMF builds upon the existing Lower Athabasca Region SWQMF. Together, these two frameworks establish a basin-wide approach for managing cumulative effects on the Athabasca River from the Rocky Mountain headwaters to its discharge in the Peace-Athabasca Delta. The purpose of the UAR SWQMF is to "clearly define a regional approach to managing the cumulative effects of development on the surface water quality of the upper reaches of the Athabasca River (i.e., in the Upper Athabasca Region)" (GOA, 2022, pg. 9). To achieve this, the UAR SWQMF (GOA, 2022) establishes a regional objective for surface water quality, selects key indicators of water quality, sets surface water quality thresholds for these indicators, and outlines a management response process for instances where indicators exceed a threshold. Cumulatively, this system creates an integrated and robust management system that is consistent across the province's land use planning regions, while outlining the roles and responsibilities of relevant parties.

In the UAR SWQMF (GOA, 2022), management thresholds have been established to evaluate the surface water quality indicators to help understand if the UAR SWQMF regional objective is being met. The main objective of this annual SWQMF report is to determine if a threshold has been exceeded, which then informs the need to initiate a management response for primary indicators included in the UAR SWQMF.

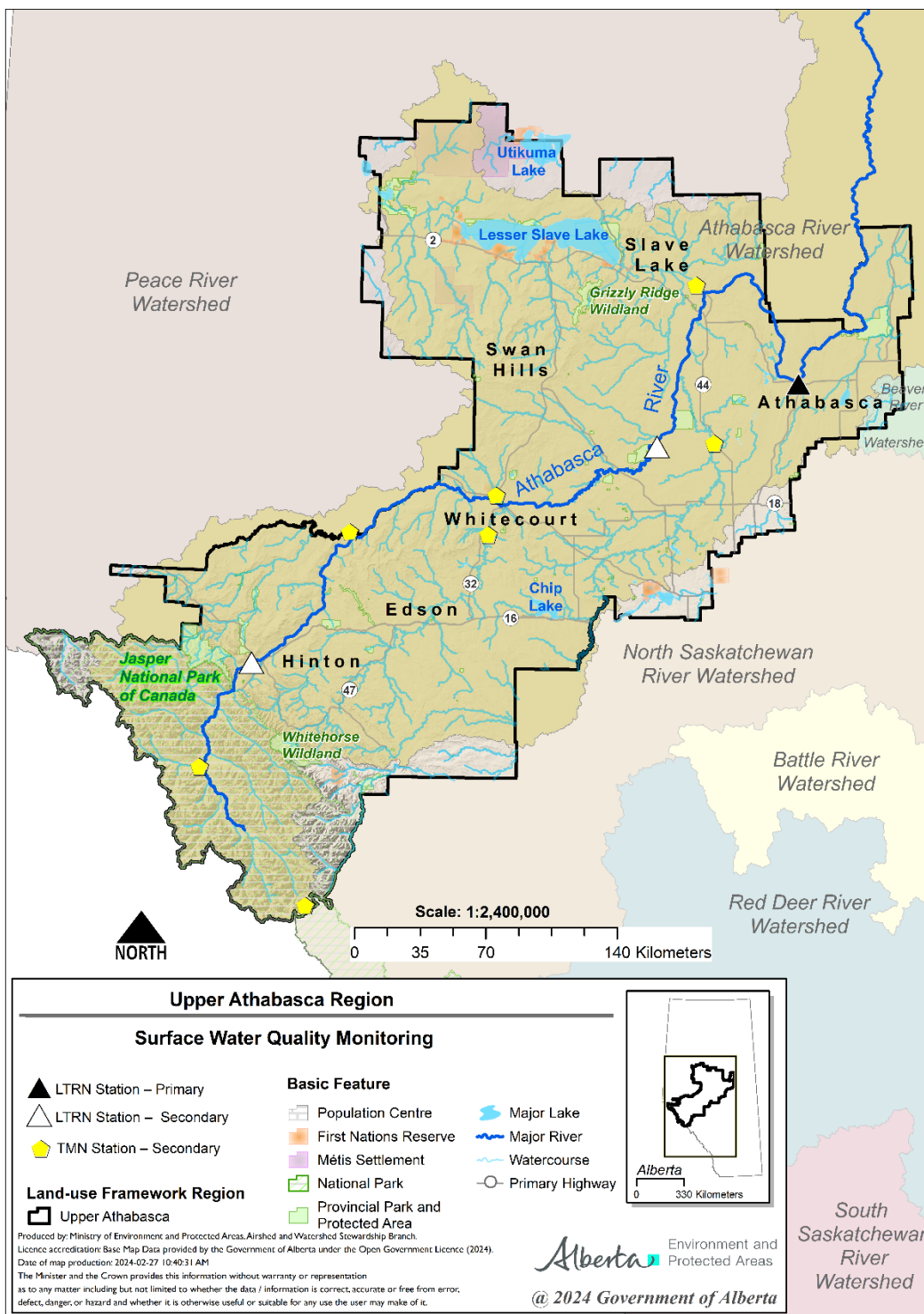


Figure 1. Administrative boundaries of the Upper Athabasca Region along with adjacent Land-use Framework regions from the UAR SWQMF (GOA, 2022). Location of surface water quality monitoring stations in the Upper Athabasca Region are shown as well.

Methodology

Monitoring Stations

Alberta's Long-term River Network (LTRN) program generates monthly river water quality monitoring data at 36 stations across 13 of Alberta's major rivers year-round (Kerr and Cooke, 2019). In the Upper Athabasca Region (UAR), there are three LTRN stations:

- Athabasca River at Old Entrance, upstream of Hinton (Station No: AB07AD0100),
- Athabasca River at Vega Ferry crossing (Station No: AB07BD0010), and
- Athabasca River at Town of Athabasca (Station No: AB07BE0010).

At the time of framework development, one LTRN station met the criteria for inclusion as a primary station: Athabasca River at Town of Athabasca (GOA, 2022). The remaining two stations either did not have sufficient period of record or did not have significant upstream land use pressures under the jurisdiction of the GOA.

The Tributary Monitoring Network (TMN) program was established in 2016 (Kerr and Cooke, 2019) to augment the LTRN program by increasing water quality monitoring on tributaries of Alberta's major rivers. In the UAR SWQMF, there are seven TMN stations:

- Lesser Slave River 9.5 km upstream of Athabasca River Confluence (Station No: AB07BK0125),
- Pembina River near Jarvie (Station No: AB07BC0025),
- Sakwatamau River near Whitecourt (Station No: AB07AH0005),
- Mcleod River upstream Whitecourt (Station No: AB07AG0345),
- Berland River near Mouth (Station No: AB07AC0015),
- Miette River near Jasper (Station No: AB07AA0007), and
- Sunwapta River at Athabasca Glacier (Station No: AB07AA0005).

The TMN stations did not have a sufficient length of data record to be included as primary stations with established thresholds. Nonetheless, the TMN sites, along with the Athabasca River at Old Entrance and the Athabasca River at Vega Ferry crossing will be reported on in these annual SWQMF condition reports as secondary stations. These nine secondary stations help inform on the condition of the environment, providing information on water quality in tributaries flowing into the Athabasca River across the UAR and on other locations on the mainstem of the Athabasca River. More information on station selection is provided in Section 4.3 and Section 7 of the UAR SWQMF (GOA, 2022).

Surface Water Quality Indicators

More than 100 physical and chemical water quality indicators are analyzed typically monthly at the LTRN stations, including general surface water indicators, major ions, nutrients, bacteria, trace elements, and pesticides. A similar suite of parameters is monitored at the TMN stations, with the exception of pesticide samples.

Of these parameters, 29 primary indicators are identified in the UAR SWQMF through an analysis that was based on numerous statistical analyses, evaluation of effluent sources to the Upper Athabasca River, comparison with provincial surface water quality guidelines, and consideration of the Lower Athabasca Region SWQMF. The UAR SWQMF assigns management thresholds for these primary indicators. Three secondary indicators, total recoverable cobalt, total recoverable copper, and total mercury are also identified in the UAR SWQMF. These secondary indicators do not meet the criteria for primary indicators and therefore do not have thresholds assigned but are important to understand and are evaluated in this report. More information on indicators selection, can be found in Section 8 in the UAR SWQMF (GOA, 2022).

Table 1. Primary and secondary indicators (marked with an *) included the UAR SWQMF (2022).

Trace Elements	Dissolved Aluminum	Biological Ions	<i>Escherichia coli</i>
	Dissolved Boron		Chloride
	Dissolved Cadmium		Potassium
	Dissolved Cobalt		Sodium
	Dissolved Copper		Specific Conductance
	Dissolved Iron		Sulphate
	Dissolved Nickel	General	Total Suspended Solids
	Dissolved Strontium		pH (Field)
	Dissolved Uranium		Dissolved Oxygen
	Dissolved Vanadium		Colour
	Total Recoverable Cadmium	Nutrients	Total Ammonia
	Total Recoverable Cobalt*		Nitrate
	Total Recoverable Copper*		Total Nitrogen
	Total Mercury*		Total Phosphorus
	Total Recoverable Zinc		Total Dissolved Phosphorus
	Total Recoverable Selenium		Dissolved Organic Carbon

Management Thresholds

Management thresholds set for the 29 primary indicators at the primary station in the UAR SWQMF (GOA, 2022) provide a benchmark to help understand whether the regional objective is being met. The UAR regional surface water quality objective is defined as “surface water quality for the mainstem Athabasca River in the Upper Athabasca Region is managed so current and future water used are protected” (GOA, 2022). There are two types of thresholds listed in the UAR SWQMF, triggers and limits, which are reported upon in this annual SWQMF condition report. Flow charts of the assessment of these management thresholds are outlined in Figures 2 and 3, respectively.

Water Quality Triggers

Median and peak triggers are used to identify potential changes in the condition of primary indicators. Median and peak trigger values were developed from the historical dataset over a baseline data period; for details about periods of record particular to an indicator or station please refer to the UAR SWQMF (GOA, 2022). Median triggers often represent longer term, chronic changes in condition whereas peak triggers help identify short-term acute changes in indicator condition (GOA, 2022). Peak trigger exceedances flag statistically significant shifts in the occurrence of extreme values in the reporting dataset. The identification of median and peak trigger exceedances is intended to serve as an early warning system of potential changes in surface water quality; a signal to highlight the need for further investigation.

Across Alberta, many indicators have seasonal patterns due to various environmental and climatic drivers. Therefore, triggers are calculated separately for the winter season (November to March) and the open water season (April to October). Accordingly, median and peak triggers were calculated for each of these two seasons. The Turnbull method for interval-censored data, a variation of the Kaplan-Meier approach, was used to calculate the water quality triggers in the R programming language using the cenfit function from the NADA Package (Lee, 2022).

Often there are indicators that have concentrations below the laboratories level of detection (i.e., censored data). When there were changes in the level of detection for indicators, the maximum detection limit from the baseline and reporting data was selected, excluding potential detection limit outliers, for each indicator. All values in the dataset, at or below the maximum detection limit, were considered to be censored data.

The maximum detection limit from the baseline and potential reporting data was then substituted for all censored data. In cases where more than 50%, or 90%, of the dataset was censored, the maximum detection limit was applied as the median or peak trigger values, respectively. The objective of this approach is to prevent false step changes and trends

in the datasets and facilitate data analysis for indicators that may have varying levels of analytical detection. A detailed description of the process for setting trigger values is provided in Appendix A of the UAR SWQMF (GOA, 2022), including the baseline data used, the statistical tests conducted, and the treatment of censored data used to develop the triggers.

Water Quality Limits

Limits are not intended to act as “pollute up to” values; rather, water quality conditions following the UAR regional surface water quality objective are expected to be protected below limits and within triggers. Limit exceedances indicate that current or potential future water uses may not be protected, and that a potential use protection issue is then flagged for a management response.

Although indicators may have multiple guidelines for different uses (e.g., Irrigation, Livestock, Recreation and Aesthetics, and Protection of Aquatic Life), the most stringent guideline was predominantly used to define the ambient limit for each indicator under the UAR SWQMF (Table 2). When the most stringent limit published in the Environmental Quality Guidelines for Alberta Surface Waters (GOA, 2018) was for the PAL, the chronic guideline was used to define the limit for a given indicator. Acute guidelines are more appropriate for short-term exposure, whereas the chronic guidelines are more appropriate for exposure over extended temporal periods and more relatable to the sampling regime.

Table 2. Limit values that are applicable to primary indicators at primary stations for the UAR SWQMF.

Indicator	Category	Guideline	Limit	Units
<i>Escherichia coli</i>	Biological	Recreation Aesthetics	100	cfu/100 mL
pH (Field)	General	PAL Chronic	6.5, 9	pH units
Oxygen Dissolved	General	PAL Chronic	6.5	mg/L
Dissolved Chloride	Ions	Irrigation	100	mg/L
Dissolved Sulphate	Ions	PAL Chronic	Hardness dependent	mg/L
Dissolved Iron	Trace Elements	PAL Chronic	300	ug/L
Total Recoverable Selenium	Trace Elements	PAL Chronic	2	ug/L
Total Recoverable Zinc	Trace Elements	PAL Chronic	30	ug/L
Dissolved Aluminum	Trace Elements	PAL Chronic	Equation-based	ug/L
Total Recoverable Cadmium	Trace Elements	PAL Chronic	Equation-based	ug/L
Nitrate as Nitrogen	Nutrients	PAL Chronic	3	mg/L
Total Ammonia	Nutrients	PAL Chronic	Equation-based	mg/L

Threshold Evaluation

Water Quality Triggers

For water quality trigger evaluation, the reporting dataset consists of data collected over the most recent three hydrological years (November 1st to October 31st). Similar to the baseline data, the reporting dataset is separated into two seasons that are assessed independently: the winter season (November to March) and the open water season (April to October). Three years of reporting data are used to increase the robustness of the statistical tests that assess the significance of potential median and peak trigger exceedances. The evaluation of median and peak trigger exceedances involves two steps (see Figure 2).

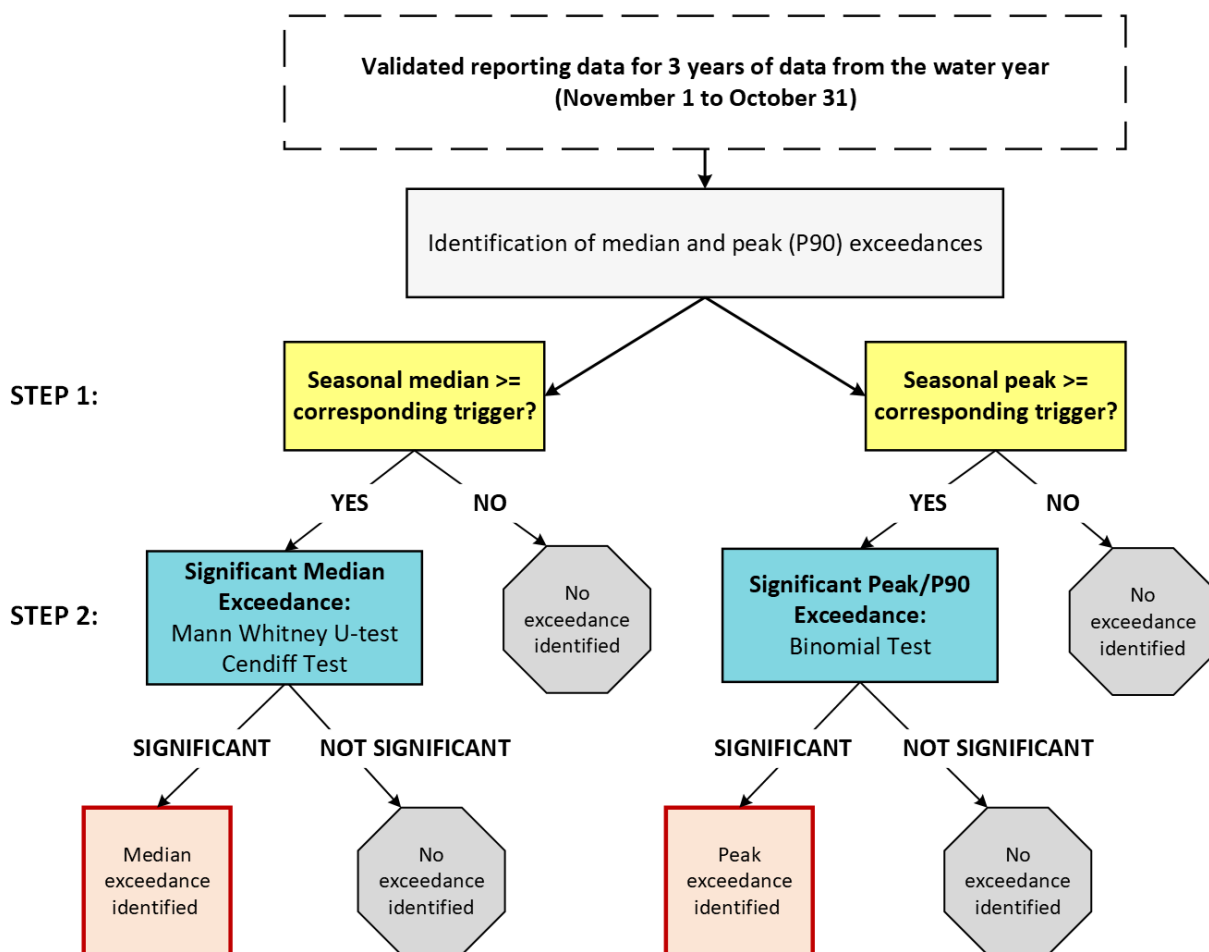


Figure 2. Flow chart of the approach to assessing trigger exceedances in the UAR SWQMF.

Step one directly compares the median and peak values calculated from the reporting data against the triggers developed from the baseline dataset. To help facilitate a direct comparison, the median (i.e. 50th percentile) and peak (90th percentile) are calculated for the reporting dataset in the statistical software R with the cenfit function from the NADA Package, following the procedure used to address censored data in the baseline data outlined above.

Cases where the median and/or peak of the reporting data are equal to or greater than the baseline trigger values will proceed to step two for further statistical assessment. For instances where 50% or more of the baseline or reporting dataset is censored, the percent of detected data will be compared between the reporting and baseline datasets to assess shifts in median triggers. Cases where there is an increase in the percent detected in the reporting data relative to the baseline data will proceed to step two for further statistical assessment of a potential median trigger exceedance. Regarding the peak trigger step one assessment, there is limited impact of censored data as the analysis focusses on

individual samples exceeding the 90th percentile, which is not affected by the amount of data below the limits of detection.

Step two assesses whether differences between the reporting data and trigger values observed in the first step are statistically significant. In this case, statistically significant indicates that the differences between the reporting and trigger values are unlikely to be caused by chance or sampling error, rather, that the differences between the reporting and trigger values likely reflect an effect or relationship that exists in the reporting dataset. In other words, this likelihood is statistically significant if the p-value (0.05) is less than the chosen significance level ($\alpha = 0.05$, i.e. 95% confidence level).

For median trigger exceedances, step two uses two tests to determine whether there are a significant number of samples in the reporting dataset that exceeded the median trigger or their corresponding baseline dataset. For instances where there are less than 50% censored data in the reporting and/or baseline datasets, the non-parametric Wilcoxon rank sum test (i.e., Mann Whitney U-test) is used to assess significant shifts in the two datasets using the `wilcox.exact` function from the `exactRankTests` package (Hothorn and Hormik, 2019) in R using an exact one-sided test and a significance level of 0.05. For instances where either the reporting or baseline dataset has equal to or greater than 50% censored data, the `cendiff` function from the `NADA` package (Lee, 2022) is used to assess significant differences for highly censored dataset. A median trigger exceedance is deemed to occur when the appropriate test indicates a statistically significant difference (i.e., a p-value < 0.05) between the reporting and baseline data.

For peak triggers, step two assesses whether there are a significant number of samples in the reporting dataset that exceeded the peak trigger of their corresponding baseline dataset. The binomial test is used to determine whether the number of samples in the reporting dataset that are above the peak trigger limit (developed from the baselined data) is statistically significant. A peak trigger exceedance occurs when the binomial test indicates that the observed number of individual exceedances in the reporting dataset is likely to be greater than an acceptable degree of violation (i.e., 5%). The binomial test is conducted with the `binom.test` function from the `stats` package (R Core Team, 2020) running a one-sided test and a significance level (p-value) of 0.05.

Water Quality Limits

For the evaluation of water quality limits, the reporting dataset consists of data obtained from the most recent hydrological year (November 1st to October 31st) separated into the open water and winter seasons. A single year is used for the evaluation of water quality limits as data from a single year were determined to be more conservative when assessing exceedances of limits compared to using three years of data. In particular, the assessment of limit exceedances does not require tests of statistical significance, and thus, a smaller dataset is acceptable.

A limit exceedance occurs when the seasonal median, calculated with the reporting dataset, exceeds the limit defined in the UAR SWQMF for a given indicator. There are several indicators that have guidelines with toxicity modifying factors which means that the guideline value depends on other substances in the water, for example the guideline value for sulphate depends on the hardness of the water. For indicators with limits that are assessed with toxicity modifying factors (e.g., total ammonia, Table 2), individual limits are calculated for each sample in the reporting dataset with guideline equations listed in Environmental Quality Guidelines for Alberta Surface Waters (GOA, 2018). The sample-based individual limits were then compared against values from each sample in the reporting dataset. For limits with toxicity modifying factors, a limit exceedance occurs when more than 50% of all the months' samples within a season exceeded their individual calculated limits for a specific indicator (Figure 3).

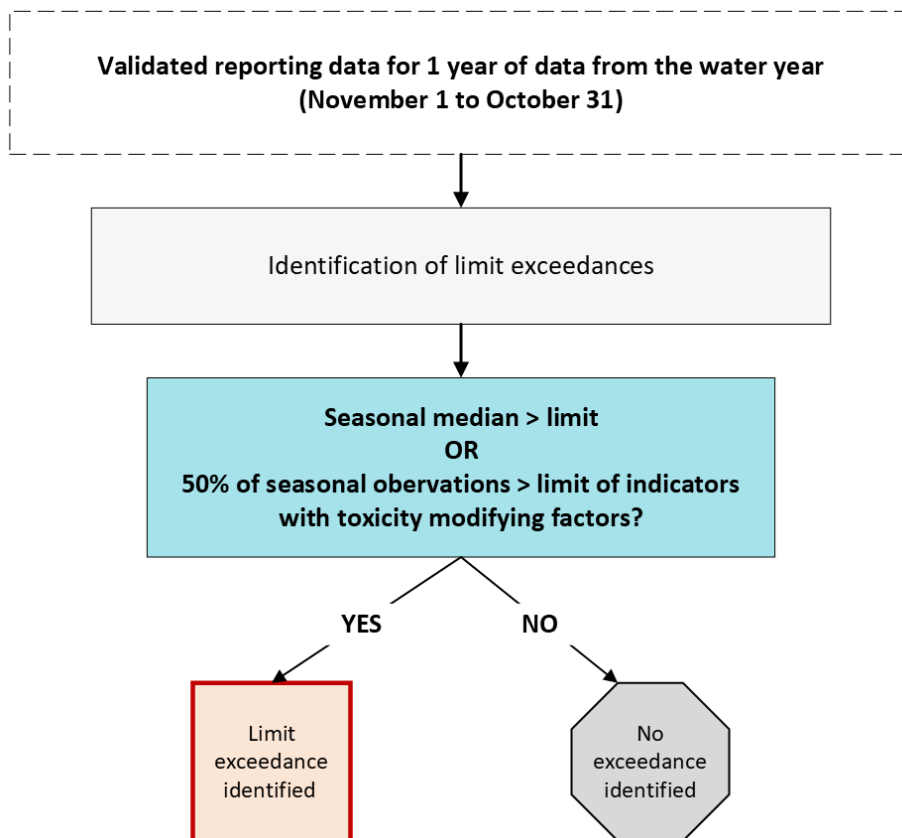


Figure 3. Flow chart of the approach to assessing limit exceedances in the UAR SWQMF.

Reporting

Triggers are only applicable to primary indicators at primary monitoring stations. Nonetheless, the two step assessment processes, comparing median and peak values in the baseline and reporting datasets was also conducted for secondary indicators where possible. For primary indicators at the secondary monitoring stations, and for the secondary indicators at the primary and secondary monitoring stations summary statistics for the reporting dataset were reported (including seasonal median and peak values). Limits similarly apply only to primary indicators at the primary station and exceedances were calculated and reported as described above. In addition, all indicators from all monitoring stations were compared to all water quality guidelines listed in Appendix A (Table A1), where applicable. These additional results will be used to provide additional context regarding the condition of surface water quality in the UAR in support of potential management response for limit and trigger exceedances occurring at the primary monitoring stations for primary indicators.

Not all undesirable changes in water quality indicators occur in a positive (i.e., increasing concentration) direction. There are indicators where undesirable changes occur in a negative direction (i.e., dissolved oxygen) and there are indicators where changes in either direction may be considered to be undesirable (i.e., pH), and low or high concentrations could be harmful to the environment. In these instances, the value for comparison would be the 10th percentile of the baseline dataset for dissolved oxygen, and both the 10th and 90th percentiles for pH, and exceeding either trigger refers to the undesirable change. The tables in Appendix A (Table A2 through A5) then show analysis results of the movement away from trigger values in both directions for each indicator. This was done to present a balanced (multidirectional) picture of all changes from baseline values and to provide additional context to the significant median and peak trigger exceedances.

Results

This report communicates changes in the central tendency (median) and peak (90th percentile) values for 29 primary and 3 secondary water quality indicators at 1 primary monitoring station (Athabasca River at the Town of Athabasca) from November 1, 2019, to October 31, 2022. In addition, this report identifies relevant water quality limits or guidelines that were exceeded from November 1, 2021, to October 31, 2022, at 1 primary station and 9 secondary stations in the Upper Athabasca Region.

Primary Indicators - Water Quality Trigger Exceedances

For the UAR SWQMF there were 29 primary indicators resulting in 58 potential season/indicator combinations that were assessed for median and peak trigger exceedances at the primary station (Athabasca River at the Town of Athabasca). From these potential combinations, there were 8 (14%) median water quality trigger exceedances and 2 (3%) peak water quality trigger exceedances. In total, there were 6 (21%) primary indicators that exceeded the median and/or peak trigger, in either the winter or the open water season at the primary station (Athabasca River at Town of Athabasca). These are summarized as text below and in Table 3.

Summary statistics, including the reporting and baseline medians and peak values are presented in Appendix A Tables A2 and A3 for information relevant to the median assessment and Tables A4 and A5 for results relevant to the peak assessment.

Median Trigger Exceedances

For primary indicators, a statistically significant exceedance of the median trigger was observed for:

- dissolved cobalt (winter),
- dissolved nickel (open and winter),
- potassium (winter),
- total suspended solids (winter),
- sulphate (open), and
- dissolved uranium (open and winter).

There were also a few instances where the reporting data showed a decreased change from median trigger values. For example, total dissolved phosphorus was lower than baseline values during the open and winter season, and dissolved chloride was lower in the open season. For a complete picture of the results please see the tables in Appendix A (A2 through A5).

Peak Trigger Exceedances

For primary indicators, a statistically significant exceedance of the peak trigger was observed for:

- sulphate (open), and
- dissolved uranium (winter).

There were also a few instances where the reporting data showed a decreased change from peak trigger values. For example, Total phosphorus was lower than baseline P10 values during the open and winter season and dissolved chloride during the winter season. For a complete picture of the results please see the tables in Appendix A (A2 through A5).

Table 3. Median and peak (P90 – 90th percentile) triggers (from the baseline data) and reporting median and peak values for primary indicators at the primary station (Athabasca River at Town of Athabasca) exhibiting a statistically significant trigger exceedance. Cells shaded in blue highlight which trigger was exceeded. Detailed test results are available in tables in Appendix A (Table A2 and A4) for median and peak triggers, respectively.

Primary Indicator	Units	Season	Median Trigger	Reporting Median	Peak Trigger	Reporting P90
Dissolved Cobalt	ug/L	winter	0.0354	0.07	0.146	0.14
Dissolved Nickel	ug/L	open	0.589	0.78	1.98	3.47
Dissolved Nickel	ug/L	winter	0.467	0.95	1.17	1.46
Dissolved Potassium	mg/L	winter	1.7	2	2.3	2.3
Total Suspended Solids	mg/L	winter	1.3	2.2	6	21
Dissolved Sulphate	mg/L	open	25.2	33	39.4	70
Dissolved Uranium	ug/L	open	0.405	0.492	0.587	0.632
Dissolved Uranium	ug/L	winter	0.63	0.672	0.736	0.812

Secondary Indicators - Water Quality Changes

There are 3 secondary indicators (total recoverable cobalt, total recoverable copper, and total mercury) in the UAR SWQMF resulting in 6 potential season/indicator combinations (3 indicators at 1 primary station for 2 seasons each). For these season/indicator combinations, the secondary indicators from the reporting period were assessed for change relative to their respective baseline median and peak values at the primary station (Athabasca River at Town of Athabasca). This assessment revealed that the medians of total recoverable cobalt (winter) and total mercury (open, winter) during the reporting period were significantly higher than the respective median of the baseline period. The P90 of total mercury (winter) during the reporting period was significantly higher than the P90 of the baseline period.

Table 4. Median and peak (P90 – 90th Percentile) values from the baseline and reporting data for secondary indicators at the primary station (Athabasca River at Town of Athabasca) exhibiting a statistically significant change, with cells shaded in blue highlighting the type of exceedance that occurred. Detailed test results are available in tables in Appendix A (Table A3 and A5) for median and peak triggers, respectively.

Secondary Indicator	Units	Season	Baseline Median	Reporting Median	Baseline P90	Reporting P90
Total Recoverable Cobalt	ug/L	winter	0.061	0.081	0.272	0.229
Total Mercury	ng/L	open	2.39	3.47	16.4	12.49
Total Mercury	ng/L	winter	0.512	0.62	0.9	1.45

Water Quality Limit and Guideline Exceedances

For the 12 primary indicators for which surface water quality limits have been assigned, there were no exceedances at the primary station (Athabasca River at Town of Athabasca) in neither the open or winter seasons including indicators with and without toxicity modifying factors.

When evaluating the total number of individual guideline exceedances for all primary and secondary indicators at primary and secondary stations, there were 14 indicators assessed for exceedances against five surface water quality guidelines (i.e., Irrigation, Livestock, Recreation and Aesthetics, PAL Chronic and PAL Acute) assessed for exceedances (See Table A1 in Appendix A for all the potential guidelines). In total, 646 indicator values from primary and secondary stations were assessed against the five potential guidelines with 20 (3%) values exceeding a potential guideline.

At the primary station, Athabasca River at the Town of Athabasca, 2 secondary indicators exceeded PAL Chronic guideline once each during the open water season: total mercury and total recoverable cobalt.

For the secondary stations, 5 indicators exceeded guidelines at the Pembina River TMN station: dissolved oxygen, total mercury, *Escherichia coli*, total recoverable copper, and total recoverable cobalt. Of note, there were 3 dissolved oxygen exceedances at the Pembina River TMN station for both the PAL Chronic and PAL Acute guidelines in the winter season with the other exceedances at this site occurring in the open water season. There were also 3 indicators with 1 guideline exceedance at the Sakwatamau River TMN station (total recoverable cobalt, dissolved iron, and total mercury in the open water season), 2 indicators with 1 guideline exceedance at the Lesser Slave River TMN station in the open water season (total mercury and total recoverable cobalt) and 1 total mercury exceedance in the open water season at the Athabasca River at Vega Ferry LTRN station. A summary of all limit and guideline exceedances can be found in Table A6 of Appendix A.



Conclusion

The main objective of this annual condition report was to outline instances where primary indicators exceeded a water quality median or peak trigger, or a surface water quality limit as outlined in the UAR SWQMF (GOA, 2022). From a total of 58 potential season/primary indicator combinations that were assessed for median and peak trigger exceedances, 8 (14%) were found to be exceeding the median and/or peak trigger. In total, 6 (21%) primary indicators exceeded the median and/or peak trigger, in either the winter or the open water season. There were no limit exceedances reported for 12 indicators with a surface water quality limit. Furthermore, the assessment of 646 indicator values from primary and secondary stations found that 20 values, or 3% exceeded a surface water quality guideline.

Results from this assessment will inform a management response under the UAR SWQMF (GOA, 2022) and will be published on [publications - Open Government \(alberta.ca\)](#).

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Appendix A

Table A1. All surface water guidelines used in the assessment of primary and secondary water quality indicators.

Indicator	Category	Guideline	Limit	Units
Dissolved Aluminum	Trace Elements	PAL Acute	Equation-based	ug/L
Dissolved Aluminum	Trace Elements	PAL Chronic	Equation-based	ug/L
Dissolved Chloride	Ions	PAL Chronic	120	mg/L
Dissolved Chloride	Ions	PAL Acute	640	mg/L
Dissolved Chloride	Ions	Irrigation	100	mg/L
Dissolved Iron	Trace Elements	PAL Chronic	300	ug/L
Dissolved Sulphate	Ions	Livestock	1000	mg/L
Dissolved Sulphate	Ions	PAL Chronic	Hardness-based	mg/L
<i>Escherichia coli</i>	Biological	Recreation Aesthetics	100	cfu/100 mL
Nitrate as Nitrogen	Nutrients	PAL Chronic	3	mg/L
Nitrate as Nitrogen	Nutrients	PAL Acute	124	mg/L
Oxygen Dissolved	General	PAL Chronic	6.5, 8.3	mg/L
Oxygen Dissolved	General	PAL Acute	5	mg/L
Total Ammonia	Nutrients	PAL Chronic	Equation-based	mg/L
Total Mercury	Trace Elements	PAL Chronic	5	ng/L
Total Mercury	Trace Elements	PAL Acute	13	ng/L
Total Mercury	Trace Elements	Livestock	3000	ng/L
Total Recoverable Cadmium	Trace Elements	Irrigation	8.2	ug/L
Total Recoverable Cadmium	Trace Elements	Livestock	80	ug/L
Total Recoverable Cadmium	Trace Elements	PAL Chronic	Equation-based	ug/L
Total Recoverable Cobalt	Trace Elements	Irrigation	50	ug/L
Total Recoverable Cobalt	Trace Elements	Livestock	1000	ug/L
Total Recoverable Cobalt	Trace Elements	PAL Chronic	Equation-based	ug/L
Total Recoverable Copper	Trace Elements	PAL Chronic	7	ug/L
Total Recoverable Copper	Trace Elements	Irrigation	200	ug/L
Total Recoverable Copper	Trace Elements	Livestock	500	ug/L
Total Recoverable Copper	Trace Elements	PAL Acute	Equation-based	ug/L
Total Recoverable Selenium	Trace Elements	PAL Chronic Alert	1	ug/L
Total Recoverable Selenium	Trace Elements	PAL Chronic	2	ug/L
Total Recoverable Selenium	Trace Elements	Irrigation	20	ug/L
Total Recoverable Selenium	Trace Elements	Livestock	50	ug/L
Total Recoverable Zinc	Trace Elements	PAL Chronic	30	ug/L
Total Recoverable Zinc	Trace Elements	Irrigation	1000	ug/L
Total Recoverable Zinc	Trace Elements	Livestock	50000	ug/L

Table A2. Primary indicator relevant values for the assessment of median triggers at the primary monitoring station in the UAR; where, * is indicative of a significant test result i.e., when a p-value is less than 0.05. A difference in both directions from the trigger value (baseline median) was assessed using the Mann-Whitney test or the cendiff function and all test outcomes for every indicator for every season and station are displayed. A (numerically) positive change means the reporting median is higher than the baseline median. The cendiff function was used to assess trigger exceedance when the detection frequency was less than 50%. Empty cells indicate that an indicator did not meet the criteria for a particular significance test.

Station Name	Indicator	Season	Units	Baseline Median	Reporting Median	Baseline sample count	Reporting sample count	Baseline % detect	Reporting % detect	Max % censored	Mann-Whitney positive p-Value	Mann-Whitney negative p-Value	Difference test (censored data) p-Value
Athabasca River at Town of Athabasca	Dissolved Aluminum	open	ug/L	10.4	6.0	76	19	100.0	100.0	0.0	1	<0.001*	
Athabasca River at Town of Athabasca	Dissolved Aluminum	winter	ug/L	3.0	2.4	39	15	100.0	100.0	0.0	0.938	0.063	
Athabasca River at Town of Athabasca	Total Ammonia	open	mg/L	0.05	0.05	211	19	8.5	0.0	100.0			0.193
Athabasca River at Town of Athabasca	Total Ammonia	winter	mg/L	0.05	0.05	146	15	26.7	33.3	73.3			0.983
Athabasca River at Town of Athabasca	Dissolved Boron	open	ug/L	11.5	11.1	76	19	100.0	100.0	0.0	0.406	0.596	
Athabasca River at Town of Athabasca	Dissolved Boron	winter	ug/L	18.6	18.3	39	15	100.0	100.0	0.0	0.269	0.734	
Athabasca River at Town of Athabasca	Dissolved Cadmium	open	ug/L	0.0126	0.0140	76	19	98.7	100.0	1.3	0.401	0.601	
Athabasca River at Town of Athabasca	Dissolved Cadmium	winter	ug/L	0.0220	0.0200	39	15	100.0	100.0	0.0	0.915	0.086	
Athabasca River at Town of Athabasca	Total Recoverable Cadmium	open	ug/L	0.0300	0.0300	76	19	94.7	78.9	21.1	0.965	0.035*	
Athabasca River at Town of Athabasca	Total Recoverable Cadmium	winter	ug/L	0.0250	0.0300	39	15	94.9	93.3	6.7	0.979	0.022*	
Athabasca River at Town of Athabasca	Dissolved Organic Carbon	open	mg/L	5.8	5.3	213	19	100.0	100.0	0.0	0.73	0.271	

Station Name	Indicator	Season	Units	Baseline Median	Reporting Median	Baseline sample count	Reporting sample count	Baseline % detect	Reporting % detect	Max % censored	Mann-Whitney positive p-Value	Mann-Whitney negative p-Value	Difference test (censored data) p-Value
Athabasca River at Town of Athabasca	Dissolved Organic Carbon	winter	mg/L	6.1	6.6	146	15	100.0	100.0	0.0	0.323	0.678	
Athabasca River at Town of Athabasca	Dissolved Chloride	open	mg/L	1.7	1.7	208	19	77.4	78.9	22.6	0.444	0.557	
Athabasca River at Town of Athabasca	Dissolved Chloride	winter	mg/L	3.9	3.5	146	15	99.3	100.0	0.7	0.977	0.023*	
Athabasca River at Town of Athabasca	Dissolved Cobalt	open	ug/L	0.053	0.057	76	19	97.4	100.0	2.6	0.202	0.799	
Athabasca River at Town of Athabasca	Dissolved Cobalt	winter	ug/L	0.035	0.070	39	15	94.9	100.0	5.1	0.009*	0.991	
Athabasca River at Town of Athabasca	Colour	open	rel units	17	19	74	19	100.0	100.0	0.0	0.736	0.265	
Athabasca River at Town of Athabasca	Colour	winter	rel units	18	17	53	15	100.0	100.0	0.0	0.647	0.356	
Athabasca River at Town of Athabasca	Dissolved Copper	open	ug/L	0.88	0.80	76	19	100.0	100.0	0.0	0.913	0.087	
Athabasca River at Town of Athabasca	Dissolved Copper	winter	ug/L	0.82	0.71	39	15	100.0	100.0	0.0	0.989	0.012*	
Athabasca River at Town of Athabasca	<i>Escherichia coli</i>	open	cfu/100 mL	10	10	137	19	23.4	26.3	76.6			0.673
Athabasca River at Town of Athabasca	<i>Escherichia coli</i>	winter	cfu/100 mL	10	10	93	15	9.7	6.7	93.3			0.676
Athabasca River at Town of Athabasca	Dissolved Iron	open	ug/L	45	22	76	19	89.5	100.0	10.5	0.933	0.068	
Athabasca River at Town of Athabasca	Dissolved Iron	winter	ug/L	42	37	39	15	97.4	100.0	2.6	0.581	0.422	

Station Name	Indicator	Season	Units	Baseline Median	Reporting Median	Baseline sample count	Reporting sample count	Baseline % detect	Reporting % detect	Max % censored	Mann-Whitney positive p-Value	Mann-Whitney negative p-Value	Difference test (censored data) p-Value
Athabasca River at Town of Athabasca	Dissolved Nickel	open	ug/L	0.59	0.78	76	19	89.5	100.0	10.5	0.036*	0.965	
Athabasca River at Town of Athabasca	Dissolved Nickel	winter	ug/L	0.47	0.95	39	15	89.7	100.0	10.3	<0.001*	1	
Athabasca River at Town of Athabasca	Total Nitrogen	open	mg/L	0.265	0.360	212	19	54.2	100.0	45.8	0.791	0.21	
Athabasca River at Town of Athabasca	Total Nitrogen	winter	mg/L	0.475	0.440	146	15	87.0	100.0	13.0	0.566	0.435	
Athabasca River at Town of Athabasca	Nitrate as Nitrogen	open	mg/L	0.005	0.005	140	19	55.0	57.9	45.0	0.498	0.503	
Athabasca River at Town of Athabasca	Nitrate as Nitrogen	winter	mg/L	0.130	0.110	92	15	89.1	93.3	10.9	0.748	0.253	
Athabasca River at Town of Athabasca	Oxygen Dissolved	open	mg/L	9.65	9.75	204	19	100.0	100.0	0.0	0.492	0.508	
Athabasca River at Town of Athabasca	Oxygen Dissolved	winter	mg/L	10.89	10.77	134	15	100.0	100.0	0.0	0.08	0.921	
Athabasca River at Town of Athabasca	pH (Field)	open	pH units	8.10	8.12	216	19	100.0	100.0	0.0	0.32	0.681	
Athabasca River at Town of Athabasca	pH (Field)	winter	pH units	7.65	7.64	149	15	100.0	100.0	0.0	0.418	0.583	
Athabasca River at Town of Athabasca	Total Phosphorus	open	mg/L	0.038	0.025	101	19	99.0	100.0	1.0	0.887	0.114	
Athabasca River at Town of Athabasca	Total Phosphorus	winter	mg/L	0.012	0.011	66	15	98.5	93.3	6.7	0.893	0.108	
Athabasca River at Town of Athabasca	Total Dissolved Phosphorus	open	mg/L	0.006	0.003	100	19	81.0	42.1	57.9			0.007*

Station Name	Indicator	Season	Units	Baseline Median	Reporting Median	Baseline sample count	Reporting sample count	Baseline % detect	Reporting % detect	Max % censored	Mann-Whitney positive p-Value	Mann-Whitney negative p-Value	Difference test (censored data) p-Value
Athabasca River at Town of Athabasca	Total Dissolved Phosphorus	winter	mg/L	0.007	0.006	66	15	98.5	80.0	20.0	0.968	0.032*	
Athabasca River at Town of Athabasca	Dissolved Potassium	open	mg/L	1.01	1.20	209	19	100.0	100.0	0.0	0.074	0.926	
Athabasca River at Town of Athabasca	Dissolved Potassium	winter	mg/L	1.70	2.00	146	15	100.0	100.0	0.0	0.013*	0.987	
Athabasca River at Town of Athabasca	Total Suspended Solids	open	mg/L	34	39	213	19	94.8	100.0	5.2	0.767	0.234	
Athabasca River at Town of Athabasca	Total Suspended Solids	winter	mg/L	1	2	147	15	54.4	93.3	45.6	0.007*	0.993	
Athabasca River at Town of Athabasca	Total Recoverable Selenium	open	ug/L	0.2	0.2	76	19	50.0	63.2	50.0			0.074
Athabasca River at Town of Athabasca	Total Recoverable Selenium	winter	ug/L	0.3	0.4	39	15	76.9	93.3	23.1	0.21	0.793	
Athabasca River at Town of Athabasca	Dissolved Sodium	open	mg/L	6.8	6.8	209	19	100.0	100.0	0.0	0.659	0.342	
Athabasca River at Town of Athabasca	Dissolved Sodium	winter	mg/L	17.1	15.0	146	15	100.0	100.0	0.0	0.995	0.005*	
Athabasca River at Town of Athabasca	Specific Conductance	open	uS/cm	250	280	209	19	100.0	100.0	0.0	0.075	0.925	
Athabasca River at Town of Athabasca	Specific Conductance	winter	uS/cm	419	410	145	15	100.0	100.0	0.0	0.904	0.096	
Athabasca River at Town of Athabasca	Dissolved Strontium	open	ug/L	237	254	76	19	100.0	100.0	0.0	0.261	0.74	
Athabasca River at Town of Athabasca	Dissolved Strontium	winter	ug/L	384	370	39	15	100.0	100.0	0.0	0.878	0.124	

Station Name	Indicator	Season	Units	Baseline Median	Reporting Median	Baseline sample count	Reporting sample count	Baseline % detect	Reporting % detect	Max % censored	Mann-Whitney positive p-Value	Mann-Whitney negative p-Value	Difference test (censored data) p-Value
Athabasca River at Town of Athabasca	Dissolved Sulphate	open	mg/L	25.2	33.0	209	19	100.0	100.0	0.0	0.001*	0.999	
Athabasca River at Town of Athabasca	Dissolved Sulphate	winter	mg/L	49.1	49.0	146	15	100.0	100.0	0.0	0.373	0.628	
Athabasca River at Town of Athabasca	Dissolved Uranium	open	ug/L	0.405	0.492	76	19	100.0	100.0	0.0	0.004*	0.996	
Athabasca River at Town of Athabasca	Dissolved Uranium	winter	ug/L	0.630	0.672	39	15	100.0	100.0	0.0	0.005*	0.995	
Athabasca River at Town of Athabasca	Dissolved Vanadium	open	ug/L	0.222	0.208	76	19	100.0	100.0	0.0	0.946	0.055	
Athabasca River at Town of Athabasca	Dissolved Vanadium	winter	ug/L	0.178	0.159	39	15	100.0	100.0	0.0	0.762	0.241	
Athabasca River at Town of Athabasca	Total Recoverable Zinc	open	ug/L	4.3	3.5	76	19	100.0	100.0	0.0	0.951	0.05	
Athabasca River at Town of Athabasca	Total Recoverable Zinc	winter	ug/L	2.0	1.8	39	15	100.0	100.0	0.0	0.812	0.19	

Table A3. Secondary indicator relevant values for the assessment of a median change at the primary monitoring station in the UAR, where * is indicative of a significant test result i.e., a change from baseline conditions. A statistically significant change from baseline conditions occurs when a p-value is less than 0.05. A difference in both directions from the baseline median was assessed using the Mann Whitney or the cendiff function and all test outcomes for every indicator for every season and station are displayed. A (numerically) positive change means the reporting median is higher than the baseline median. The cendiff function was used to assess the difference between baseline and reporting medians when the detection frequency was less than 50%.

Station Name	Indicator	Season	Units	Baseline Median	Reporting Median	Baseline sample count	Reporting sample count	Baseline % detect	Reporting % detect	Max % censored	Mann-Whitney positive p-Value	Mann-Whitney negative p-Value
Athabasca River at Town of Athabasca	Total Recoverable Cobalt	open	ug/L	0.43	0.42	76	19	100.0	100	0.0	0.804	0.197
Athabasca River at Town of Athabasca	Total Recoverable Cobalt	winter	ug/L	0.06	0.08	39	15	100.0	100	0.0	0.033*	0.968
Athabasca River at Town of Athabasca	Total Recoverable Copper	open	ug/L	1.55	1.60	76	19	100.0	100	0.0	0.893	0.108
Athabasca River at Town of Athabasca	Total Recoverable Copper	winter	ug/L	0.90	0.79	39	15	100.0	100	0.0	0.985	0.016*
Athabasca River at Town of Athabasca	Total Mercury	open	ng/L	2.39	3.47	60	19	100.0	100	0.0	0.615	0.387
Athabasca River at Town of Athabasca	Total Mercury	winter	ng/L	0.51	0.62	37	15	94.6	100	5.4	0.04*	0.961

Table A4. Primary indicator relevant values for the assessment of peak triggers at the primary monitoring station in the UAR, where P=percentile, and * is indicative of a significant test result i.e., when a p-value is less than 0.05. A difference in both, the P10 and the P90 value was assessed with a binomial test and all test outcomes for every indicator for every season and station are displayed. The binomial test is used to determine whether the number of samples in the reporting dataset that are above and/or below the P90 and P10, respectively, are significant. Empty cells indicate that an indicate did not meet the criteria for a particular significance test.

Station Name	Indicator	Season	Units	Baseline p10	Reporting p10	Baseline p90	Reporting p90	Baseline sample count	Reporting sample count	#samples above P90	Binomial test p-Value (above P90)	#samples below P10	Binomial test p-Value (below P10)
Athabasca River at Town of Athabasca	Dissolved Aluminum	open	ug/L	4.0	2.5	41.7	12.7	76	19			5	0.002*
Athabasca River at Town of Athabasca	Dissolved Aluminum	winter	ug/L	1.8	1.7	8.1	6.5	39	15			5	0.001*
Athabasca River at Town of Athabasca	Total Ammonia	open	mg/L	0.05	0.05	0.05	0.05	211	19				
Athabasca River at Town of Athabasca	Total Ammonia	winter	mg/L	0.05	0.05	0.08	0.07	146	15				
Athabasca River at Town of Athabasca	Dissolved Boron	open	ug/L	8.4	8.5	15.9	16.4	76	19	1	0.623	2	0.245
Athabasca River at Town of Athabasca	Dissolved Boron	winter	ug/L	14.1	16.3	24.0	21.0	39	15				
Athabasca River at Town of Athabasca	Dissolved Cadmium	open	ug/L	0.0076	0.0090	0.0265	0.1120	76	19	1	0.623	1	0.623
Athabasca River at Town of Athabasca	Dissolved Cadmium	winter	ug/L	0.0129	0.0150	0.0450	0.0360	39	15				
Athabasca River at Town of Athabasca	Total Recoverable Cadmium	open	ug/L	0.0178	0.0100	0.1440	0.2200	76	19	1	0.623	4	0.013*
Athabasca River at Town of Athabasca	Total Recoverable Cadmium	winter	ug/L	0.0160	0.0300	0.0500	0.0360	39	15				

Station Name	Indicator	Season	Units	Baseline p10	Reporting p10	Baseline p90	Reporting p90	Baseline sample count	Reporting sample count	#samples above P90	Binomial test p-Value (above P90)	#samples below P10	Binomial test p-Value (below P10)
Athabasca River at Town of Athabasca	Dissolved Organic Carbon	open	mg/L	3.0	2.9	11.1	13.0	213	19	1	0.623	3	0.067
Athabasca River at Town of Athabasca	Dissolved Organic Carbon	winter	mg/L	4.9	5.2	8.5	12.0	146	15	1	0.537	2	0.171
Athabasca River at Town of Athabasca	Dissolved Chloride	open	mg/L	1.0	1.0	3.8	4.4	208	19	2	0.245		
Athabasca River at Town of Athabasca	Dissolved Chloride	winter	mg/L	2.6	2.5	5.9	4.0	146	15			3	0.036*
Athabasca River at Town of Athabasca	Dissolved Cobalt	open	ug/L	0.026	0.036	0.136	1.270	76	19	2	0.245	2	0.245
Athabasca River at Town of Athabasca	Dissolved Cobalt	winter	ug/L	0.018	0.040	0.146	0.140	39	15				
Athabasca River at Town of Athabasca	Colour	open	rel units	6	8	69	57	74	19				
Athabasca River at Town of Athabasca	Colour	winter	rel units	12	14	28	35	53	15	1	0.537	1	0.537
Athabasca River at Town of Athabasca	Dissolved Copper	open	ug/L	0.57	0.50	2.03	2.67	76	19	1	0.623	6	<0.001*
Athabasca River at Town of Athabasca	Dissolved Copper	winter	ug/L	0.60	0.56	1.19	1.01	39	15			3	0.036*
Athabasca River at Town of Athabasca	<i>Escherichia coli</i>	open	cfu/100 mL	10	10	40	173	137	19	2	0.245		
Athabasca River at Town of Athabasca	<i>Escherichia coli</i>	winter	cfu/100 mL	10	10	10	10	93	15	1	0.537		

Station Name	Indicator	Season	Units	Baseline p10	Reporting p10	Baseline p90	Reporting p90	Baseline sample count	Reporting sample count	#samples above P90	Binomial test p-Value (above P90)	#samples below P10	Binomial test p-Value (below P10)
Athabasca River at Town of Athabasca	Dissolved Iron	open	ug/L	2	6	161	686	76	19	1	0.623		
Athabasca River at Town of Athabasca	Dissolved Iron	winter	ug/L	13	27	90	103	39	15	1	0.537		
Athabasca River at Town of Athabasca	Dissolved Nickel	open	ug/L	0.01	0.54	1.98	3.47	76	19	1	0.623		
Athabasca River at Town of Athabasca	Dissolved Nickel	winter	ug/L	0.01	0.80	1.17	1.46	39	15	2	0.171		
Athabasca River at Town of Athabasca	Total Nitrogen	open	mg/L	0.071	0.190	0.907	1.200	212	19	2	0.245		
Athabasca River at Town of Athabasca	Total Nitrogen	winter	mg/L	0.248	0.390	0.610	1.300	146	15	2	0.171	2	0.171
Athabasca River at Town of Athabasca	Nitrate as Nitrogen	open	mg/L	0.003	0.003	0.089	0.240	140	19	1	0.623		
Athabasca River at Town of Athabasca	Nitrate as Nitrogen	winter	mg/L	0.003	0.050	0.213	0.200	92	15				
Athabasca River at Town of Athabasca	Oxygen Dissolved	open	mg/L	8.47	8.51	12.16	13.59	204	19	2	0.245		
Athabasca River at Town of Athabasca	Oxygen Dissolved	winter	mg/L	8.68	10.00	13.72	13.85	134	15	2	0.171		
Athabasca River at Town of Athabasca	pH (Field)	open	pH units	7.68	7.86	8.39	8.32	216	19				
Athabasca River at Town of Athabasca	pH (Field)	winter	pH units	7.28	7.47	8.17	8.18	149	15	1	0.537	1	0.537

Station Name	Indicator	Season	Units	Baseline p10	Reporting p10	Baseline p90	Reporting p90	Baseline sample count	Reporting sample count	#samples above P90	Binomial test p-Value (above P90)	#samples below P10	Binomial test p-Value (below P10)
Athabasca River at Town of Athabasca	Total Phosphorus	open	mg/L	0.011	0.007	0.246	0.370	101	19	2	0.245	4	0.013*
Athabasca River at Town of Athabasca	Total Phosphorus	winter	mg/L	0.008	0.007	0.021	0.022	66	15	1	0.537	5	0.001*
Athabasca River at Town of Athabasca	Total Dissolved Phosphorus	open	mg/L	0.003	0.003	0.023	0.015	100	19				
Athabasca River at Town of Athabasca	Total Dissolved Phosphorus	winter	mg/L	0.005	0.003	0.015	0.011	66	15			7	<0.001*
Athabasca River at Town of Athabasca	Dissolved Potassium	open	mg/L	0.71	0.98	2.10	2.70	209	19	2	0.245		
Athabasca River at Town of Athabasca	Dissolved Potassium	winter	mg/L	1.30	1.60	2.30	2.30	146	15				
Athabasca River at Town of Athabasca	Total Suspended Solids	open	mg/L	5	4	255	480	213	19	2	0.245	4	0.013*
Athabasca River at Town of Athabasca	Total Suspended Solids	winter	mg/L	1	2	6	21	147	15	2	0.171		
Athabasca River at Town of Athabasca	Total Recoverable Selenium	open	ug/L	0.2	0.2	0.5	0.6	76	19	1	0.623		
Athabasca River at Town of Athabasca	Total Recoverable Selenium	winter	ug/L	0.2	0.4	0.4	0.4	39	15				
Athabasca River at Town of Athabasca	Dissolved Sodium	open	mg/L	4.5	4.9	12.5	10.0	209	19	2	0.245	2	0.245
Athabasca River at Town of Athabasca	Dissolved Sodium	winter	mg/L	12.1	13.0	22.0	18.0	146	15				

Station Name	Indicator	Season	Units	Baseline p10	Reporting p10	Baseline p90	Reporting p90	Baseline sample count	Reporting sample count	#samples above P90	Binomial test p-Value (above P90)	#samples below P10	Binomial test p-Value (below P10)
Athabasca River at Town of Athabasca	Specific Conductance	open	uS/cm	212	230	324	330	209	19	1	0.623		
Athabasca River at Town of Athabasca	Specific Conductance	winter	uS/cm	350	370	473	432	145	15				
Athabasca River at Town of Athabasca	Dissolved Strontium	open	ug/L	167	205	326	325	76	19				
Athabasca River at Town of Athabasca	Dissolved Strontium	winter	ug/L	329	328	473	432	39	15			3	0.036*
Athabasca River at Town of Athabasca	Dissolved Sulphate	open	mg/L	15.5	24.0	39.4	70.0	209	19	6	<0.001*		
Athabasca River at Town of Athabasca	Dissolved Sulphate	winter	mg/L	35.8	38.0	61.0	62.0	146	15	1	0.537	2	0.171
Athabasca River at Town of Athabasca	Dissolved Uranium	open	ug/L	0.313	0.392	0.587	0.632	76	19	1	0.623		
Athabasca River at Town of Athabasca	Dissolved Uranium	winter	ug/L	0.519	0.606	0.736	0.812	39	15	4	0.005*		
Athabasca River at Town of Athabasca	Dissolved Vanadium	open	ug/L	0.139	0.099	0.466	0.981	76	19	1	0.623	6	<0.001*
Athabasca River at Town of Athabasca	Dissolved Vanadium	winter	ug/L	0.120	0.111	0.320	0.304	39	15			3	0.036*
Athabasca River at Town of Athabasca	Total Recoverable Zinc	open	ug/L	1.8	1.3	20.9	28.3	76	19	2	0.245	5	0.002*
Athabasca River at Town of Athabasca	Total Recoverable Zinc	winter	ug/L	1.1	1.4	4.7	3.0	39	15				

Table A5. Secondary indicator relevant values for the assessment of P10 and P90 change at the primary monitoring station in the UAR, where P=percentile, and * indicates a significant test result i.e., a significant change from baseline. A statistically significant change from baseline occurs when a p-value is less than 0.05. A difference in both the P10 and the P90 value were assessed with a binomial test and all test outcomes for every indicator for every season and station are displayed. The binomial test is used to determine whether the number of samples in the reporting dataset that are above and/or below the P90 and P10, respectively, is significant. Empty cells indicate that an indicator did not meet the criteria for a particular significance test.

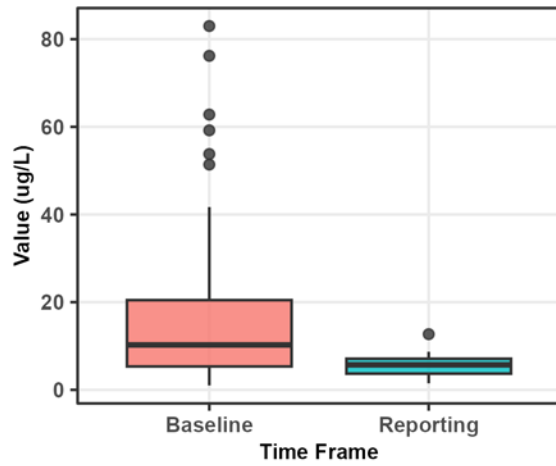
Station Name	Indicator	Season	Units	Baseline p10	Reporting p10	Baseline p90	Reporting p90	Baseline sample count	Reporting sample count	#samples above P90	Binomial test p-Value (above P90)	#samples below P10	Binomial test p-Value (below P10)
Athabasca River at Town of Athabasca	Total Recoverable Cobalt	open	ug/L	0.09	0.08	2.67	3.41	76	19	3	0.067	3	0.067
Athabasca River at Town of Athabasca	Total Recoverable Cobalt	winter	ug/L	0.03	0.06	0.27	0.23	39	15				
Athabasca River at Town of Athabasca	Total Recoverable Copper	open	ug/L	0.73	0.61	7.31	9.68	76	19	2	0.245	3	0.067
Athabasca River at Town of Athabasca	Total Recoverable Copper	winter	ug/L	0.71	0.66	1.44	1.20	39	15			4	0.005*
Athabasca River at Town of Athabasca	Total Mercury	open	ng/L	0.63	0.78	16.40	12.49	60	19				
Athabasca River at Town of Athabasca	Total Mercury	winter	ng/L	0.36	0.47	0.90	1.45	37	15	4	0.005*		

Table A6. All station/indicator/season combinations in the UAR with a guideline exceedance, sorted in decreasing order of the number of guideline (GL) exceedances. Reporting medians are displayed for primary and secondary indicators at the primary station, and primary and secondary indicators at secondary stations.

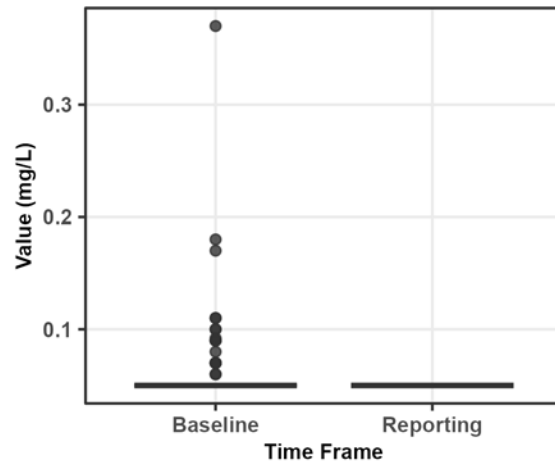
Station	Indicator	Season	Median	Guideline	Guideline Value	Units	GL Exceedances	GL not Assessed	n samples
Pembina River	Oxygen Dissolved	winter	4.69	PAL Chronic	6.5, 8.3	mg/L	3	0	5
Pembina River	Oxygen Dissolved	winter	4.69	PAL Acute	5	mg/L	3	0	5
Athabasca River at Town of Athabasca	Total Mercury	open	3.69	PAL Chronic	5	ng/l	2	0	7
Athabasca River at Town of Athabasca	Total Mercury	open	3.69	PAL Chronic	5	ng/l	2	0	7
Sakwatamau River	Dissolved Iron	open	142	PAL Chronic	300	ug/L	1	0	7
Sakwatamau River	Total Mercury	open	2.23	PAL Chronic	5	ng/l	1	0	7
Sakwatamau River	Total Mercury	open	2.23	PAL Chronic	5	ng/l	1	0	7
Pembina River	Total Recoverable Copper	open	2.34	PAL Chronic	7	ug/L	1	0	7
Pembina River	<i>Escherichia coli</i>	open	40	Recreation Aesthetics	100	cfu/100 mL	1	0	7
Pembina River	Total Mercury	open	2.47	PAL Chronic	5	ng/L	1	0	7
Pembina River	Total Mercury	open	2.47	PAL Chronic	5	ng/L	1	0	7
Pembina River	Total Mercury	open	2.47	PAL Acute	13	ng/l	1	0	7
Pembina River	Total Mercury	open	2.47	PAL Acute	13	ng/l	1	0	7
Athabasca River at Vega Ferry crossing	Total Mercury	open	2.39	PAL Chronic	5	ng/l	1	0	7
Athabasca River at Vega Ferry crossing	Total Mercury	open	2.39	PAL Chronic	5	ng/l	1	0	7
Lesser Slave River	Total Mercury	open	2.21	PAL Chronic	5	ng/l	1	0	7
Lesser Slave River	Total Mercury	open	2.21	PAL Chronic	5	ng/l	1	0	7
Sakwatamau River	Total Recoverable Cobalt	open	0.1	PAL Chronic	Equation-based	ug/L	1	0	7
Pembina River	Total Recoverable Cobalt	open	0.408	PAL Chronic	Equation-based	ug/L	1	0	7
Athabasca River at Town of Athabasca	Total Recoverable Cobalt	open	0.522	PAL Chronic	Equation-based	ug/L	1	0	7
Lesser Slave River	Total Recoverable Cobalt	open	0.262	PAL Chronic	Equation-based	ug/L	1	0	7

Appendix B

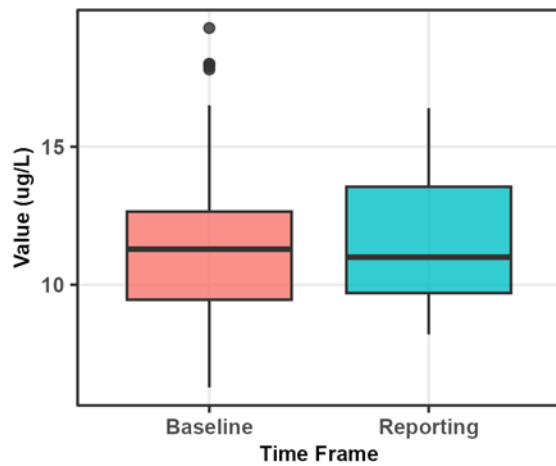
ATHABASCA RIVER, AT TOWN OF ATHABASCA (
ALUMINUM DISSOLVED (AL) - open season
 Primary indicator



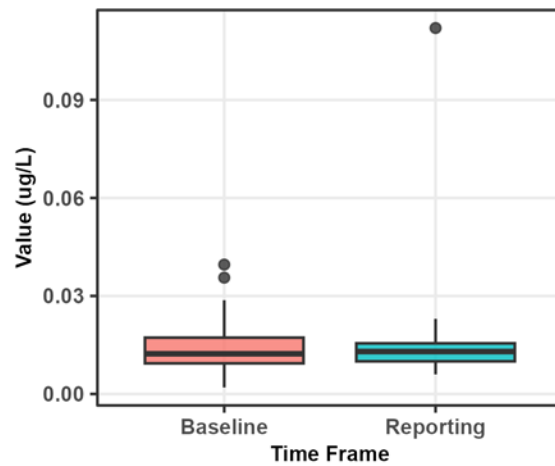
ATHABASCA RIVER, AT TOWN OF ATHABASCA
AMMONIA TOTAL - open season
 Primary indicator



ATHABASCA RIVER, AT TOWN OF ATHABASCA (
BORON DISSOLVED - open season
 Primary indicator

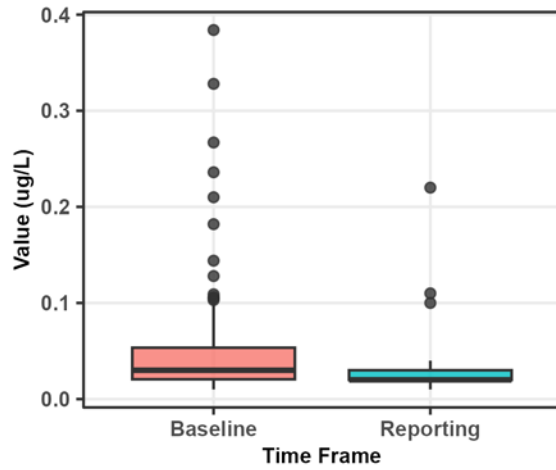


ATHABASCA RIVER, AT TOWN OF ATHABASCA/
CADMIUM DISSOLVED - open season
 Primary indicator



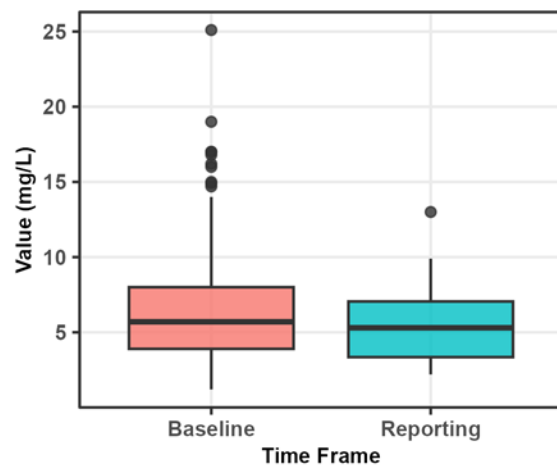
ATHABASCA RIVER, AT TOWN OF ATHABASCA

CADMIUM TOTAL RECOVERABLE - open season
Primary indicator



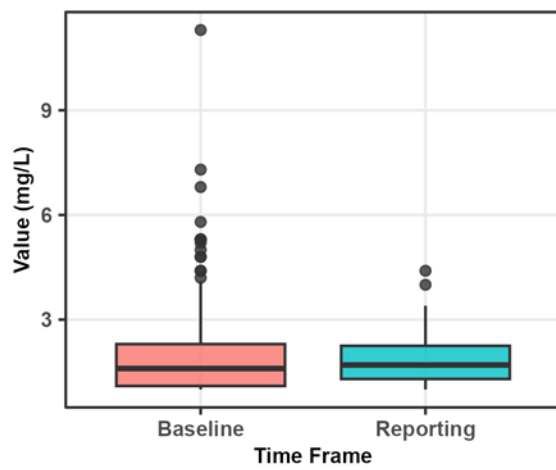
ATHABASCA RIVER, AT TOWN OF ATHABASCA (

CARBON DISSOLVED ORGANIC - open season
Primary indicator



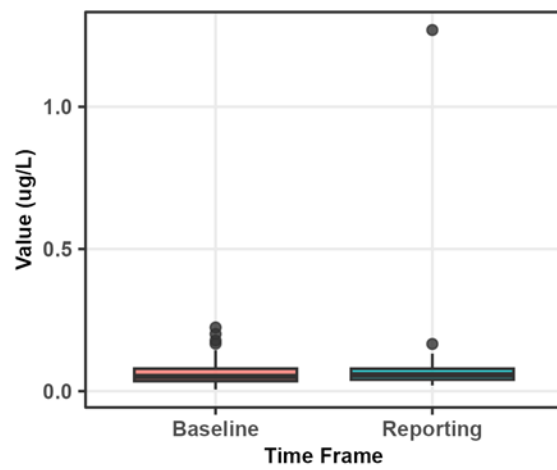
ATHABASCA RIVER, AT TOWN OF ATHABASCA (2

CHLORIDE DISSOLVED - open season
Primary indicator



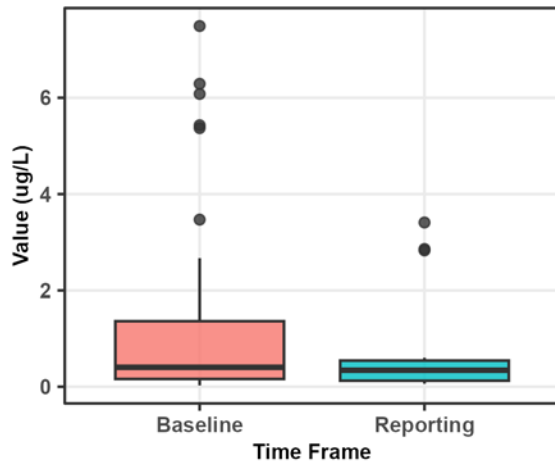
ATHABASCA RIVER, AT TOWN OF ATHABASCA

COBALT DISSOLVED - open season
Primary indicator



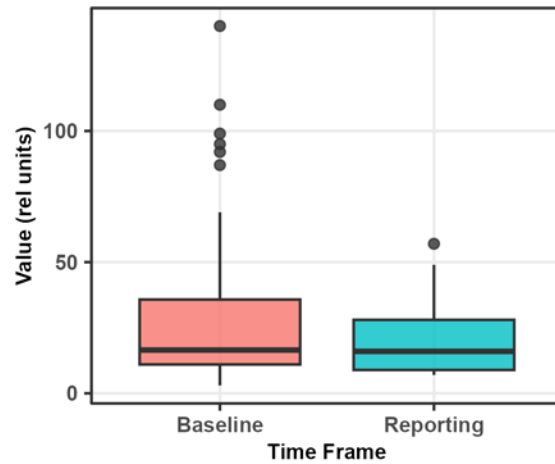
ATHABASCA RIVER, AT TOWN OF ATHABASCA (2)

COBALT TOTAL RECOVERABLE - open season
Secondary indicator



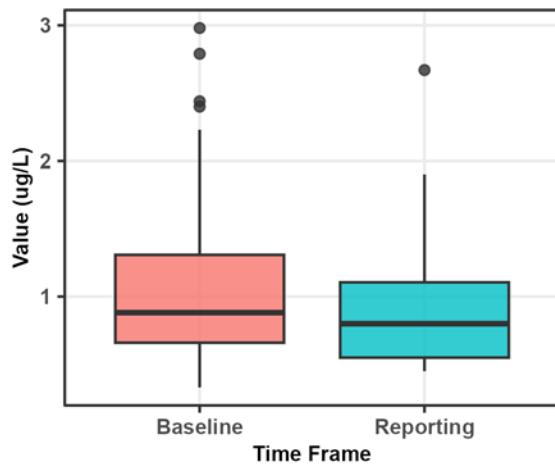
ATHABASCA RIVER, AT TOWN OF ATHABASCA

COLOUR TRUE - open season
Primary indicator



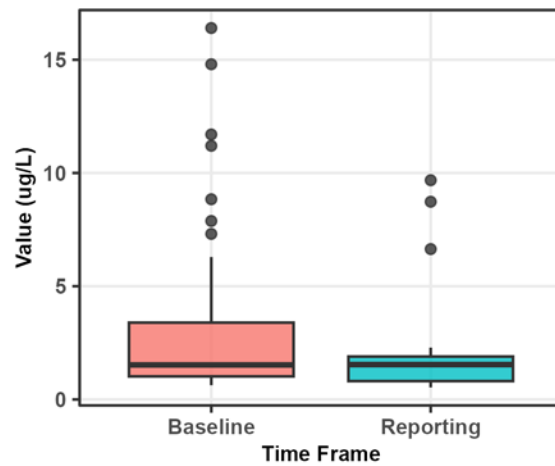
ATHABASCA RIVER, AT TOWN OF ATHABASCA (2)

COPPER DISSOLVED - open season
Primary indicator



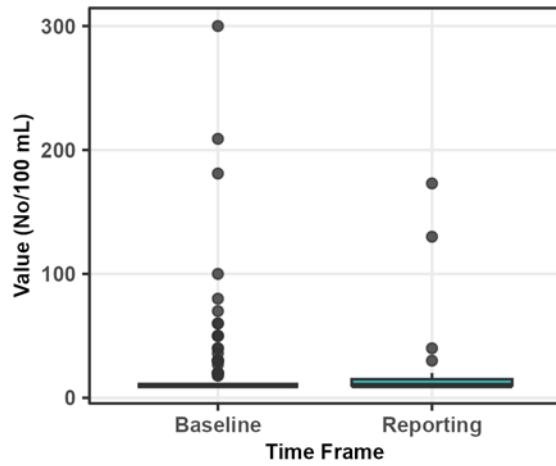
ATHABASCA RIVER, AT TOWN OF ATHABASCA (

COPPER TOTAL RECOVERABLE - open season
Secondary indicator



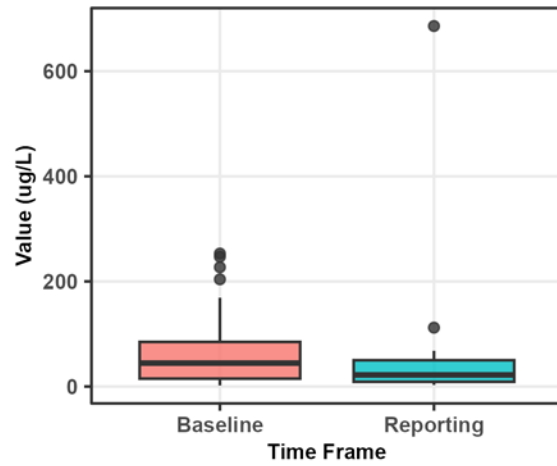
ATHABASCA RIVER, AT TOWN OF ATHABASCA

ESCHERICHIA COLI - open season
Primary indicator



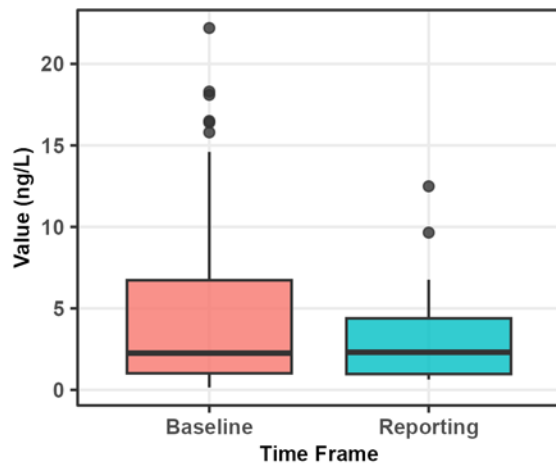
ATHABASCA RIVER, AT TOWN OF ATHABASCA

IRON DISSOLVED - open season
Primary indicator



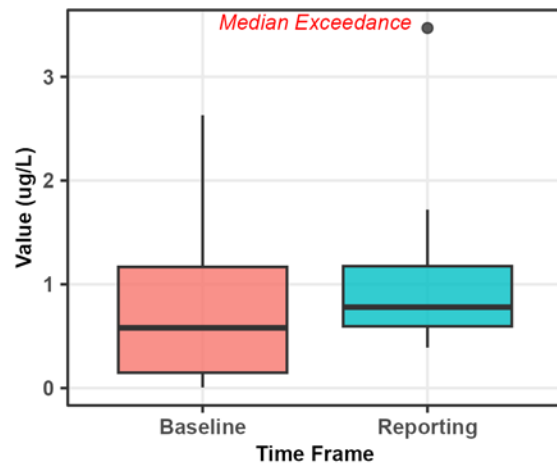
ATHABASCA RIVER, AT TOWN OF ATHABASCA (

MERCURY TOTAL - open season
Secondary indicator



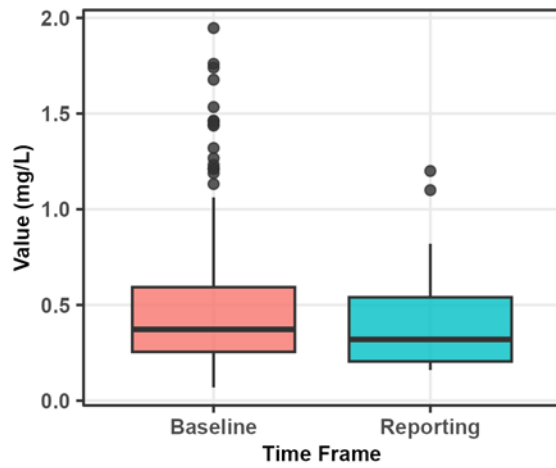
ATHABASCA RIVER, AT TOWN OF ATHABASCA (2

NICKEL DISSOLVED - open season
Primary indicator



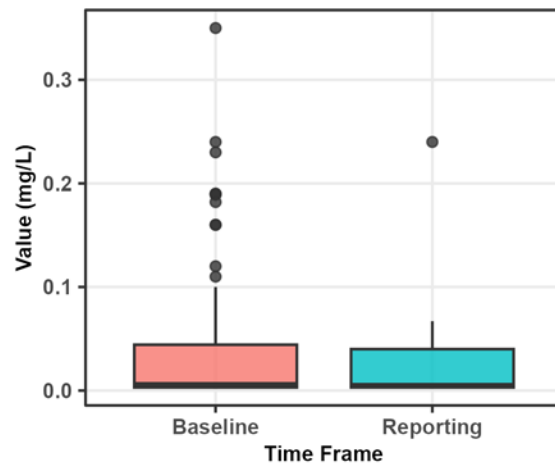
ATHABASCA RIVER, AT TOWN OF ATHABASCA

NITROGEN TOTAL (CALCD WS) - open season
Primary indicator



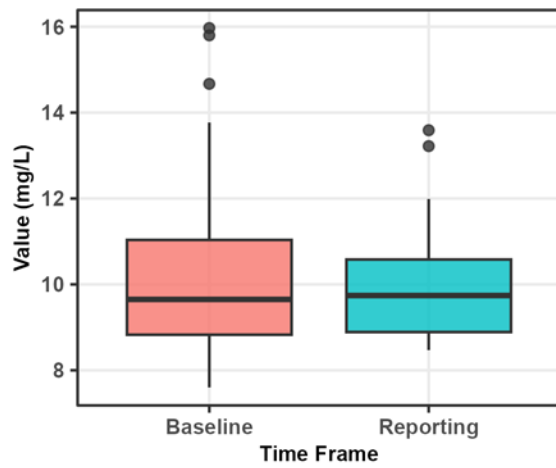
ATHABASCA RIVER, AT TOWN OF ATHABASCA

NITROGEN, NITRATE - open season
Primary indicator



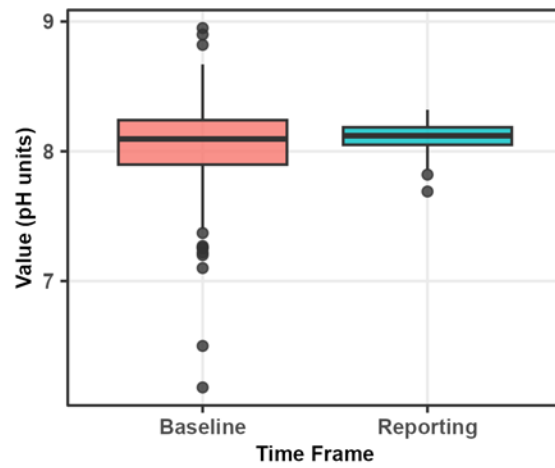
ATHABASCA RIVER, AT TOWN OF ATHABASCA (

OXYGEN DISSOLVED (FIELD METER) - open seas
Primary indicator



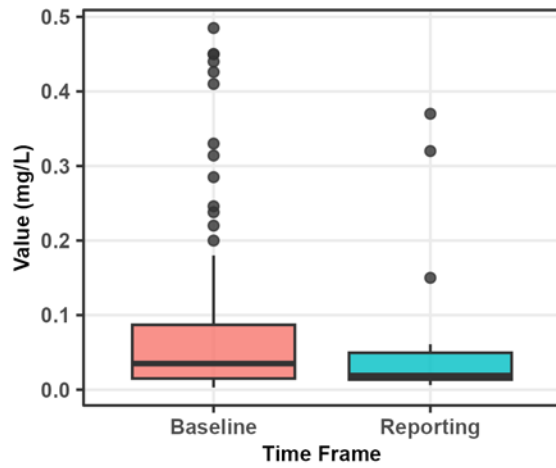
ATHABASCA RIVER, AT TOWN OF ATHABASCA (2

PH (FIELD) - open season
Primary indicator



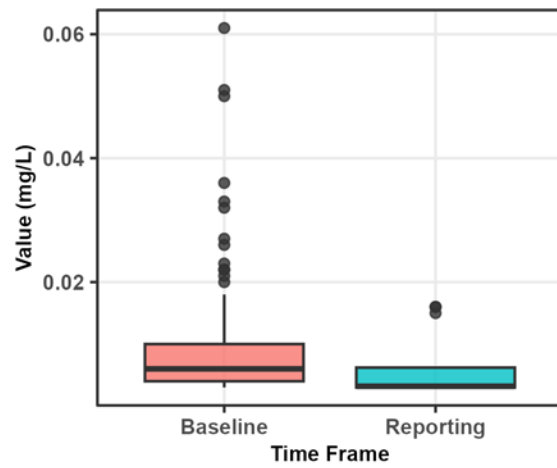
ATHABASCA RIVER, AT TOWN OF ATHABASCA

PHOSPHORUS TOTAL (P) - open season
Primary indicator



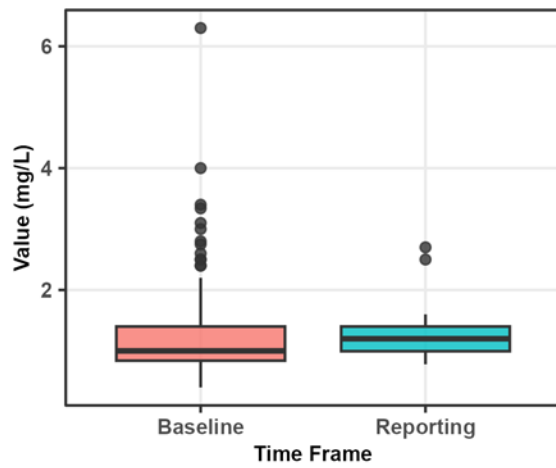
ATHABASCA RIVER, AT TOWN OF ATHABASCA/

PHOSPHORUS TOTAL DISSOLVED - open season
Primary indicator



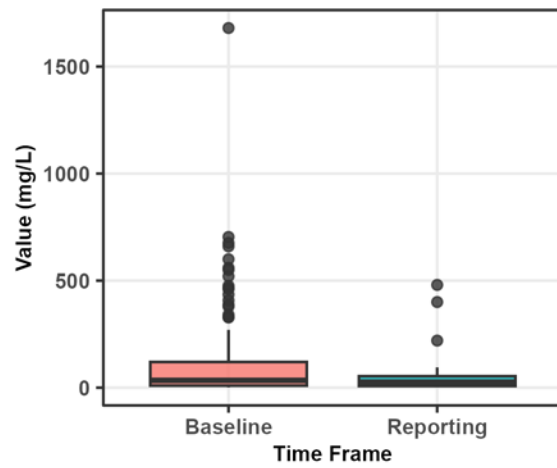
ATHABASCA RIVER, AT TOWN OF ATHABASCA (2

POTASSIUM DISSOLVED/FILTERED - open season
Primary indicator

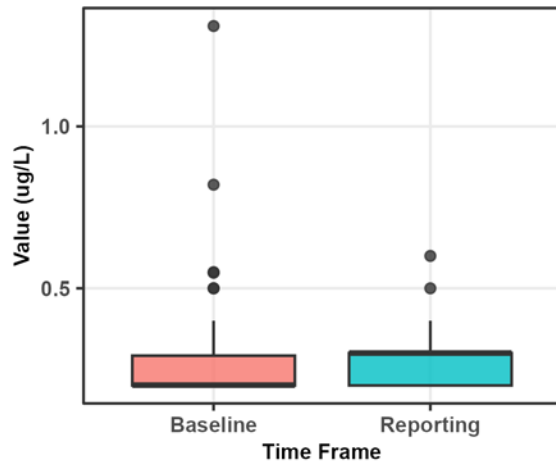


ATHABASCA RIVER, AT TOWN OF ATHABASC.

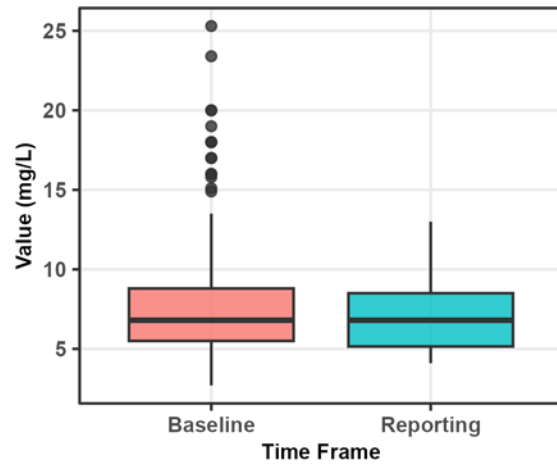
RESIDUE NONFILTERABLE - open season
Primary indicator



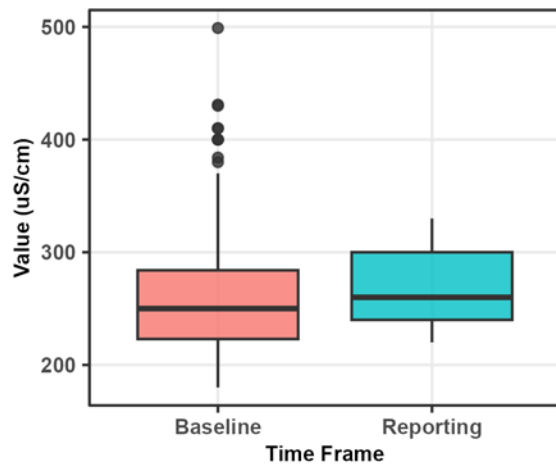
ATHABASCA RIVER, AT TOWN OF ATHABASCA
SELENIUM TOTAL RECOVERABLE - open season
Primary indicator



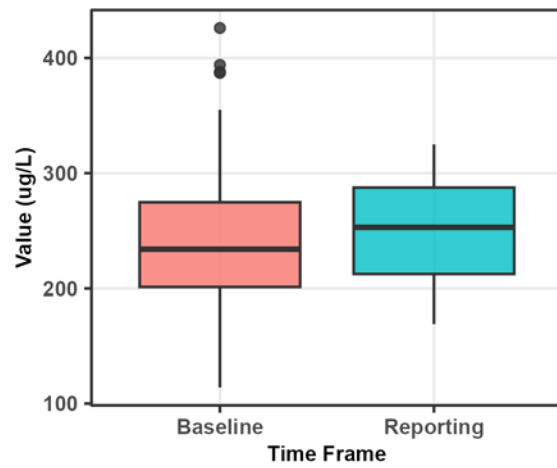
ATHABASCA RIVER, AT TOWN OF ATHABASCA (
SODIUM DISSOLVED/FILTERED - open season
Primary indicator



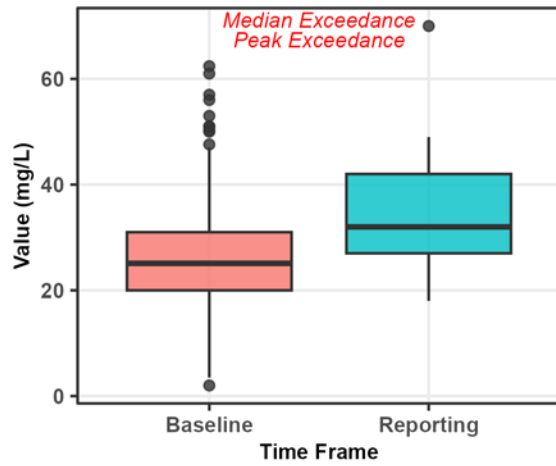
ATHABASCA RIVER, AT TOWN OF ATHABASCA
SPECIFIC CONDUCTANCE (LAB) - open season
Primary indicator



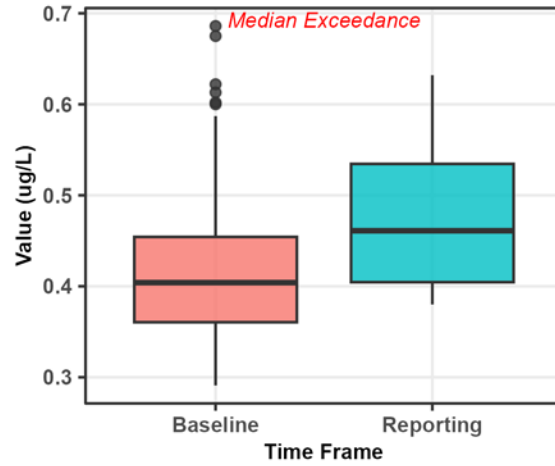
ATHABASCA RIVER, AT TOWN OF ATHABASCA
STRONTIUM DISSOLVED - open season
Primary indicator



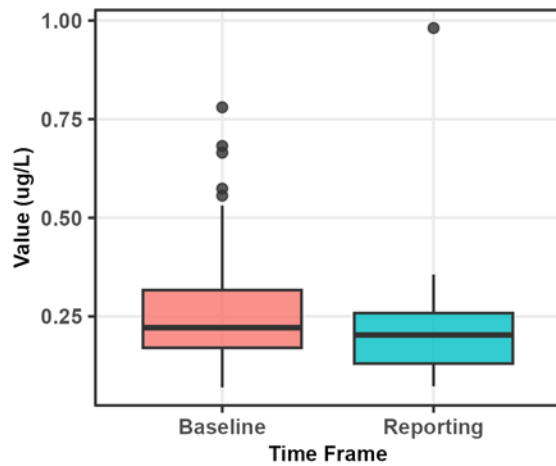
ATHABASCA RIVER, AT TOWN OF ATHABASCA (
SULPHATE DISSOLVED - open season
 Primary indicator



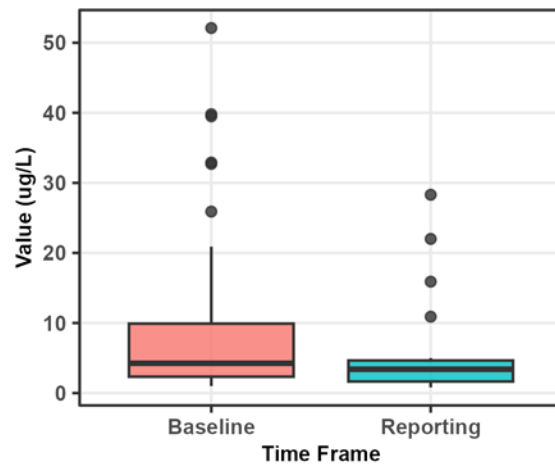
ATHABASCA RIVER, AT TOWN OF ATHABASCA
URANIUM DISSOLVED - open season
 Primary indicator



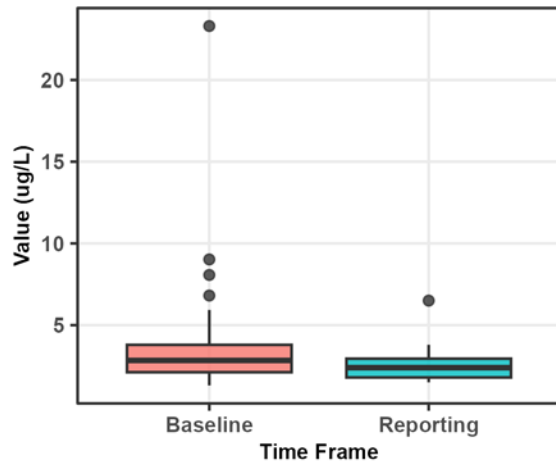
ATHABASCA RIVER, AT TOWN OF ATHABASCA/
VANADIUM DISSOLVED - open season
 Primary indicator



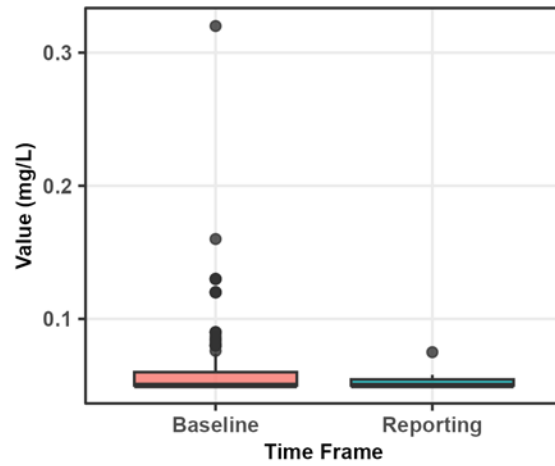
ATHABASCA RIVER, AT TOWN OF ATHABASCA (
ZINC TOTAL RECOVERABLE - open season
 Primary indicator



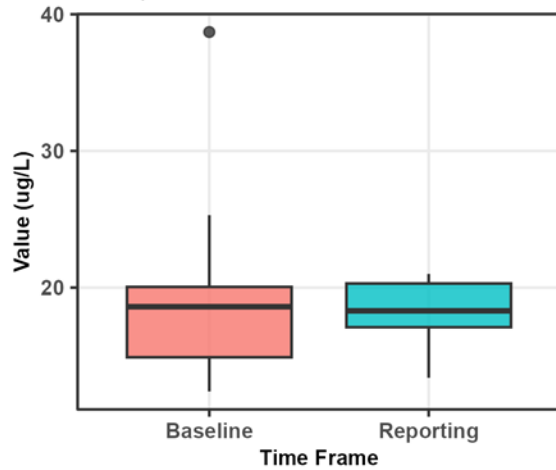
ATHABASCA RIVER, AT TOWN OF ATHABASCA (
ALUMINUM DISSOLVED (AL) - winter season
 Primary indicator



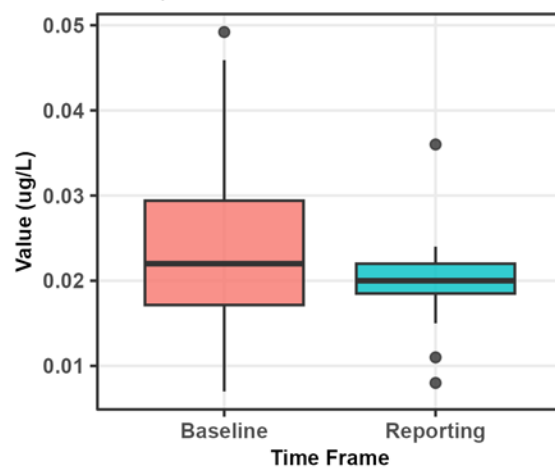
ATHABASCA RIVER, AT TOWN OF ATHABASCA
AMMONIA TOTAL - winter season
 Primary indicator



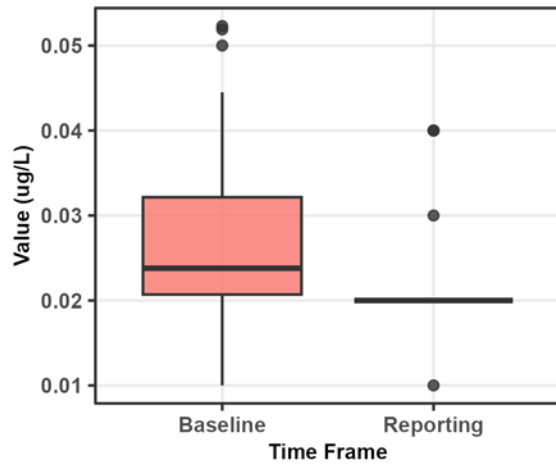
ATHABASCA RIVER, AT TOWN OF ATHABASCA (
BORON DISSOLVED - winter season
 Primary indicator



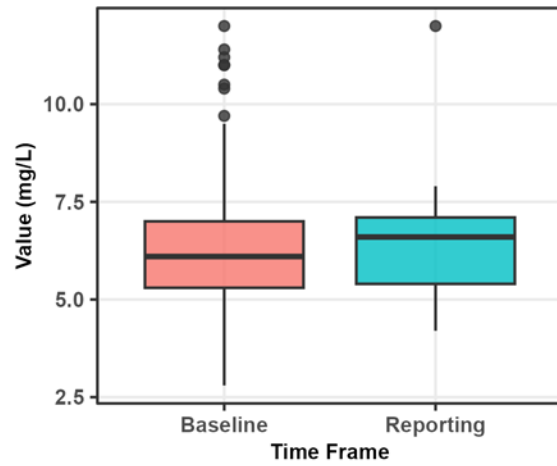
ATHABASCA RIVER, AT TOWN OF ATHABASCA/
CADMIUM DISSOLVED - winter season
 Primary indicator



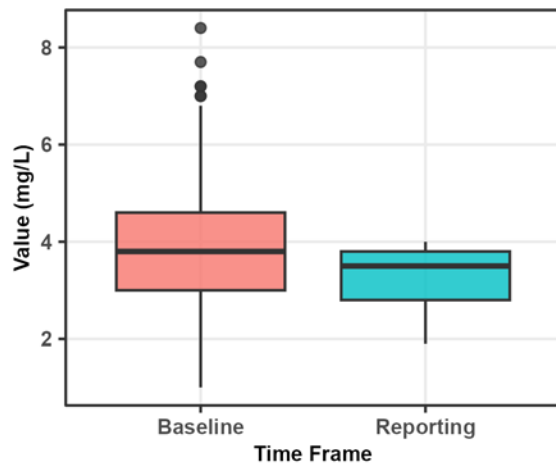
ATHABASCA RIVER, AT TOWN OF ATHABASCA/
 CADMIUM TOTAL RECOVERABLE - winter season
 Primary indicator



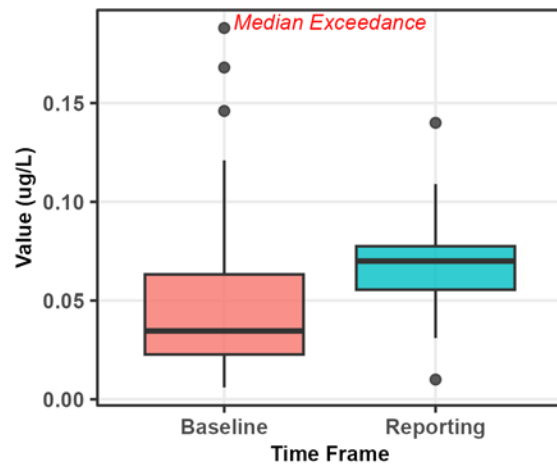
ATHABASCA RIVER, AT TOWN OF ATHABASCA/
 CARBON DISSOLVED ORGANIC - winter season
 Primary indicator



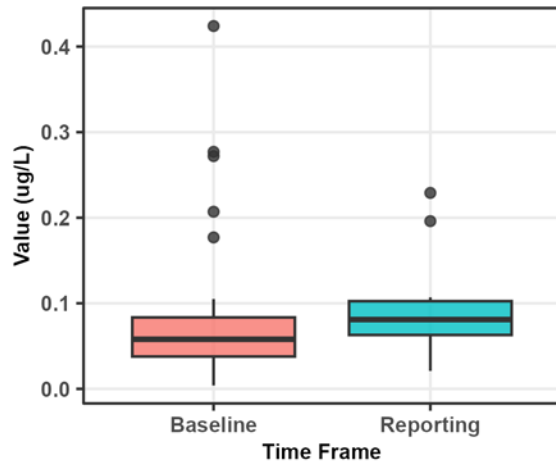
ATHABASCA RIVER, AT TOWN OF ATHABASCA (2)
 CHLORIDE DISSOLVED - winter season
 Primary indicator



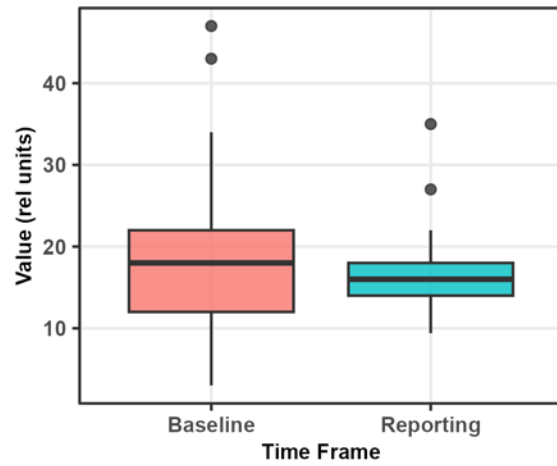
ATHABASCA RIVER, AT TOWN OF ATHABASCA/
 COBALT DISSOLVED - winter season
 Primary indicator



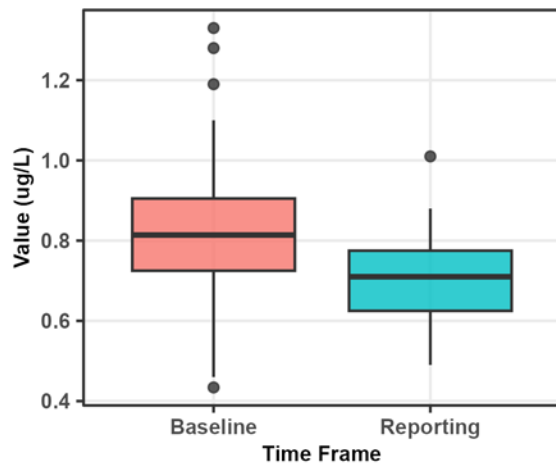
ATHABASCA RIVER, AT TOWN OF ATHABASCA
COBALT TOTAL RECOVERABLE - winter season
Secondary indicator



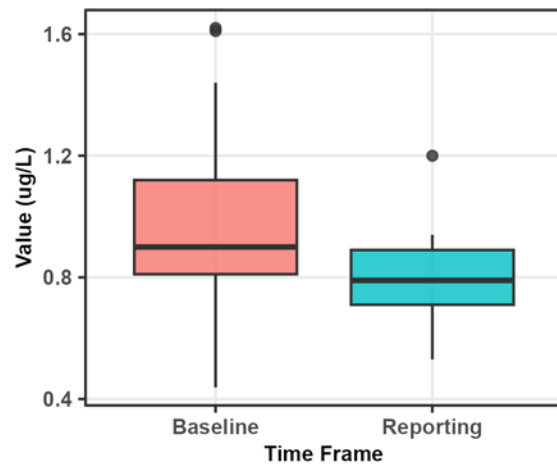
ATHABASCA RIVER, AT TOWN OF ATHABASCA (
COLOUR TRUE - winter season
Primary indicator



ATHABASCA RIVER, AT TOWN OF ATHABASCA
COPPER DISSOLVED - winter season
Primary indicator

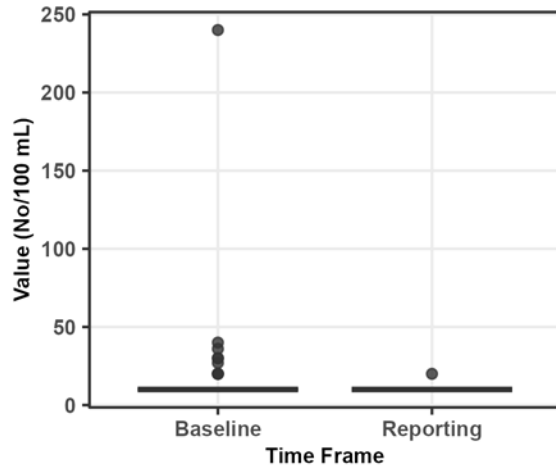


ATHABASCA RIVER, AT TOWN OF ATHABASCA
COPPER TOTAL RECOVERABLE - winter season
Secondary indicator



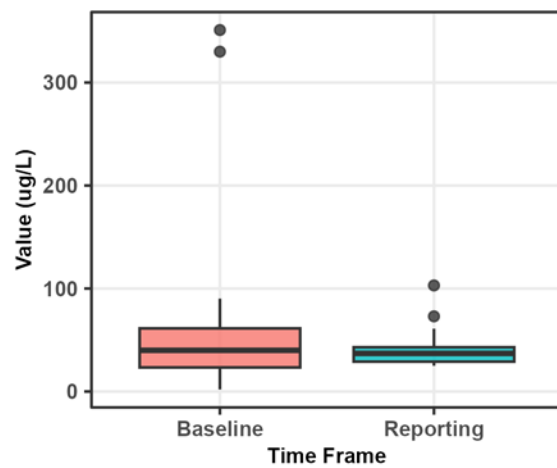
ATHABASCA RIVER, AT TOWN OF ATHABASCA

ESCHERICHIA COLI - winter season
Primary indicator



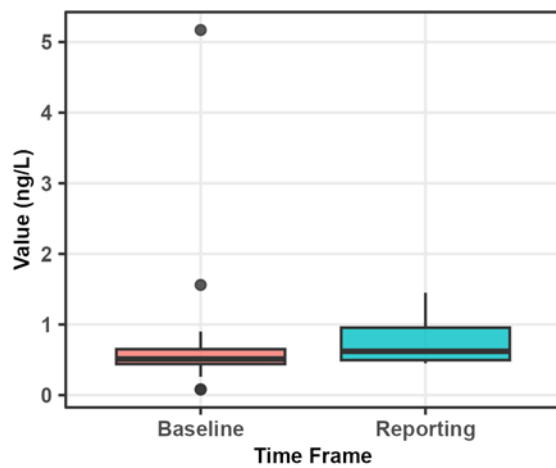
ATHABASCA RIVER, AT TOWN OF ATHABASCA

IRON DISSOLVED - winter season
Primary indicator



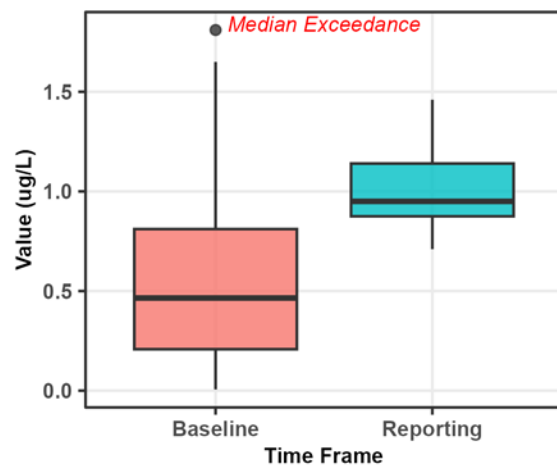
ATHABASCA RIVER, AT TOWN OF ATHABASCA (2)

MERCURY TOTAL - winter season
Secondary indicator

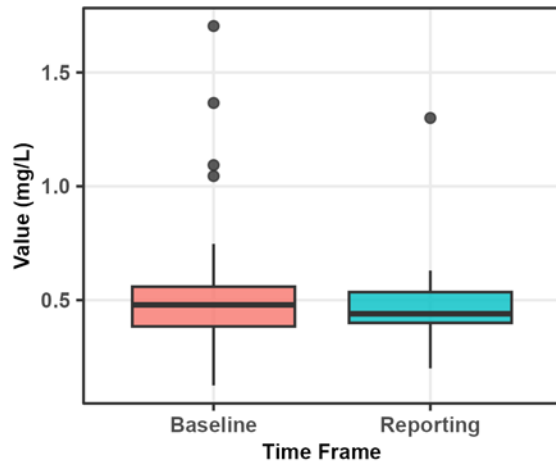


ATHABASCA RIVER, AT TOWN OF ATHABASCA

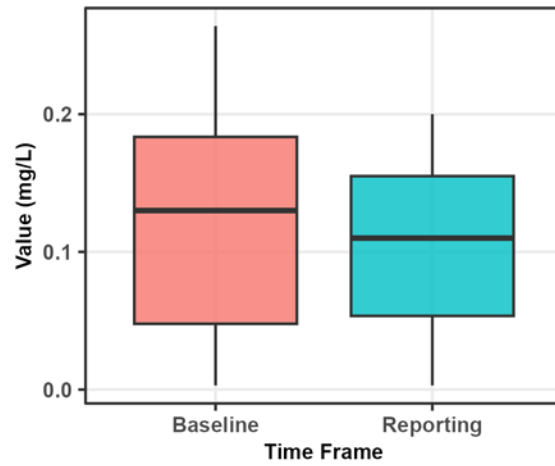
NICKEL DISSOLVED - winter season
Primary indicator



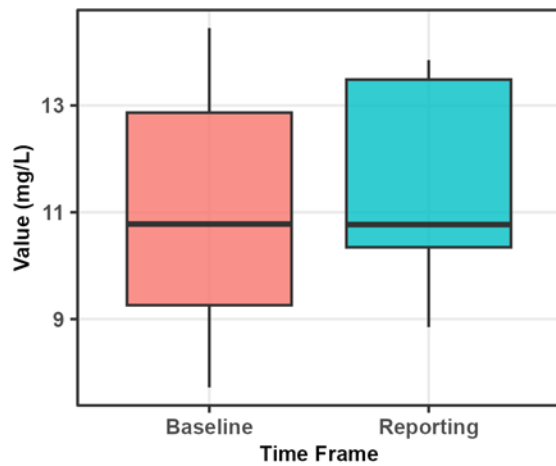
ATHABASCA RIVER, AT TOWN OF ATHABASCA
 NITROGEN TOTAL (CALCD WS) - winter season
 Primary indicator



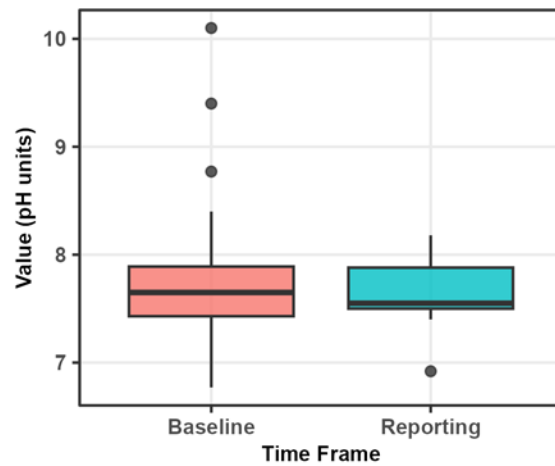
ATHABASCA RIVER, AT TOWN OF ATHABASCA
 NITROGEN, NITRATE - winter season
 Primary indicator



ATHABASCA RIVER, AT TOWN OF ATHABASCA (
 OXYGEN DISSOLVED (FIELD METER) - winter sea
 Primary indicator

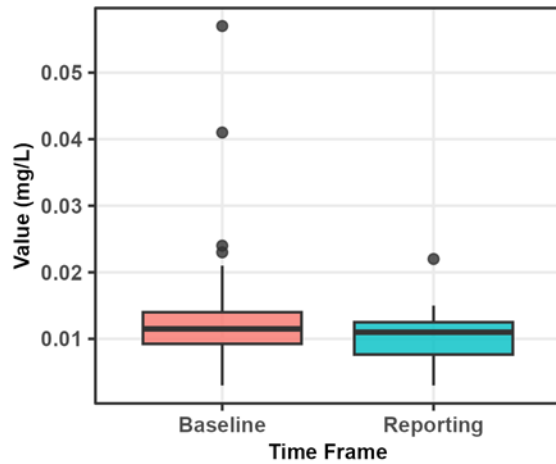


ATHABASCA RIVER, AT TOWN OF ATHABASCA (
 PH (FIELD) - winter season
 Primary indicator



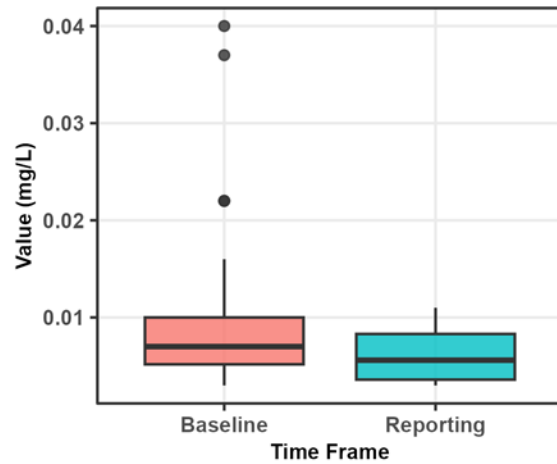
ATHABASCA RIVER, AT TOWN OF ATHABASCA/

PHOSPHORUS TOTAL (P) - winter season
Primary indicator



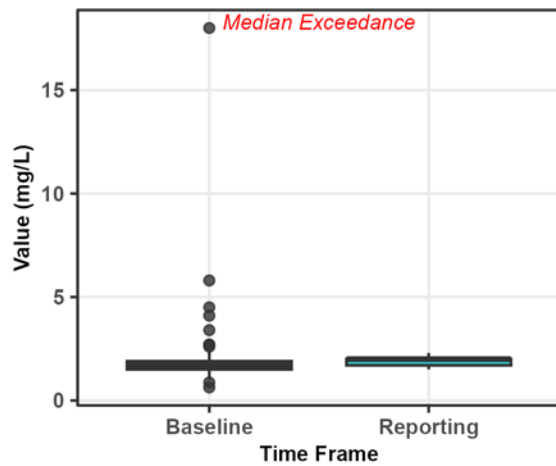
ATHABASCA RIVER, AT TOWN OF ATHABASCA/

PHOSPHORUS TOTAL DISSOLVED - winter season
Primary indicator



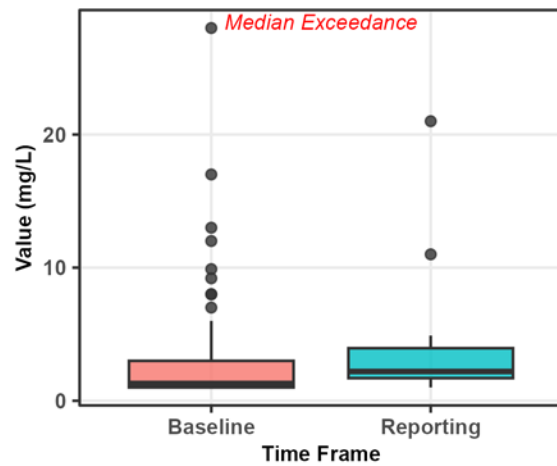
ATHABASCA RIVER, AT TOWN OF ATHABASCA (

POTASSIUM DISSOLVED/FILTERED - winter season
Primary indicator

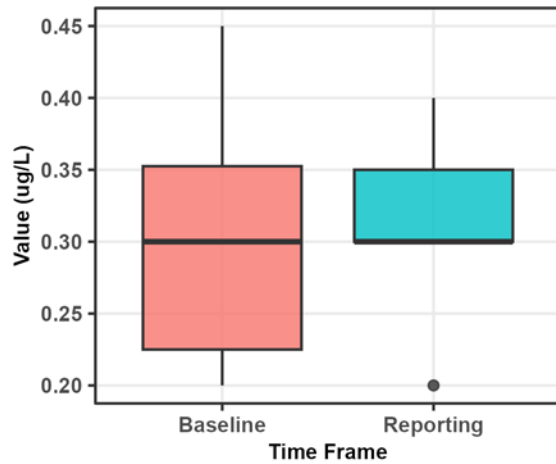


ATHABASCA RIVER, AT TOWN OF ATHABASCA (

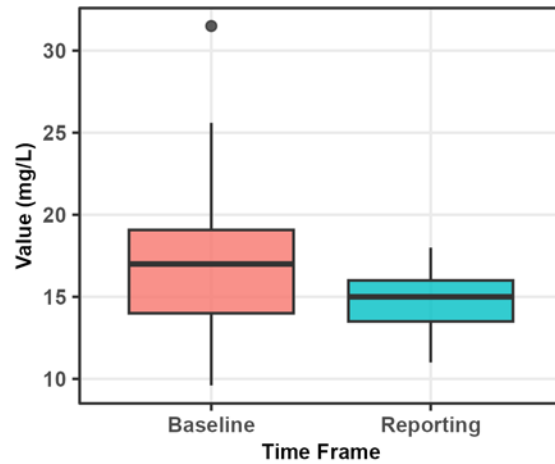
RESIDUE NONFILTERABLE - winter season
Primary indicator



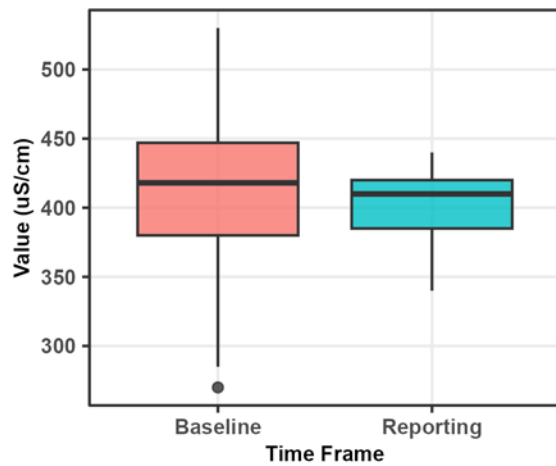
ATHABASCA RIVER, AT TOWN OF ATHABASCA/
SELENIUM TOTAL RECOVERABLE - winter seas
 Primary indicator



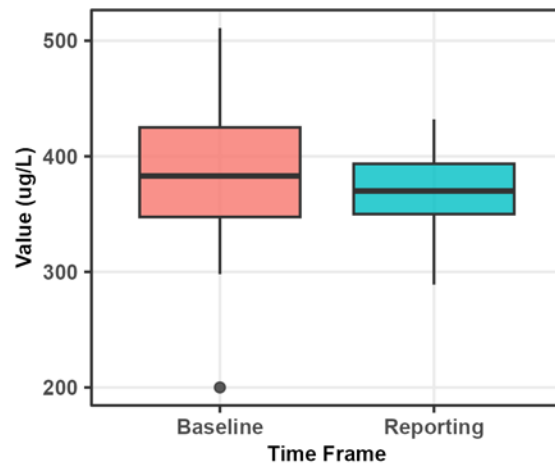
ATHABASCA RIVER, AT TOWN OF ATHABASCA (
SODIUM DISSOLVED/FILTERED - winter season
 Primary indicator



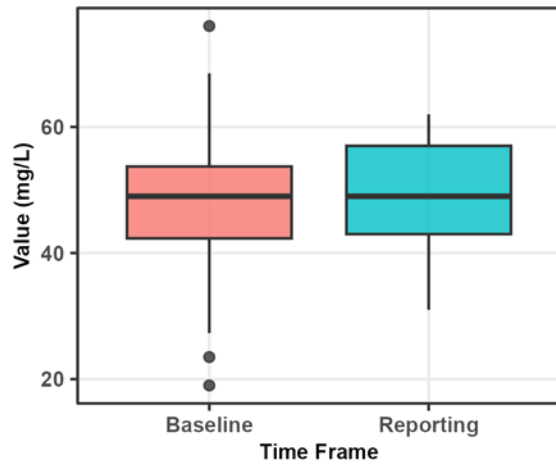
ATHABASCA RIVER, AT TOWN OF ATHABASCA
SPECIFIC CONDUCTANCE (LAB) - winter season
 Primary indicator



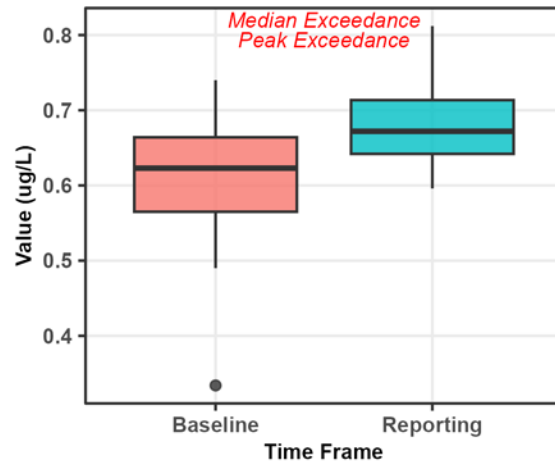
ATHABASCA RIVER, AT TOWN OF ATHABASCA
STRONTIUM DISSOLVED - winter season
 Primary indicator



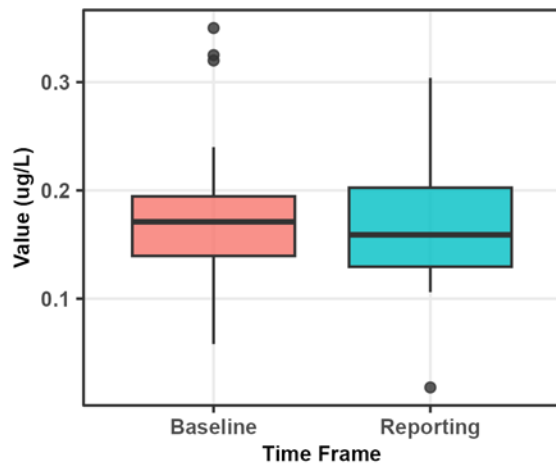
ATHABASCA RIVER, AT TOWN OF ATHABASCA (
 SULPHATE DISSOLVED - winter season
 Primary indicator



ATHABASCA RIVER, AT TOWN OF ATHABASCA
 URANIUM DISSOLVED - winter season
 Primary indicator



ATHABASCA RIVER, AT TOWN OF ATHABASCA
 VANADIUM DISSOLVED - winter season
 Primary indicator



ATHABASCA RIVER, AT TOWN OF ATHABASCA (2
 ZINC TOTAL RECOVERABLE - winter season
 Primary indicator

