Lower Athabasca Region

Status of Management Response for Environmental Management Frameworks, as of December 2020

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Executive Summary

Air Quality

This report communicates the status of the Government of Alberta's management response to air quality trigger exceedances for Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2) in the Lower Athabasca Region since 2012. This fulfills commitments made to Albertans in the Lower Athabasca Region Air Quality Management Framework for Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2). The report informs engaged stakeholders, Indigenous Peoples and those involved in the implementation of the Air Quality Management Framework and is available to the public.

In 2019, 22 air monitoring stations measuring nitrogen dioxide (NO_2) and 26 stations measuring sulphur dioxide (SO_2) were assessed under the Lower Athabasca Region Air Quality Management Framework. A complete report on conditions can be found in the Status of the Ambient Condition for Air Quality (Thi, 2021).

This report summarizes key findings and provides an update on the status management response to date.

Key results from 2019 monitoring data include:

- No limits were exceeded for air quality indicators.
- Triggers were exceeded as follows:
  - Lower Camp station exceeded the trigger into Level 3 for the upper range of ambient concentrations of SO_2.
  - Mildred Lake, Mannix and Buffalo Viewpoint stations exceeded the Level 2 trigger for the upper range of ambient concentrations of SO_2.
  - Barge landing, Fort Hills and Horizon stations exceeded the trigger into Level 2 for both the annual average and upper range concentrations of NO_2.
  - Buffalo Viewpoint, Fort McKay –Bertha Ganter, Fort McKay South and Fort McMurray Athabasca Valley stations exceeded the trigger into Level 2 for the upper range of ambient concentrations of NO_2.

Investigation activities in 2020 focused on understanding sources of SO_2 around Lower Camp station and any correlation with hydrogen sulfide (H_2S). Trend assessment was completed for NO_2 and SO_2 at various stations to better understand changes in air quality over time. The evaluation of potential SO_2 sources (i.e. flaring, petroleum coke piles) around Lower Camp and Christina Lake stations will continue.

Surface Water Quality

This report communicates the status of the Government of Alberta's management response to seven water quality indicators exceeding a trigger in 2019. This fulfils commitments made to Albertans in the Lower Athabasca Region: Surface Water Quality Management Framework for the Lower Athabasca River. The report informs engaged stakeholders, Indigenous Peoples and those involved in the implementation of the framework and is available to the public.

The following is a summary of some key findings and the management response to date:

- No limits were exceeded for the water quality indicators at the Old Fort station in 2019
- Exceedances included five mean triggers (Uranium D, Barium D, Potassium (K+), Selenium D, Uranium T) and two peak triggers (Cobalt D, Uranium D). A complete report on conditions can be found in the Status of the Ambient Condition for Surface Water Quality (Chung and Kerr, In P).
- Investigations are ongoing for the following parameters: chloride, dissolved iron, dissolved lithium, total nitrogen, total Kjeldahl nitrogen, nitrate plus nitrite, potassium, sulphate, dissolved uranium, dissolved barium, dissolved selenium, and total uranium. The purpose of the investigation is to determine the likely factors influencing the performance of an indicator and inform decisions about management actions
- Investigations were initiated for dissolved barium, dissolved selenium, and total uranium based on preliminary assessment of 2019 trigger exceedances.
- After preliminary assessment, the management response for the indicator 'Cobalt D' was closed.

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Key investigative actions are summarized below:

- Procure and integrate the relevant water quality data available to inform an assessment of seasonal patterns in water quality trends
- Stations and parameters where undesirable trends exist:
  - Summarize existing land use activity information within potential source-areas
  - Identify existing department- and community-led management plans that could support improvement of water quality
  - Explore opportunities for additional monitoring of parameters under investigation in relevant water quality monitoring programs conducted by regulated facilities and stakeholders
  - Explore opportunities to enhance geographical resolution in provincial water quality monitoring programs by adding additional stations to the network

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Part 1: Air Quality

1.0 Introduction to Air Quality

Under *the Lower Athabasca Regional Plan* (GoA, 2012), a management response is initiated when the Minister of Environment and Parks determines that a trigger or limit for an indicator identified in the Lower Athabasca Region Air Quality Management Framework (LAR AQMF, AESRD 2012) has been exceeded.

Alberta Environment and Parks (AEP) is responsible for undertaking the management response and works with other government departments and regulators (e.g. Alberta Energy Regulator) and external parties, as required, to identify and implement a management response.

Presently, nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) are reported annually under the LAR AQMF using data collected at monitoring stations shown in Figure 1.

Alignment with Canadian Ambient Air Quality Standards (CAAQS)

Through the Canadian Council of Ministers of the Environment (CCME), Alberta agreed to implement a national Air Quality Management System (AQMS), which included reporting annually on NO_2, SO_2, O_3, and $PM_{2.5}$ against the Canadian Ambient Air Quality Standards (CAAQS) in the Alberta Air Zone Report.

The intent is to update the Lower Athabasca Region Air Quality Management Framework to align with the CAAQS indicators and thresholds.

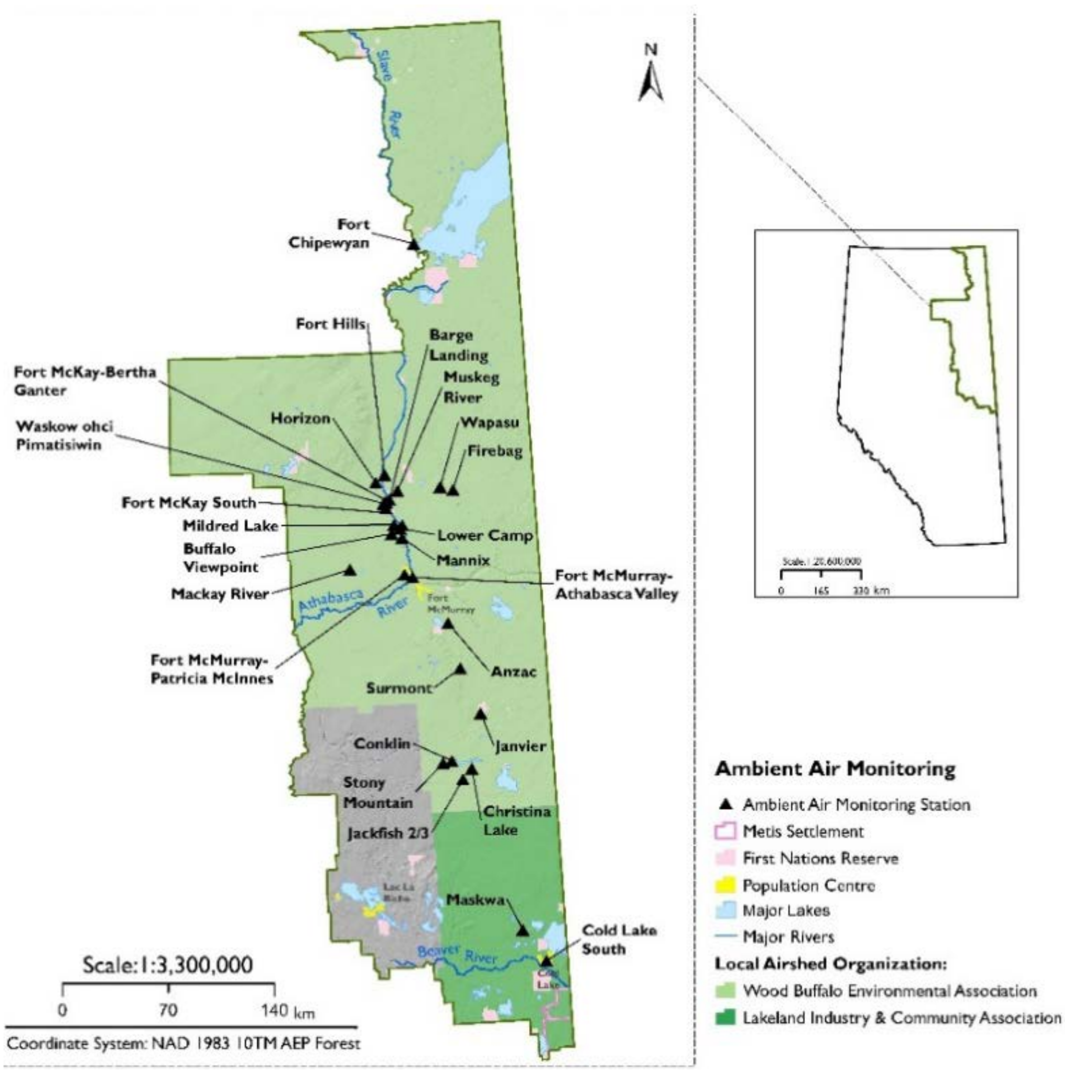

Figure 1: Map of the continuous monitoring station used in the assessment

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Nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) levels are reported annually through the Lower Athabasca Region Status of Air Quality report. A management response was initiated for the Lower Athabasca Region after triggers were crossed for nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) during the first reporting cycle. As each annual report on conditions becomes available, the management response is re-evaluated and updated based on new information. This current report provides an update on the management response since the last status report in October 2019 (AEP, 2020).

The management response is a seven-step process that is undertaken, in full or in part, when an ambient air quality trigger is crossed or a limit is exceeded. Part of the management response is determining the need for management action. A full description of the management system can be found in the LAR AQMF (AESRD, 2012).

The management response for air quality considers a variety of factors including but not limited to the type and location of the monitoring station, averaging time (i.e. hourly, 24-hour or annual) and the ambient air quality trigger or limit that was exceeded. In addition, the management response can also include investigation into the cause of an exceedance, notification of the identified sources and affected First Nations, Métis communities and stakeholders, and the identification of management actions to prevent a re-occurrence.

The LAR AQMF and all previous status of ambient air quality and status of management response reports are available on the Environment and Parks website (www.alberta.ca/lower-athabasca-regional-planning.aspx), as well as on Open Alberta Government (https://open.alberta.ca/publications).

2.0 Summary of Ambient Levels Assigned for Air Quality

2.1 Verification and Preliminary Assessment

Alberta Environment and Parks conducts the annual assessment of ambient air quality data gathered from continuous ambient air monitoring stations in the Lower Athabasca Region. Data are downloaded from Alberta's ambient air data warehouse and checked for accuracy and completeness. Once these data have been verified, the air quality metrics are used to assess ambient conditions relative to triggers and limits in the LAR AQMF.

The methodology and procedures set out in the Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards (CAAQS) for Fine Particulate Matter and Ozone (CCME, 2012) are followed to determine the CAAQS achievement status. This includes examination of data for transboundary flows and exceptional events (e.g. forest or grass fires).

In 2019, 22 air monitoring stations measuring nitrogen dioxide (NO_2) and 26 stations measuring sulphur dioxide (SO_2) were assessed. In 2019, Surmont station for both NO_2 and SO_2 and Surmont 2 station for SO_2 did not fulfill the data completeness criteria and are not included in the report.

More information on the methodology, procedures, verification and preliminary assessments are reported in the 2019 Status of Air Quality, Lower Athabasca Region, Alberta (Thi, 2021).

2.2 Minister's Determination

The Minister's Determination confirmed that no limits were exceeded for any air quality indicators in 2019, in the Lower Athabasca Region. However, exceedances of air quality triggers occurred at several monitoring stations, resulting in the assignment of air quality levels as summarized in Table 1 and detailed in the 2019 Status of Air Quality, Lower Athabasca Region, Alberta (Thi, 2021).

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TABLE 1: AMBIENT LEVELS ASSIGNED TO AIR QUALITY MONITORING STATIONS IN THE LOWER ATHABASCA REGION FOR 2015-2019 BASED ON TRIGGERS AND LIMITS ESTABLISHED IN THE FRAMEWORK.

Station Name	Nitrogen Dioxide (NO_2)										Sulphur Dioxide (SO_2)									
	Annual Average					Upper Range					Annual Average					Upper Range				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Anzac	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Barge Landing				-	2				-	2				-	1				-	1
Buffalo Viewpoint			-	1	1			-	1	2	1	1	1	1	1	1	2	2	2	1
Christina Lake				-	1				-	1				-	1				-	2
Cold Lake South	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Conklin		-	1	1	1		-	1	1	1		-	1	1	1		-	1	1	1
Firebag	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1
Fort Chipewyan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fort Hills			-	2	2			-	2	2			-	1	1			-	1	1
Fort McKay-Bertha Ganter	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	2	2	2	1	1
Fort McKay South	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	2	2	2	1	1
Fort McMurray-Athabasca Valley	1	1	1	1	1	2	1	2	1	2	1	1	1	1	1	1	1	1	1	1
Fort McMurray-Patricia McInnes	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Horizon	1	1	1	1	2	2	1	2	2	2	1	1	1	1	1	1	1	1	1	1
Jackfish 2/3				-	1				-	1				-	1				-	1
Janvier			1	1	1			1	1	1			1	1	1			1	1	1
Lower Camp											1	1	1	1	1	3	4	4	3	3
MacKay River		1	1	1	1		1	1	1	1		1	1	1	1		1	1	1	1
Mannix											1	1	1	1	1	3	3	3	2	2
Maskwa	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mildred Lake											1	1	1	1	1	3	3	3	2	2
Muskeg River	2	2	2	2		2	2	2	2		1	1	1	1		2	2	2	2	
Stony Mountain		1	1	1	1		1	1	1	1		1	1	1	1		1	1	1	1
Surmont			1	1	-			1	1				1	1				1	1	-
Surmont 2					1					1					-					-
Wapasu	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1
Waskow ohchi Pimatisiwin*													-	1	1			-	1	1

▭ : Parameter was not measured at this location and period. – Station did not fulfil the criteria of 75 percent data completeness.

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3.0 Status of Management Response for Air Quality

The management response is a set of steps taken, in full or in part, when an ambient trigger or limit is exceeded. The management response will support the management intent associated with each trigger or limit exceeded (Table 2). A full description of the management system is found in the Lower Athabasca Region Air Quality Management Framework (AESRD, 2012). The status of management response is reported on a regular basis and may be supported by supplemental technical reports. This section of the report provides an update on the investigation being advanced as part of the management response.

TABLE 2: AMBIENT AIR QUALITY LEVELS – DESCRIPTION AND MANAGEMENT INTENT FOR ANNUAL AVERAGE

Level	Description	Management Intent
4	Ambient air quality exceeding the air quality limit.	Improve ambient air quality to below the limit.
	Limit	
3	Ambient air quality below but approaching the air quality limits.	Proactively maintain air quality below the limit.
	Trigger into Level 3	
2	Ambient air quality below air quality limits.	Improve knowledge and understanding, and plan.
	Trigger into Level 2	
1	Ambient air quality below air quality limits.	Maintain air quality through standard regulatory and non-regulatory approaches.

3.1 Investigation

The purpose of the investigation is to determine the likely factors influencing the performance of an indicator and inform decisions about management actions. The scale of the investigation depends on the management level as well as the complexity of the issue identified. Support from the public, Indigenous Peoples, industry, non-governmental groups, government at multiple levels, and regulatory agencies may all be important for understanding regional issues and exploring options to address the ambient air quality issues. Analysis of ambient concentrations, trends, and the identification of potential emission sources leading to elevated ambient concentrations are ongoing. A summary of the completed, ongoing and proposed activities is provided in Table 3 and detailed in the sections below.

TABLE 3: STATUS OF COMPLETED, PROPOSED AND ONGOING INVESTIGATIONS AS OF DECEMBER 2020

Investigation Task	Lead	Status	Notes
Assess and improve monitoring network	AEP	Complete	An air monitoring network assessment for the Oil Sands area was completed in 2015 and used to inform the Oil Sands Monitoring plan. No further work is required at this time.
Cross-validation of trend assessment tools	AEP	Complete	Comparison of trend assessment tools is described in Nunifu and Fu, 2019. Trend analysis method and results are reported in Section 3.1.1 and Appendix C of this report
Investigation of the influence of industry flaring on elevated SO_2 levels at Lower Camp station	AEP/AER	Ongoing	Assessment methods and results reported in Section 3.1.1 and Appendix B of this report.

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Investigation Task	Lead	Status	Notes
			AER Flare Model could be used for investigating the influence (Proposed future work).
Investigation of the influence of flaring and other SAGD operations on elevated SO_2 levels at Christina Lake station	AEP	Proposed	Described in Section 3.1.2 of this report.
Investigation of the influence of fugitive emissions from petroleum coke deposits on elevated SO_2 levels at the Lower Camp station	AEP	Proposed	Described in Section 3.1.2 of this report. Analytical work to be conducted; proposed monitoring under consideration.
Review of studies that use satellite SO_2 and NO2 data in the LAR	AEP	Ongoing	Described in Section 3.1.2 of this report.

3.1.1 Investigation Activities Completed in 2020

Investigation of SO_2 Emissions at Lower Camp Station

Investigations conducted in 2020 focused on sulphur dioxide, in response to trigger exceedances observed at Lower Camp station since the framework took effect.

The Joint Oil Sands Monitoring Emissions report (ECCC and AEP, 2016) indicates that industrial point sources in the Athabasca Oil Sands Region (AOSR) are the major contributors of SO_2. Correspondingly, most of the industrial air monitoring stations, where Level 2 exceedances occurred, are located in the heart of the oil sands operations. Extensive mining, upgrading and processing occur in the area with large stacks emitting SO_2. Emissions from these stacks typically travel and disperse greatly before reaching ground level. Therefore, the elevated SO_2 episodes at these stations may be related to continuous emission sources or intermittent flaring.

Alberta Environment and Parks (AEP) implemented a joint work-plan with the Alberta Energy Regulator (AER) to investigate elevated levels of SO_2 (Level 3) at Lower Camp station. The main objective of this analysis was to identify potential local sources of SO_2 surrounding the station. The study also compared concentrations of H_2S and SO_2 to understand any correlations.

To understand the geographical location of the source and movement of pollutants, the investigation used a variety of statistical tools to conduct an analysis for both 5-min data and hourly exceedances of SO_2 and H_2S at the Lower Camp station. Details for these analyses and additional results are in Appendix B.

The study found:

- No 1-Hr exceedances (AAAQO) of SO_2 from 2017 to 2019.
- Multiple 1-Hr exceedances of the H_2S AAAQO from 2017 to 2019 (18 in 2017, 5 in 2018, 32 in 2019).
- H_2S exceedances generally occurred when the wind speed was less than 10 km/hr, while SO_2 high values were observed when the winds were in the range of 2 to 25 km/hr. (Tables A1 and A2 in Appendix B).
- SO_2 emissions are almost exclusively from stack sources in LAR (CASA, 2018) and ambient SO_2 concentrations occasionally increase when emissions are high, depending on wind direction and dispersion meteorology (Figure A7 in Appendix B)
- High correlations between SO_2 and H_2S suggests recirculation and mixing of emissions from multiple sources during the day, while low correlations suggest non-combustion sources.
- There are no approved stack sources of SO_2 to the southwest but there are ground based H_2S sources such as Suncor's active pond 2/3 in the south.
- Higher SO_2 values occur from SW and SSW, which is also the direction of the petroleum coke pile, 1 kilometre away from Lower Camp station. These higher SO_2 values may be related to possible burning and/or smouldering at the pile or could be attributed to the nearby active tailing pond (Pond 2/3) (Figure 2).

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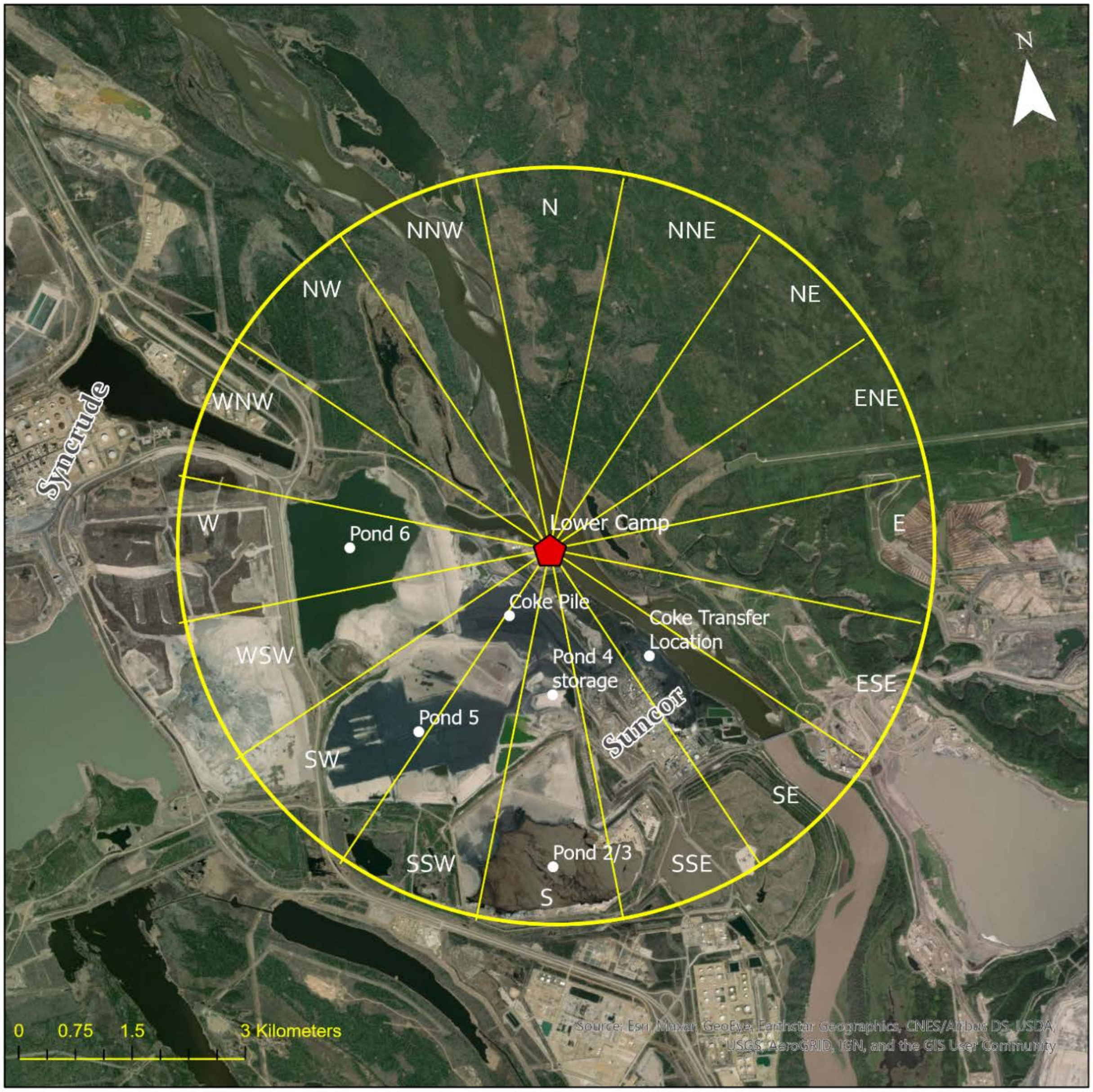

Figure 2: Location of potential SO_2 sources relative to Lower Camp station

Trend Analysis

Investigation activities previously conducted as part of the Lower Athabasca air quality management response included the evaluation and comparison of trend assessment methodologies to understand and address statistical challenges typically encountered when conducting trend analysis of air quality data (Nunifu and Fu, 2019). When conducting trend analysis on the LAR air data, this work suggests comparing parametric and non-parametric tests of significance on de-trended time series data to ensure that conclusions are not dependent on assumptions around data structure (e.g., normality and heteroscedasticity).

The recommended trend analyses were conducted as part of the 2020 management response for 13 stations where continuous monitoring data were available. Trends were assessed for SO_2 at all 13 stations and for NO_2 at nine stations. The direction and significance of the trend assessment results were consistent for both parametric and non-parametric tests. Increasing (positive) trends were observed for NO_2 at Fort Chipewyan and for SO_2 and Lower Camp, while all other analyses yielded either decreasing (negative) or no trends. These results are shown in Table 4 and Figure 3; details of the analysis are provided in Appendix C.

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TABLE 4: RESULTS OF TREND ASSESSMENT CONDUCTED IN THE LOWER ATHABASCA REGION.

Station	NO_2	SO_2
Fort Chipewyan	+	NS
Horizon	NS	NS
Fort McKay Bertha Ganther	NS	-
Fort McKay South	NS	-
Mildred Lake		NS
Lower Camp		+
Buffalo Viewpoint		NS
Mannix		NS
Fort McMurray Particia McInnes	-	NS
Fort McMurray Athabasca Valley	-	NS
Anzac	-	NS
Maskwa	NS	NS
Cold Lake South	-	NS

- + means positive trend detected; - means negative trend detected;
- NS means no significant trend detected; blank means insufficient data to conduct analysis

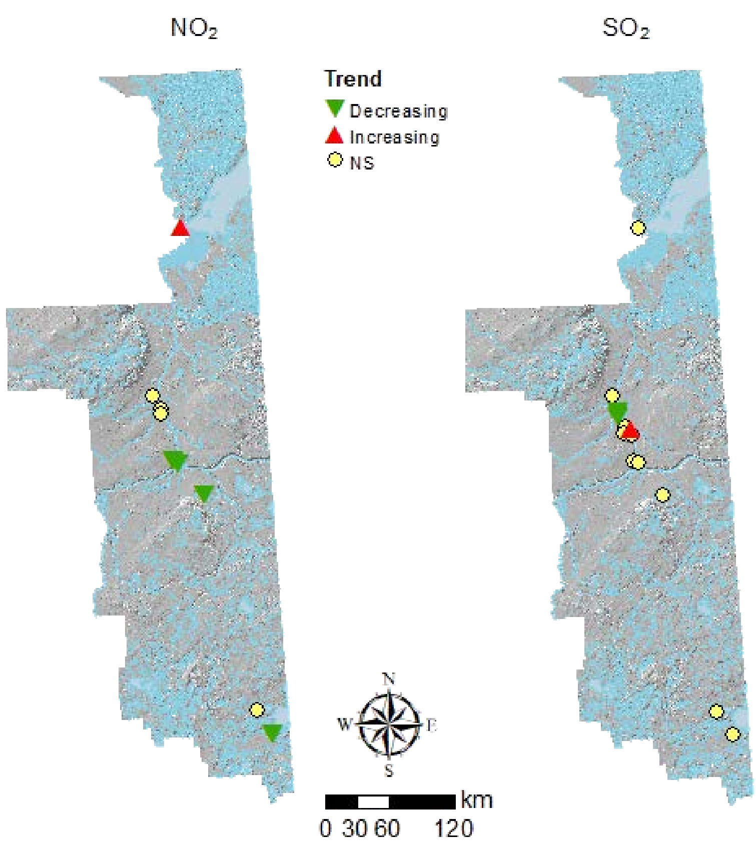

Figure 3: Results of trend assessment for NO_2 (left) and SO_2 (right). Green arrow represents a decreasing trend; red arrow represents an increasing trend; yellow circle represents no significant trend.

Classification: Public

3.1.2 Proposed and Ongoing Investigation Activities

Building on the investigation activities completed in 2020 and in previous years, the following activities are proposed or ongoing to support understanding of conditions and trends for NO_2 and SO_2 concentrations in the LAR.

SO_2 Episodes as Christina Lake Station

Description: Investigation of SO_2 episodes at Christina Lake monitoring station of the Cenovus SAGD Operations Project.

Status: Proposed

The Christina Lake station, which is a compliance monitoring station of the Cenovus SAGD (Steam-Assisted Gravity Drainage) Operations Project and also at Level 2, is located south of Fort McMurray.

Detailed investigations are required to understand the relationship of SO_2 episodes with flaring and SAGD operations. Simple statistical analysis will be done to understand if SO_2 episodes at Christina Lake station are associated with SAGD operations, including flaring.

SO_2 Episodes at Lower Camp Station

Description: Investigation of fugitive emissions from petroleum coke deposits and identification of potential emission sources that contribute to elevated SO_2 levels in the Lower Camp monitoring station

Status: Proposed

Analysis of monitoring data collected at the Lower Camp station indicates that SO2 episodes often occur when winds originate from the southwest; however, there are no known significant SO2 emissions sources located to the southwest of Lower Camp. Therefore, AEP proposes further exploratory work in order to identify potential influences on SO2. This work could include further evaluation of meteorology, using advanced methods such as modelling, and the additional review of potential SO2 emissions sources in the area.

As the Upper Range trigger level of SO2 at Lower Camp station during 2018 and 2019 was at Level 3, which is below the Level 4 measured during 2016 and 2017, AEP is looking at this station to do our due diligence and in case the SO2 trigger level goes back to Level 4. If this were to occur, further investigations would be advanced, which may include additional monitoring.

Engagement with industry is ongoing.

Literature Review

Description: Review of ongoing and completed studies that use satellite SO_2 and NO_2 in the Lower Athabasca Region

Status: Ongoing

McLinden et al. (2020) use satellite-measured SO_2 to estimate emissions in the mineable oil sands area. Changes in satellite-derived SO_2 emissions are compared against the National Pollutant Release Inventory (NPRI) emissions inventory, as well as ambient concentrations from continuous and passive monitoring stations. Similar studies from Environment and Climate Change Canada of NO_2 over the oil sands demonstrate that the first TROPOMI NO_2 measurements near the Canadian Oil Sands have an outstanding ability to detect NO_2 on a very high horizontal resolution that is unprecedented for satellite NO_2 observations (Griffin et al., 2018). Pertinent information and outcomes from these studies will be used to inform current and future investigations.

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4.0 Next Steps for Air Quality

Adequate understanding of the various possible influences on indicators under investigation is required prior to moving to the identification of management objectives and management actions to support them. Without adequate information, management actions are unlikely to achieve significant improvements to ambient air quality. At this time, indicators in the Lower Athabasca Region that have exceeded thresholds remain in investigation. Next steps in the management response will focus on completing the investigation activities outlined in Table 3.

AEP will work with key stakeholders and Indigenous Peoples to inform the investigation and assist in improving the current environmental management system and identifying management actions that may be necessary to address point and non-point source emissions. Progress updates on the ongoing investigation work outlined in this report will be communicated to the public in subsequent Status of the Management Response Reports.

Classification: Public

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Air Quality Glossary

Air Quality	The composition of air, with respect to quantities of substances therein, and/or a measure of the health-related and visual characteristics of the air used most frequently in connection with standards against which the contribution of the particular source can be compared.
Air Quality Objective	A numerical concentration, value or narrative statement which is intended to provide protection of the environment and human health to the extent that is technically and economically feasible, and is socially and politically acceptable.
Airshed organization	Regional partnership associations that include government, industry, environmental groups and the public. These partnerships are responsible for air quality monitoring and, in some cases, air quality management for a specific region of Alberta. Alberta presently has nine local airshed organizations.
Air Zone	Air zones are geographic areas identified through the national Air Quality Management System to facilitate effective air quality management at a local scale. In Alberta, the air zones align with the regional Land-use Framework boundaries.
Alberta's Ambient Air Quality Data Warehouse	Alberta's central repository for ambient air quality data collected in the province, made available online to the public. Currently known as the air data warehouse.
Ambient Air	Outside air - any portion of the atmosphere not confined by walls and a roof to which the public has access.
Canadian Ambient Air Quality Standards (CAAQS)	Ambient air quality standards applied across Canada that are designed to provide a uniform measure of protection for human health and the environment.
Fine Particulate Matter	Fine particulate matter refers to airborne solid or liquid particles that are 2.5 microns or less in diameter. It is either emitted directly (primary PM) or formed in the atmosphere from precursor emissions (secondary PM). Important precursors of secondary PM are nitrogen oxides, sulphur dioxide, ammonia, and volatile organic compounds. The chemical composition of particles can vary widely and depends on location, time of year, and weather.
Indicators	Parameters that are measured to provide information about environmental condition; metrics are applied to the measurements to compare with defined triggers and limits.
Limits	Numerical thresholds at which the risk of adverse effects on health or environmental quality is becoming unacceptable.
Metric	A procedure for processing monitoring data to determine an indicator value to compare to triggers and limits. In the AQMF, metrics specify the averaging periods and statistics applied to the ambient air quality data.
Nitrogen Dioxide (NO_2)	Toxic pungent reddish-brown gas formed by the reaction of atmospheric ozone with the nitric oxide produced from combustion.
Nitrogen Oxides (Oxides of Nitrogen, NO_x)	A general term pertaining to compounds of NO, NO_2, and other oxides of nitrogen. Nitrogen oxides are created during combustion processes and are major contributors to smog formation and acid deposition.
Ozone (O_3)	Ozone is a chemical whose effect on the environment is either beneficial or detrimental depending on where it occurs. Stratospheric ozone (the layer of the earth's atmosphere above the troposphere, extending to about 50km above the earth's surface) protects us from the sun's UV light, but tropospheric ozone (the lowest region of the atmosphere, extending from the earth's surface to a height

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	of about 6-10km), can be toxic. Ozone is a highly reactive, colourless gas that is normally present in the troposphere as a result of naturally occurring photochemical and meteorological processes. It has a sharp, clean odour that can often be detected around running electric motors, after lightning storms, and around new mown hay.
Parameter	Chemical or physical characteristics of air that are measured as part of monitoring for air quality.
Primary pollutants	Primary pollutants are those, which are emitted directly from sources (e.g., sulphur dioxide emitted from a combustion process). Secondary pollutants are atmospheric contaminants, which form due to the reaction or transformation of primary pollutants and other atmospheric compounds in the atmosphere (e.g., ground-level ozone is formed through photochemical reactions of nitrogen dioxide and volatile organic compounds in the atmosphere).
Secondary pollutants	Secondary pollutants are atmospheric contaminants, which form due to the reaction or transformation of primary pollutants and other atmospheric compounds in the atmosphere (e.g., ground-level ozone is formed through photochemical reactions of nitrogen dioxide and volatile organic compounds in the atmosphere).
Source (of Emissions)	There are many sources of emissions, but these have generally been grouped into two categories: emissions from point and non-point sources. A **point source** is a stationary location or fixed facility from which substances are discharged; e.g., a smokestack. A **non-point source** is a pollution source that is not recognized to have a single point of origin. Common non-point emission sources are agriculture, forestry, urban, mining, construction, and city streets.
Sulphur Dioxide (SO_2)	A colourless gas that is formed primarily by the combustion of fossil fuels containing sulphur. Sour gas processing plants, oil sands processing plants and coal-fired power generating plants are major sources of SO_2.
Transboundary (Transport)	The long-range movement of emissions and substances across political or pre-determined spatial borders. Transboundary pollution refers to substances that originate in one jurisdiction, but have adverse effects in another area/jurisdiction at such a distance that it is not generally possible to distinguish the contribution of individual emission sources or groups of sources.
Triggers	Numerical thresholds set in advance of limits as early warning signals for evaluation and proactive management.

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Appendix A: Air Quality Conditions for Last Five Years

NITROGEN DIOXIDE

ANNUAL AVERAGE OF NO_2 CONCENTRATIONS

In 2019, the annual average concentrations of NO_2 within the Lower Athabasca Region remained at management Level 1 with the exception of Barge landing, Fort Hills and Horizon stations (Figure A1). Barge Landing station started monitoring in November 2018 following decommissioning of the nearby Muskeg River station and was for the first time at Level 2 along with the Horizon station. No specific investigations are warranted at this time.

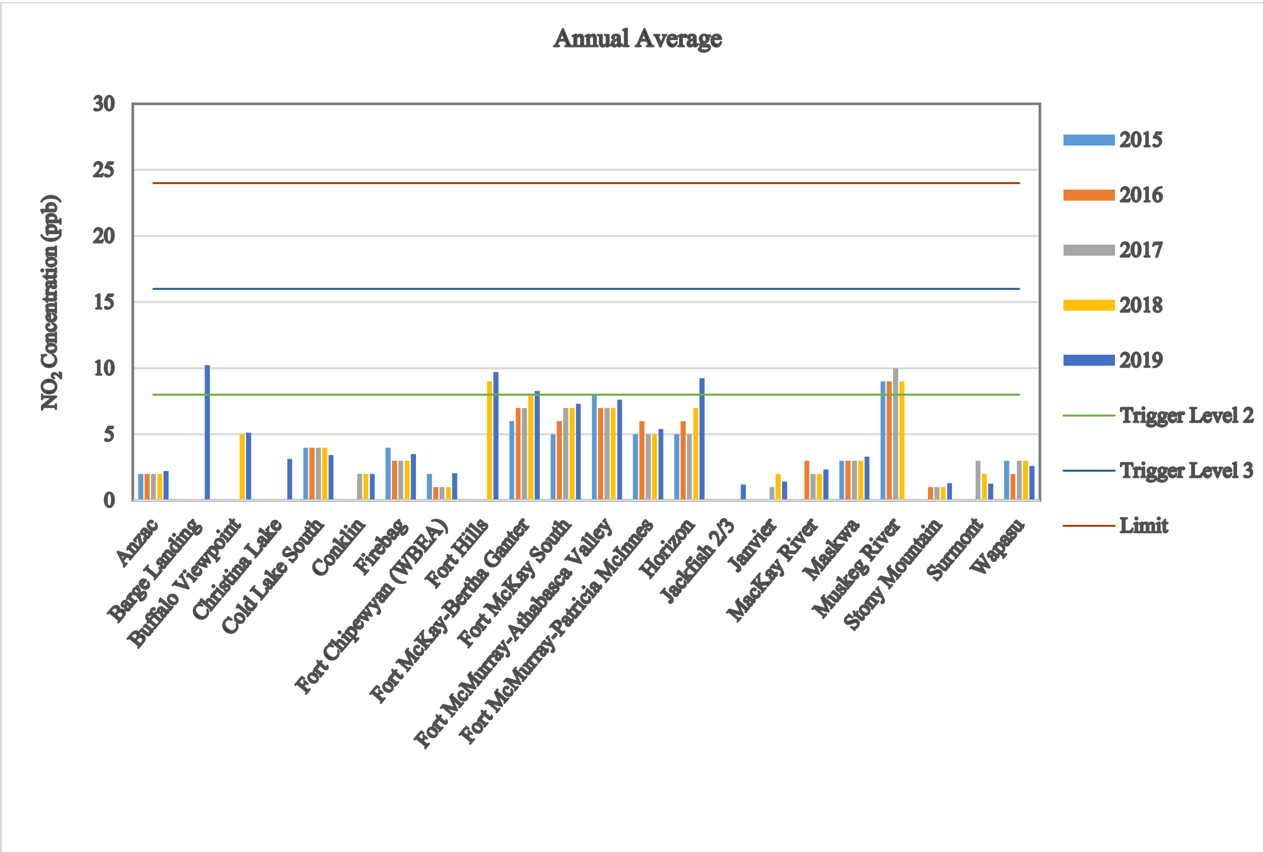

Figure A1: Annual Average of the Hourly Data for Nitrogen Dioxide for 2015-2019 in the Lower Athabasca Region.

THE UPPER RANGE OF HOURLY NO_2 CONCENTRATIONS

The Upper range of hourly ambient concentrations of NO_2 exceeded the trigger into Level 2 at Barge Landing and Buffalo Viewpoint in 2019 on their first reporting year (Figure A2). NO_2 concentrations have remained at Level 2 at Fort Hills, Fort McKay Bertha Ganter, Fort McKay South, Patricia McInnes and Horizon stations. The upper range of hourly NO_2 also moved from Level 1 to Level 2 at the Fort McMurray Athabasca Valley station in 2019.

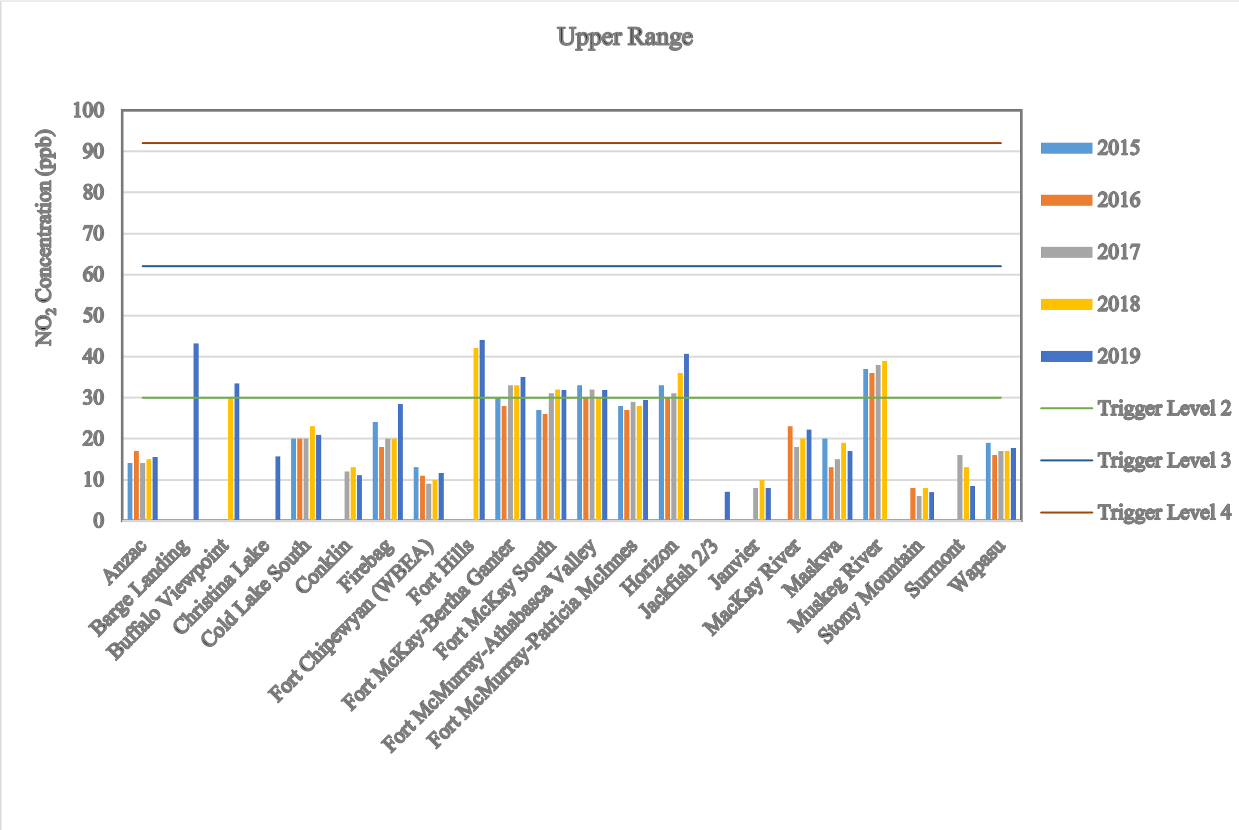

Figure A2: Upper range of the Hourly Data for Nitrogen Dioxide for 2015-2019 in Lower Athabasca Region

SULPHUR DIOXIDE

ANNUAL AVERAGE OF SO_2 CONCENTRATIONS

In 2019, the annual average ambient concentrations of SO_2 at all air monitoring stations remained below the trigger to management Level $_2$ (3 ppb) (Figure A3). No investigations assessing annual average SO_2 concentrations are required at this time.

UPPER RANGE OF HOURLY SO_2 CONCENTRATIONS

In 2019, Lower Camp station remained in the upper range ambient SO_2 concentration above the trigger into Level 3, the same as in 2018 (Figure A4).

The upper range for ambient concentrations of SO_2 exceeded the trigger for Level 2 at Cristina Lake for the first time along with Mannix and Mildred Lake stations, the levels of which remained the same as previous year. The SO_2 level was lowered at Buffalo Viewpoint from Level 2 to Level 1 in 2019.

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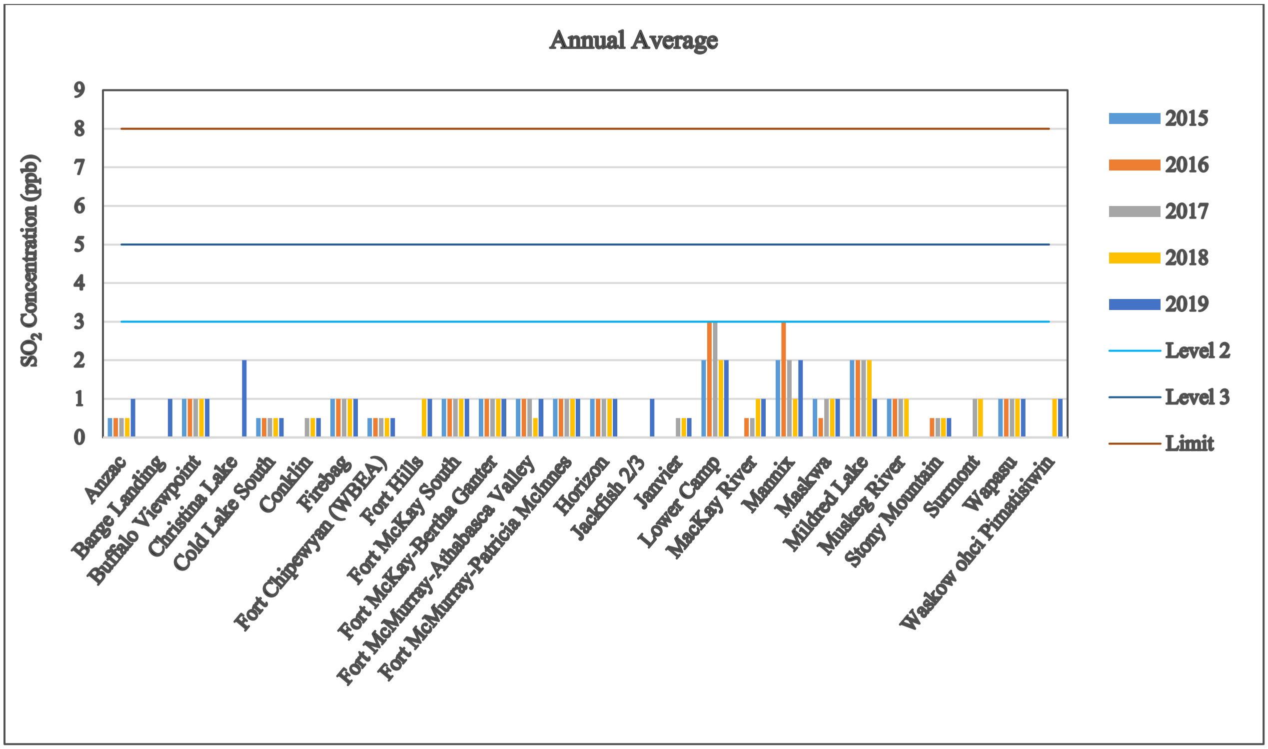

Figure A3: Annual average of the hourly data for Sulphur Dioxide for 2015-2019 in Lower Athabasca Region. Sites with annual averages that round to zero are shown as 0.5 ppb to distinguish them from sites that did not meet completeness requirements.*

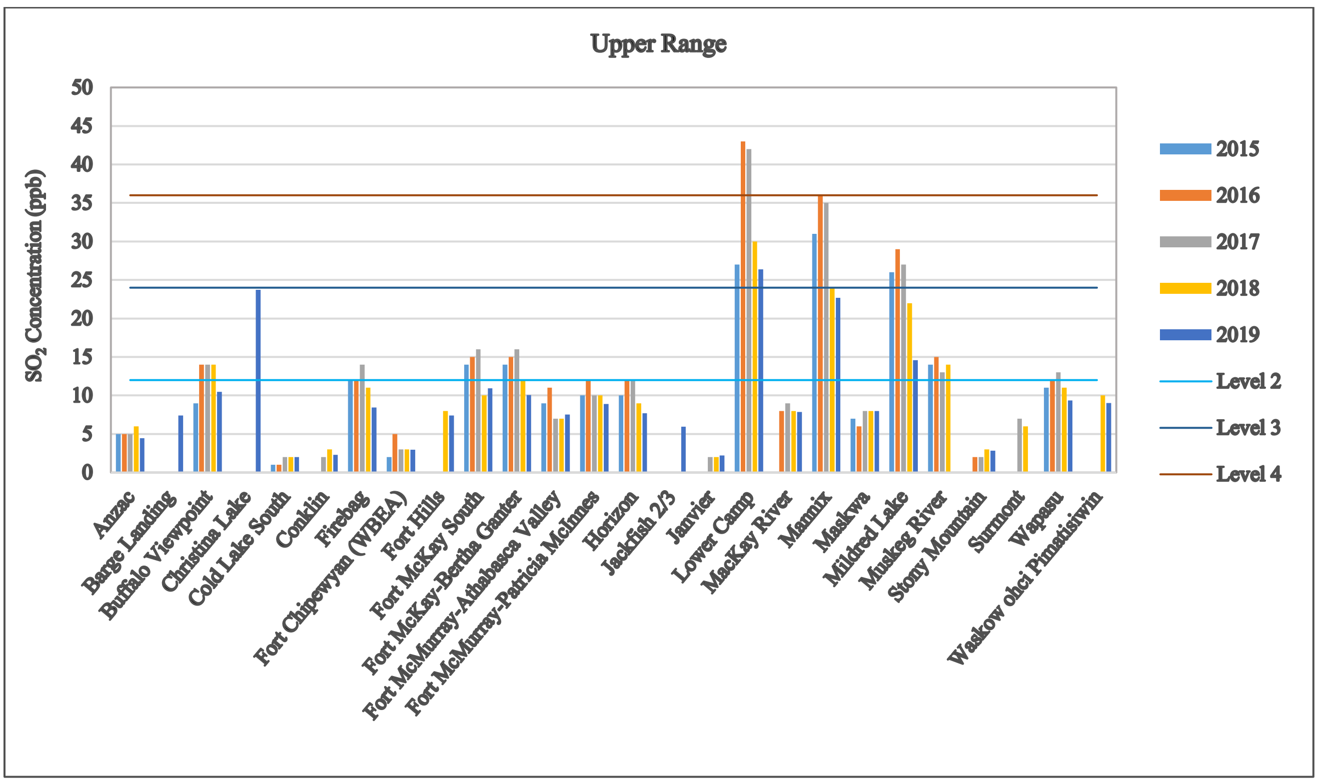

Figure A4: Upper Range of the 99th percentile hourly data for Sulphur Dioxide for 2015-2019 in Lower Athabasca Region

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Appendix B: Overview of the SO_2 Investigation Completed by Alberta Energy Regulator (AER)

Summary

This report was prepared based on a request from Alberta Environment & Parks (AEP) to support the analysis to investigate SO_2 and H_2S trigger exceedances at Lower Camp Station (AMS-11) in the Lower Athabasca Region. The data and analysis presented in this investigation serves as input to the progress report on the air quality management response to the Lower Athabasca Region's Air Quality Management Framework. This report summarizes scientific analysis of the air quality data collected from 2017 to 2020 at the Lower Camp station. The data collected includes hourly (1-Hr) and 5-minute (5-Min) average concentrations of SO_2 and H_2S in addition to meteorological data such as wind speed and wind direction. The main objective of this analysis is to identify potential local sources of SO_2 and H_2S exceedances using a variety of statistical analyses such as the tools available in OpenAir[1] and GIS[2] to understand the geographical location of the source and movement of pollutants. The primary trigger exceedance benchmarks are 1-Hr Alberta Ambient Air Quality Objectives (AAAQO) for SO_2 and H_2S.

Methodology

The analysis was completed for the 2017-2019 period. Temporal plots (time-series concentrations) for both 1-Hr and 5-Min average concentrations of SO_2 and H_2S for 2019 are shown in Figure B1.This plot also shows the AAAQO threshold line and at a glance the variation of the concentration of the pollutants, winds speed and directions and time of exceedance.

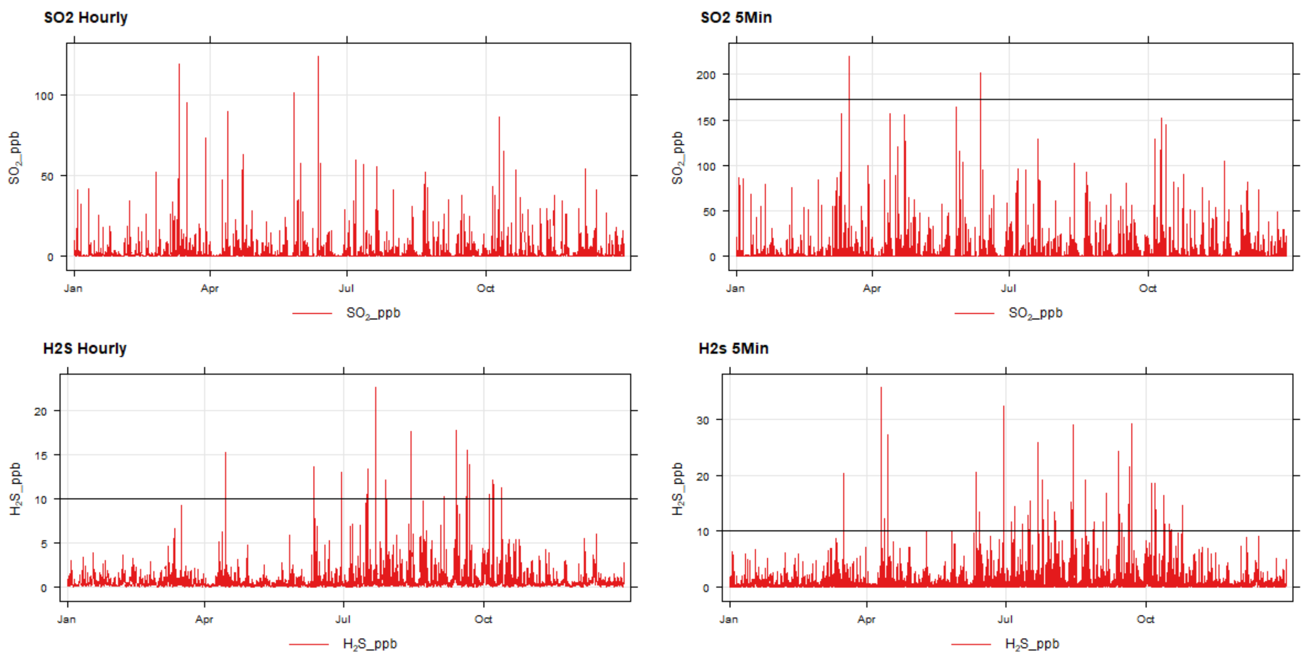

Figure A5: Temporal plots of H_2S and SO_2 in 2019

Tables B1 and B2 below summarize the dates and times of exceedances or high concentrations with the corresponding SO_2 and H_2S concentrations, wind speed and the correlation coefficients between SO_2 and H_2S for the event day. Correlation factors between SO_2 and H_2S could provide insight into the potential sources causing the exceedances.

[1] https://davidcarslaw.github.io/openair/

[2] Geographical Information Systems such as ESRI ArcGIS

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TABLE A1: SO_2 5-MIN CONCENTRATIONS >172 PPB, WINDS AND SO_2-H_2S CORRELATIONS IN 2019

Date	Time	SO_2 (ppb)	H_2S (ppb)	Wind Speed (km/h)	Wind Direction	Correlation between SO_2 and H_2S
16-Mar-19	06:35 PM	219.7	20.4	0	Undefined	95.68
11-Jun-19	08:55 PM 09:00 PM 09:05 PM	190.2 201.7 182.1	16.5 17.8 17.0	6.04 5.62 6.82	South Southwest South Southwest South Southwest	97.99

TABLE A2: H_2S 1-HR EXCEEDANCES, CONCENTRATIONS, WINDS AND H_2S-SO_2 CORRELATIONS IN 2019

Date	Time	SO_2 (ppb)	H_2S (ppb)	Wind Speed (km/h)	Wind Direction	Correlation between SO_2 and H_2S
14-Apr-19	07:00 PM 08:00 PM	0.2 0.2	12.9 15.3	13.07 8.6	North Northwest North Northwest	-21.3
11-Jun-19	10:00 PM	123.6	13.6	5.77	South Southwest	99.48
29-Jun-19	1:00 PM	28.5	13	3.34	Northwest	91.4
15-Jul-19	11:00 PM	2.6	10.5	2.21	East	1.07
16-Jul-19	10:00 PM 11:00 PM	1.3 1.9	13.4 13.0	7.14 7.32	South Southeast South Southeast	13.58
17-Jul-19	12:00 AM	0.8	10.3	7.53	South Southeast	-2.89
21-Jul-19	09:00 PM 11:00 PM	6.8 3.9	22.6 18.9	5.56 6.71	South South Southeast	41.75
22-Jul-19	12:00 AM	1.8	22.3	4.38	Southeast	9.66
28-Jul-19	09:00 PM 11:00 PM	3.3 5.9	12.2 10.1	5.36 2.93	South South Southeast	61.25
13-Aug-19	10:00 PM 11:00 PM	1.5 4.7	17.6 11.4	3.64 1.61	Southeast East Northeast	-24.43
04-Sep-19	11:00 PM	1.4	10.3	6.1	South Southeast	41.21
12-Sep-19	07:00 PM 08:00 PM 09:00 PM 10:00 PM 11:00 PM	3.4 0.2 0.3 0.9 0.6	11.8 17.8 14.6 13.5 12.8	5.23 6.36 7.07 7.85 7.47	South South Southeast South Southeast South Southeast South Southeast	-37.95
19-Sep-19	07:00 PM 08:00 PM 11:00 PM	4.2 0.9 0.9	13.5 15.6 15.3	5.92 5.96 6.12	South South Southeast South Southeast	3.14
21-Sep-19	07:00 PM 08:00 PM	6.2 15.3	13.9 13.2	3.87 3.1	South Southeast South Southwest	59.96
04-Oct-19	8:00 PM	5.5	10.5	1.2	West	79.82
06-Oct-19	06:00 PM 07:00 PM	0.6 0.3	11.5 12.1	7.44 8.47	South Southeast South Southeast	-19.02
07-Oct-19	08:00 AM 09:00 AM	1.2 0.9	11.6 11.2	12.06 13.64	South Southeast South Southeast	-8.5
12-Oct-19	5:00 PM	6.5	11.2	5.43	South	39.26

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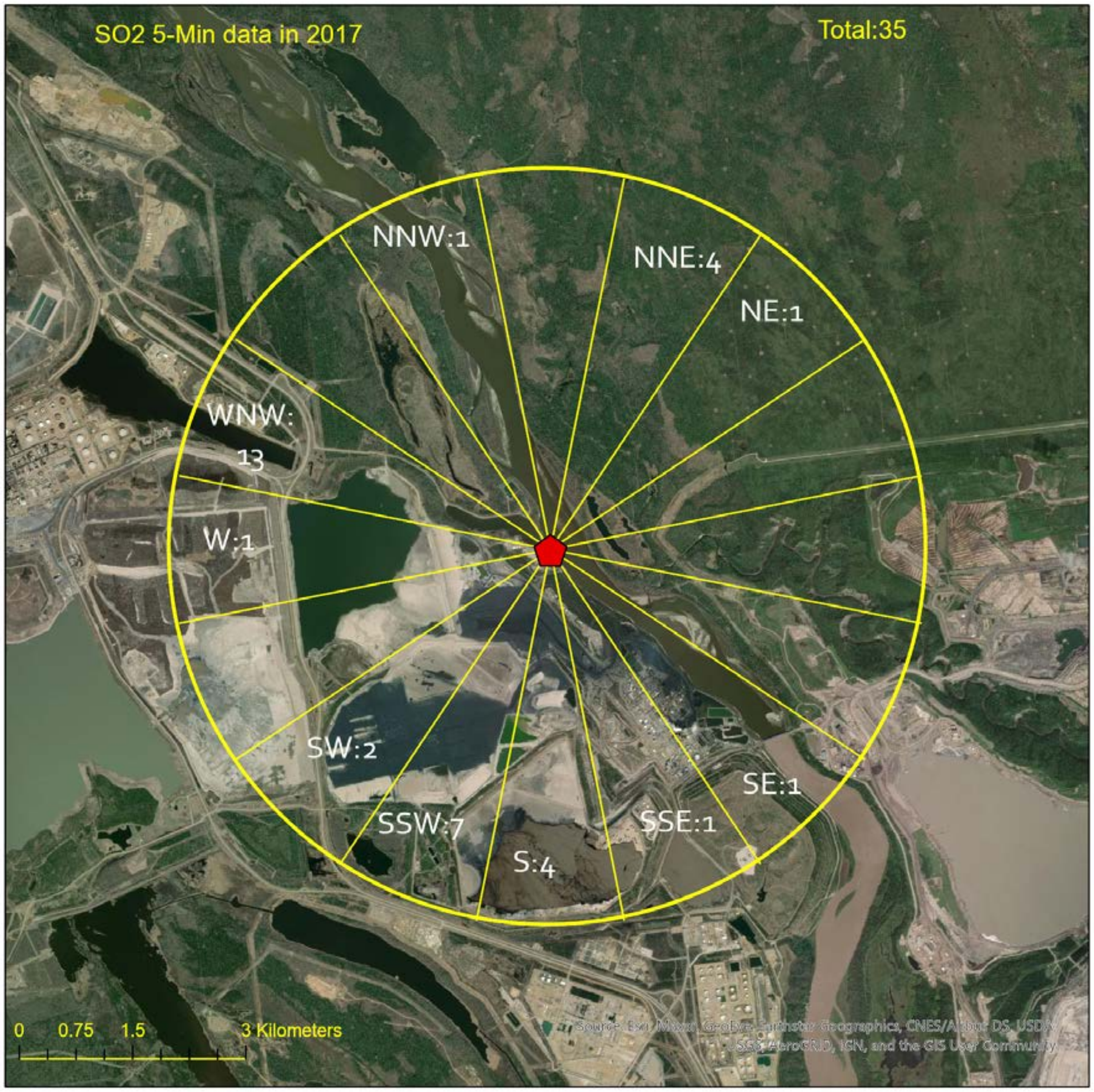

Figure A6: Number of 5-Min SO_2 concentrations above 1-Hr AAAQO limit (172 ppb) in 2017

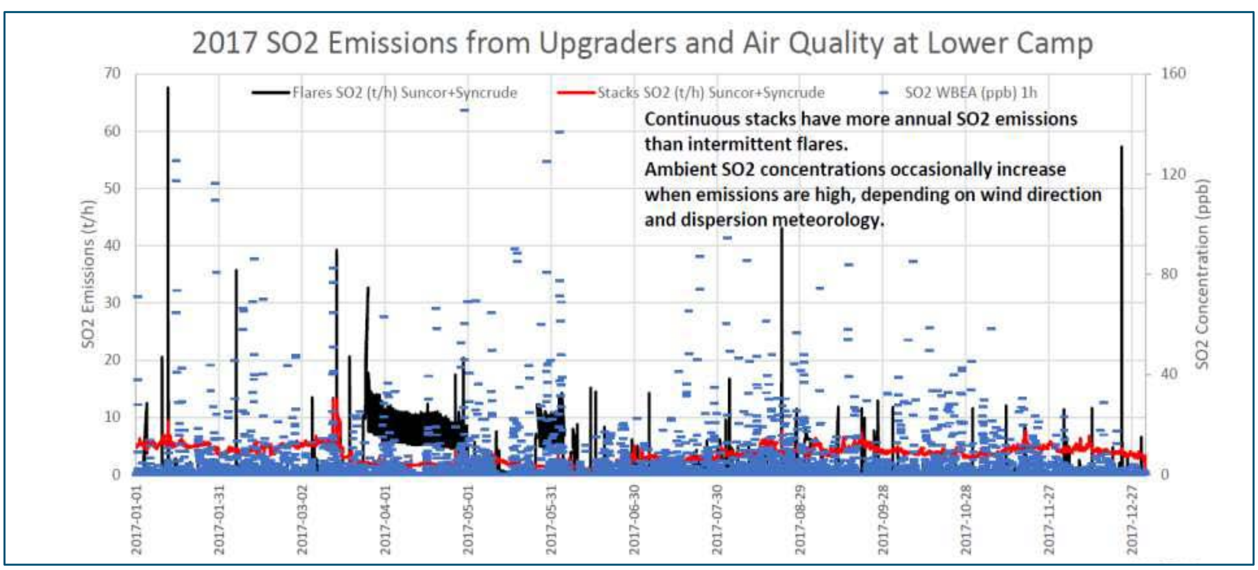

Figure A7: Flare and Stack emissions vs. Ambient Concentrations

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Summary and Conclusions

- There were no 1-Hr exceedances of the SO_2 AAAQO from 2017 to 2020.
- Generally, high concentrations occur when the wind speed is low.
- High correlation between SO_2 and H_2S when 5-Min SO_2 exceeds 172 ppb suggests combustion stack sources. Some directions such as the Southwest tend to have higher correlations. If the coke pile is burning and/or smouldering without visible flames, the combustion is incomplete.
- Low and negative correlation between SO_2 and H_2S when 5-min SO_2 exceeds 172 ppb suggests a combination of multiple elevated combustion stack sources and ground based pond and/or coke pile sources.
- There were multiple 1-Hr exceedances of the H_2S AAAQO from 2017 to 2020 (18 in 2017, 5 in 2018, 32 in 2019 and 9 in 2020). The ponds and process areas are known sources of H_2S emissions.
- High correlation between H_2S and SO_2 when 1-Hr H_2S exceeds 10 ppb suggests combustion stack sources. There are only a few cases with high correlations indicating they are predominantly pond sources.
- Low correlation between H_2S and SO_2 when 1-Hr H_2S exceeds 10 ppb suggests a combination of ground based pond and coke pile sources. The majority of events have low or negative correlation.
- There are no approved stack sources of SO_2 to the southwest but there are ground based H_2S sources such as Suncor's pond 2/3. The high correlation between SO_2 and H_2S from the southwest may be due to the recirculation and mixing of emissions from multiple sources.
- The approved sources of SO_2 in the region are the most likely source of elevated ambient SO_2 concentrations.
- Suncor's Pond 2/3 and process area is the most likely the source of H_2S in the region.

Recommendations

- A literature search should be conducted to characterize emissions from coke piles and ponds. There is a need to understand how the SO_2 and H_2S are formed.
- The coke pile could be monitored to determine the characteristics of the emissions if any. Measurements of SO_2, H_2S and hydrocarbons downwind and near the pile could be done using a combination of hand held and mobile monitoring equipment. The study should be done throughout the year.
- Consider installing a total hydrocarbon (THC) and non-methane hydrocarbon (NMHC) analyzer at the Lower Camp station to determine if the H_2S is arriving with methane and heavier hydrocarbons indicating a ground-based pond and coke pile source
- The meteorology could be investigated to understand what the dispersion conditions were during the exceedances.
- Consider modelling of the exceedance events using the Emergency Air Management Analysis System (EAMAS) based on actual emissions and meteorology. EAMAS is operated by AEP and gathers real-time meteorology data to model emergency emissions from the upgraders. CEMS data could be used to determine the SO_2 emissions from the major stack sources and is available within days. Flare emissions are not available until the next month.
- Consider analyzing the data from surrounding stations e.g. Buffalo View point station in the Southwest to understand the path of plumes.

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Appendix C: Methods and Results for NO_2 and SO_2 Trend Assessment

Previous work undertaken as part of the management response under the LAR Air Quality Management Framework produced a comparison of methods appropriate for assessing NO_2 and SO_2 trends in the region, and the code to easily conduct this analysis (Nunifu and Fu, 2019). The recommended approach includes evaluation of trends using a parametric method (Generalized Autoregressive Conditional Heteroscedasticity, GARCH) and a non-parametric method (using Theil-Sen slope after iterative pre-whitening). The recommended analyses were conducted as part of the 2020 management response (Petty, unpublished).

NO_2 and SO_2 data were downloaded from the Alberta Air Data Warehouse (https://www.alberta.ca/access-air-quality-and-deposition-data.aspx#toc-1) from thirteen air monitoring stations, including nine stations monitoring both NO_2 and SO_2 and four stations monitoring SO_2 only. Stations included in the analysis are shown in Table C1.

TABLE A3: CONTINUOUS AIR MONITORING STATIONS INCLUDED IN TREND ASSESSMENT.

Station	NO_2	SO_2
Fort Chipewyan	yes	yes
Horizon	yes	yes
Ft McKay Bertha Ganther	yes	yes
Ft McKay South	yes	yes
Mildred Lake	no	yes
Lower Camp	no	yes
Buffalo Viewpoint	no	yes
Mannix	no	yes
Ft McMurray Patricia McInnes	yes	yes
Ft McMurray Athabasca Valley	yes	yes
Anzac	yes	yes
Maskwa	yes	yes
Cold Lake South	yes	yes

Stations were selected that had continuous data in all months from 2012-2019. A month was considered 'continuous' if no single month was missing more than 50% of days, where a day was 'missing' if the day had less than 50% of hourly data reported (Nunifu and Fu, 2019). All units were converted to ppb.

Results Summaries

Results are summarized by trend (amount of change in ppb/month) or NS if trend was not significant. Significance was assessed at $p < 0.01$ level, and congruence was assessed between p-values obtained between parametric methods (using GARCH) and non-parametric (using Theil-Sen slope after iterative pre-whitening) methods. In all cases the magnitude of the trend varied by method but the direction and significance of the trend was consistent.

A summary of trend results are presented for NO_2 and SO_2 by station from north to south (Tables C2 and C3; Figures C1 and C2). Details statistical results from each assessment are provided in the following section.

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TABLE A4: SIGNIFICANCE OF NO_2 TREND RESULTS (EXPRESSED AS CHANGE IN PPB/MONTH)

Station	Parametric Method	Non-parametric Method
Ft. Chipewyan	+ 0.011	+ 0.009
Horizon	NS	NS
Ft McKay – Bertha Ganther	NS	NS
Ft McKay South	NS	NS
Ft. McMurray Patricia McInnes	-0.013	-0.011
Ft McMurray Athabasca Valley	-0.031	-0.029
Anzac	-0.009	-0.008
Maskwa	NS	NS
Cold Lake South	-0.010	-0.005

TABLE A5: SIGNIFICANCE OF SO_2 TREND RESULTS (EXPRESSED AS CHANGE IN PPB/MONTH)

Station	Parametric Method	Non-Parametric Method
Ft. Chipewyan	NS	NS
Horizon	NS	NS
Ft McKay – Bertha Ganther	-0.007	-0.007
Ft McKay South	-0.007	-0.007
Mildred Lake	NS	NS
Lower Camp	+ 0.014	+ 0.014
Buffalo Viewpoint	NS	NS
Mannix	NS	NS
Ft. McMurray Patricia McInnes	NS	NS
Ft McMurray Athabasca Valley	NS	NS
Anzac	NS	NS
Maskwa	NS	NS
Cold Lake South	NS	NS

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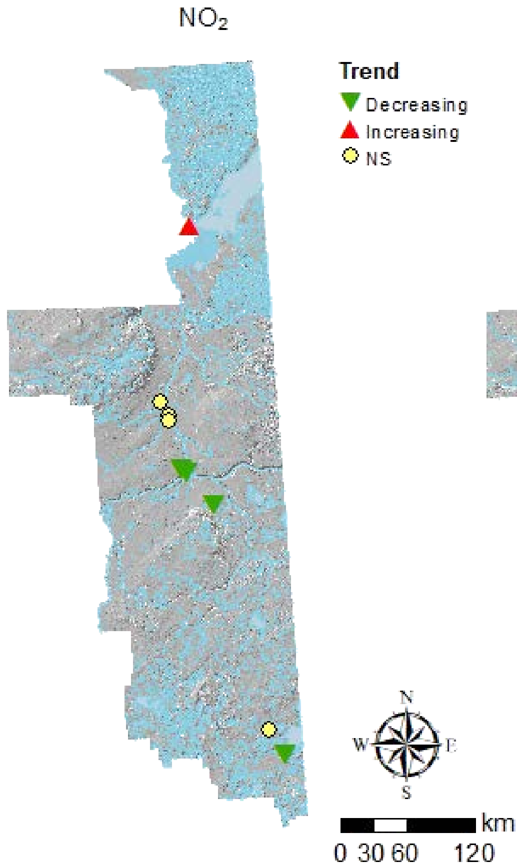

Figure A8: Map of SO_2 (left) NO_2 (right) trend results in the LAR

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TABLE A6: DETAILED TREND RESULTS FOR NO_2

FORT CHIPEWYAN (NO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.316	0.100	3.160	0.002	0.120	0.511	0.318	<0.001
Mean	0.640	0.175	3.652	0.000	0.297	0.984	0.649	<0.001
Trend	0.011	0.003	3.657	0.000	0.005	0.018	0.009	<0.001

HORIZON (NO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.540	0.087	6.208	0.000	0.369	0.710	0.565	<0.001
Mean	5.692	0.634	8.985	0.000	4.451	6.934	5.712	<0.001
Trend	0.017	0.011	1.536	0.125	-0.005	0.040	0.000	0.076

FORT MCKAY BERTHA CANTER (NO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.037	0.111	0.334	0.738	-0.180	0.254	0.034	<0.001
Mean	7.031	0.256	27.486	0.000	6.530	7.533	6.916	<0.001
Trend	0.006	0.005	1.370	0.171	-0.003	0.015	0.004	0.377

FORT MCKAY SOUTH (NO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.225	0.103	2.188	0.029	0.023	0.427	0.227	<0.001
Mean	6.352	0.309	20.538	0.000	5.745	6.958	5.995	<0.001
Trend	0.006	0.006	1.021	0.307	-0.005	0.017	0.006	0.253

FORT MCMURRAY PATRICIA MCINNES (NO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.200	0.105	1.902	0.057	-0.006	0.406	0.204	<0.001
Mean	6.159	0.240	25.648	0.000	5.688	6.629	5.931	<0.001
Trend	-0.013	0.004	-2.958	0.003	-0.021	-0.004	-0.011	<0.001

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FORT MCMURRAY ATHABASCA VALLEY (NO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.602	0.082	7.363	0.000	0.442	0.763	0.604	<0.001
Mean	9.956	0.650	15.316	0.000	8.682	11.230	9.494	<0.001
Trend	-0.031	0.012	-2.648	0.008	-0.053	-0.008	-0.029	<0.001

ANZAC (NO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.161	0.105	1.535	0.125	-0.045	0.368	0.169	<0.001
Mean	2.853	0.123	23.267	0.000	2.613	3.094	2.651	<0.001
Trend	-0.009	0.002	-4.092	0.000	-0.013	-0.005	-0.008	<0.001

MASKWA (NO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.260	0.098	2.656	0.008	0.068	0.452	0.260	<0.001
Mean	2.931	0.154	19.035	0.000	2.629	3.233	2.913	<0.001
Trend	0.002	0.003	0.903	0.367	-0.003	0.008	0.002	0.126

COLD SOUTH LAKE (NO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	-0.003	0.102	-0.030	0.976	-0.203	0.197	0.029	<0.001
Mean	4.302	0.149	28.796	0.000	4.009	4.595	4.037	<0.001
Trend	-0.010	0.003	-3.702	0.000	-0.015	-0.005	-0.005	0.002

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TABLE A7: DETAILED TREND RESULTS FOR SO_2

FORT CHIPEWYAN (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	-0.108	0.103	-1.055	0.292	-0.310	0.093	-0.107	<0.001
Mean	0.187	0.024	7.758	0.000	0.140	0.234	0.156	<0.001
Trend	0.000	0.000	-0.856	0.392	-0.001	0.000	0.000	0.235

HORIZON (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.130	0.101	1.286	0.199	-0.068	0.327	0.130	<0.001
Mean	0.902	0.077	11.684	0.000	0.750	1.053	0.784	<0.001
Trend	-0.002	0.001	-1.361	0.173	-0.005	0.001	-0.002	0.128

FORT MCKAY BERTHA GANTER (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.148	0.101	1.463	0.143	-0.050	0.345	0.152	<0.001
Mean	1.416	0.088	16.041	0.000	1.243	1.589	1.336	<0.001
Trend	-0.007	0.002	-4.699	0.000	-0.011	-0.004	-0.007	<0.001

FORT MCKAY SOUTH (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.147	0.101	1.458	0.145	-0.051	0.345	0.147	<0.001
Mean	1.316	0.084	15.619	0.000	1.151	1.481	1.234	<0.001
Trend	-0.007	0.002	-4.452	0.000	-0.010	-0.004	-0.007	<0.001

MILDRED LAKE (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.230	0.101	2.278	0.023	0.032	0.428	0.233	<0.001
Mean	2.274	0.188	12.077	0.000	1.905	2.643	2.622	<0.001
Trend	-0.007	0.003	-1.940	0.052	-0.013	0.000	-0.008	0.013

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LOWER CAMP (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.526	0.086	6.122	0.000	0.358	0.694	0.526	<0.001
Mean	1.307	0.280	4.672	0.000	0.758	1.855	1.528	<0.001
Trend	0.014	0.005	2.770	0.006	0.004	0.024	0.014	<0.001

BUFFALO VIEWPOINT (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.210	0.100	2.110	0.035	0.015	0.406	0.210	<0.001
Mean	0.607	0.086	7.033	0.000	0.438	0.777	0.537	<0.001
Trend	0.001	0.002	0.747	0.455	-0.002	0.004	0.001	0.133

MANNIX (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.182	0.102	1.792	0.073	-0.017	0.382	0.184	<0.001
Mean	2.253	0.185	12.167	0.000	1.890	2.616	2.165	<0.001
Trend	-0.006	0.003	-1.680	0.093	-0.012	0.001	-0.005	0.022

FORT MCMURRAY PATRICIA MCINNES (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.200	0.107	1.867	0.062	-0.010	0.410	0.202	<0.001
Mean	0.819	0.068	12.026	0.000	0.685	0.952	0.867	<0.001
Trend	0.000	0.001	-0.367	0.713	-0.003	0.002	-0.002	0.256

FORT MCMURRAY ATHABASCA VALLEY (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.564	0.085	6.619	0.000	0.397	0.731	0.592	<0.001
Mean	0.667	0.120	5.554	0.000	0.432	0.903	0.822	<0.001
Trend	-0.001	0.002	-0.295	0.768	-0.005	0.004	-0.004	0.350

Classification: Public

ANZAC (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.311	0.097	3.200	0.001	0.121	0.502	0.315	<0.001
Mean	0.591	0.059	9.947	0.000	0.475	0.708	0.468	<0.001
Trend	-0.002	0.001	-2.085	0.037	-0.004	0.000	-0.002	0.038

MASKAWA (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.488	0.088	5.522	0.000	0.315	0.662	0.489	<0.001
Mean	0.601	0.114	5.257	0.000	0.377	0.825	0.481	<0.001
Trend	0.001	0.002	0.447	0.655	-0.003	0.005	0.001	0.123

COLD LAKE SOUTH (SO_2)

	Parameter	Standard Error	Student	Prob (> |t|)	95% LCL	95% UCL	Theil-Sen	Mann-Kendall test
Ar1	0.689	0.073	9.461	0.000	0.546	0.832	0.700	<0.001
Mean	0.179	0.040	4.452	0.000	0.100	0.258	0.113	<0.001
Trend	-0.001	0.001	-1.511	0.131	-0.002	0.000	-0.001	0.012

Classification: Public

Part 2: Surface Water Quality

5.0 Introduction to Surface Water Quality

Under the *Lower Athabasca Regional Plan* (Government of Alberta, 2012), a management response is initiated when the Minister of Environment and Parks determines a trigger or limit as identified in the Lower Athabasca Region Surface Water Quality Management Framework (AEP, 2012) has been exceeded. As identified in the Framework, management responses may also be undertaken for indicators that exceed relevant surface water quality guidelines, or if undesirable trends are developing in the region. A full list of Framework indicators can be found in Appendix D. The triggers and limits apply to two stations in the region, from which pooled data comprises the historical dataset. These stations are Old Fort and Devil's Elbow, and collectively referred to herein as 'Old Fort' (Figure 4). Devil's Elbow data is used only where measurements are unavailable from Old Fort. Additional stations within the Athabasca basin beyond the 'Old Fort' stations are used to support investigations.

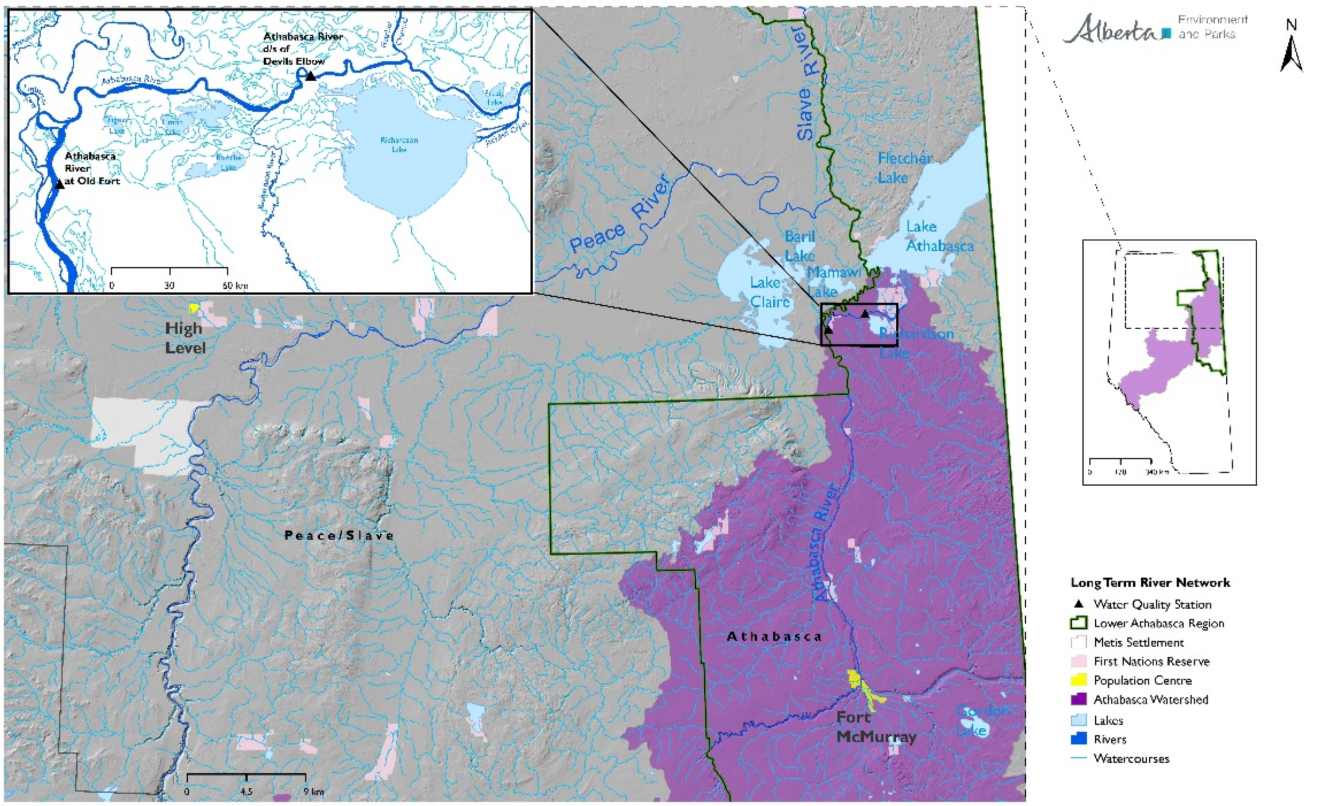


Figure 4: Map of surface water quality monitoring stations Old Fort (AB07DD0010) and Devil's Elbow (AB07DD0105) used in the assessment.

Alberta Environment and Parks (AEP) is the lead coordinator of the management response, and works with other government branches and regulators (e.g. Alberta Energy Regulator) and external parties, as required, to identify and implement a management response.

A management response was initiated for the Lower Athabasca Region after triggers were crossed for potassium, dissolved uranium, dissolved barium, dissolved selenium, total uranium, and dissolved cobalt during 2019 (Chung and Kerr, 2021). As each annual report on conditions becomes available, the management response is re-evaluated and updated based on new information.

This report provides an update on the management response since the last status report in press (AEP, 2020). This is the seventh status report produced since the Framework came into effect in August, 2012.

Classification: Public

A full description of the management response can be found in the Framework. Initial steps include preliminary assessment, and an investigation to determine the need for management actions. These steps are taken, in full or in part, when a surface water quality trigger or limit is exceeded.

Part of the management response is determining the need for management action. The management response for surface water quality may consider a variety of factors including: the number and location of monitoring stations where undesirable water quality occurs, the potential impact on the aquatic environment or water uses, and any additional influences or sources that lead to a deterioration. As the status of condition report becomes available, the management response is re-evaluated and updated based on new information.

The LAR SWQMF and all previous status of ambient surface water quality and status of management response reports can be found on the Environment and Parks website (www.alberta.ca/lower-athabasca-regional-planning.aspx), as well as on Open Government (https://open.alberta.ca/publications).

6.0 Summary of Trigger and Limit Exceedances for Surface Water Quality

6.1 Minister's Determination

The Minister's Determination for 2019 confirmed that monitoring at the 'Old Fort' Station' detected trigger exceedances for Uranium D, Barium D, Potassium (K+), Selenium D, Uranium T, and Potassium (K+) in the Lower Athabasca Region. Exceedances from previous assessment periods are summarized in Appendix E. There were no limit exceedances in 2019 at Old Fort.

TABLE 5: THRESHOLD EXCEEDANCES FOR SURFACE WATER QUALITY IN THE LOWER ATHABASCA REGION FOR 2019 BASED ON TRIGGERS AND LIMITS ESTABLISHED IN THE FRAMEWORK.

Indicator	Station	Trigger Exceedance	Limit Exceedance
Barium D	'Old Fort'	Mean	NA
Cobalt D	'Old Fort'	Peak	NA
Potassium (K+)	'Old Fort'	Mean	NA
Selenium D	'Old Fort'	Mean	NA
Uranium D	'Old Fort'	Mean, Peak	NA
Uranium T	'Old Fort'	Mean	NA

7.0 Preliminary Assessment for Surface Water Quality

Once trigger exceedances have been identified, a preliminary assessment is undertaken to determine whether the exceedances represent changing ambient conditions over time. Rare events or natural circumstances that cause an exceedance do not always result in a trend in water quality. Comparison with historical data sets, the use of trend assessments, and evaluating the influence of flow are some approaches that may be used to make this distinction and understand the environmental significance of the exceedance.

If the preliminary assessment identifies that the trigger exceedance is indicative of changing ambient conditions, the parameter is assigned a management level of 2 and an investigation into cause is initiated. If the preliminary assessment does not identify changing ambient conditions, a management level of 1 is assigned and no investigation is initiated.

Classification: Public

Preliminary assessments consist of trend analyses on un-adjusted and flow-adjusted data to identify any undesirable trends in water quality. The preliminary assessment tested if undesirable trends could be explained by flow. If not, an investigation to find the cause of changing water quality was initiated.

Flow was accounted for using flow-adjustment. Historical parameter concentrations and flow estimates were compared. If a predictable relationship existed, concentrations were adjusted to account for flow. If not, flow-adjustments were not used.

Trend directions and significance for un-adjusted parameters not already under investigation are listed in Table 6. Analogous trend directions and significance in the flow-adjusted data are listed in Table 7. Details of this analysis are provided in Appendix F.

TABLE 6: TREND DIRECTION AND SIGNIFICANCE OF PARAMETERS NOT ALREADY UNDER INVESTIGATION.

Indicator	Parameter	Trend Direction	Significance
Barium D	Dissolved barium	Increasing	Significant
Cobalt D	Dissolved cobalt	Increasing	Not significant
Selenium D	Dissolved selenium	Increasing	Significant
Uranium T	Total uranium	Increasing	Significant

TABLE 7: TREND DIRECTION AND SIGNIFICANCE OF FLOW-ADJUSTED PARAMETERS NOT ALREADY UNDER INVESTIGATION. NA INDICATES THAT FLOW-ADJUSTMENT MODELS DID NOT MEET CRITERIA FOR USE.

Indicator	Parameter	Trend Direction	Significance
Barium D	Dissolved barium	NA	NA
Cobalt D	Dissolved cobalt	NA	NA
Selenium D	Dissolved selenium	Increasing	Significant
Uranium T	Total uranium	NA	NA

The indicators Barium D, Selenium D, and Uranium T have been assigned a Management Level of 2. Investigations into the associated parameters have been initiated. The indicator Cobalt D has been assigned a Management Level of 1 and no further investigation is required at this time.

The parameters listed in Table 8 are already under investigation from previous years' assessment. Follow-up on these indicator exceedances proceed under the purview of investigations. The procedures applied for preliminary assessments are routinely updated as a component of ongoing investigations, and are reported in the Section 10.1.

TABLE 8: PARAMETERS WITH INDICATOR EXCEEDANCES THAT ARE ALREADY UNDER INVESTIGATION.

Indicator	Parameter	Trend Direction	Significance
Potassium (K+)	Potassium	Increasing	Significant
Uranium D	Dissolved uranium	Increasing	Significant

Classification: Public

8.0 Status of Management Response for Surface Water Quality

The management response is a set of steps taken, in full or in part, when an ambient trigger or limit is exceeded. The management response will support the management intent associated with each level (Table 9). Levels are set through evaluation of parameters once a threshold has been exceeded. Limit exceedances move parameters directly to investigation, whereas trigger exceedances are evaluated through preliminary assessment prior to setting a level. A full description of the management system is found in the Framework. The status of management response is reported on a regular basis and may be supported by supplemental technical reports.

This section of the report provides an update on the investigation phase of the management response.

TABLE 9: SURFACE WATER QUALITY LEVELS – DESCRIPTION AND MANAGEMENT INTENT.

Level	Description	Management Intent
3	Exceedance of water quality limits	Improve ambient water quality to below limits.
Limit Exceedance		
2	Exceedance of water quality triggers	Proactively maintain water quality below limits. Improve knowledge and understanding of trends.
Trigger Exceedance		
1	Mean and peak water quality conditions at or better than historical water quality conditions.	Apply standard regulatory and non-regulatory approaches to manage water quality

8.1 Investigation

A list of investigation activities identified in this and previous years and the progress to date for each action is provided in the sections below. It is important to recognize that investigation can take a number of years to complete and the impact of implementing certain actions may take additional time to be realized.

8.1.1 Summary of Investigation to Date

The purpose of investigation is to determine factors influencing water quality. Source attribution informs decisions about management actions. The scale of the investigation depends on the management level and the complexity of the issue. Investigations considered monitoring stations beyond Old Fort and located throughout the Athabasca River basin. Where undesirable trends were developing, an understanding where they occur, the impacts to the aquatic environment, impacts to water uses, and the natural or human-caused influences is needed.

Parameters under investigation are listed in Table 10 below. These parameters correspond to the indicators set at management level 2. They are known to exhibit increasing trends after flow-adjustment, or had increasing trends in un-adjusted data where flow-correction models did not meet criteria for use. Trend assessment was repeated for parameters previously under investigation using new data from 2019, the details of which are provided in Appendix G. New investigations starting as a result of preliminary assessment of the 2019 data include dissolved barium, dissolved selenium, and total uranium.

Where and when trends in dissolved barium, dissolved selenium, and total uranium are occurring within the basin is not known at the time of this writing. An update to the analyses presented in the previous report is underway to include the new parameters placed under investigation as of this report.

The update will involve seasonal Kendall trend analysis performed at several sites within the Athabasca Basin for each parameter. These sites span the main stem and tributaries of the Athabasca River. The update will attribute likely source areas for trends in each parameter and explore their seasonality. Coincident land use activity, seasonality, and the location of trends will help to refine options for mitigating undesirable water quality trends at their source. As of this writing, the most current investigative results were summarized in the Status of the Management Response report for 2018 data year (AEP, 2020).

Classification: Public

TABLE 10: MANAGEMENT LEVELS FOR INDICATORS AND MANAGEMENT INTENT FOR THE ASSOCIATED PARAMETERS.

Indicator	Management Level	Parameter	Current Intent
Barium D	Level 2	Dissolved barium	Under investigation
Chloride (Cl-)	Level 2	Chloride	Under investigation
Iron D	Level 2	Dissolved iron	Under investigation
Lithium D	Level 2	Dissolved lithium	Under investigation
Nitrogen NO3+NO2	Level 2	Nitrate plus nitrite	Under investigation
Nitrogen Total Kjeldahl (TKN)	Level 2	Total Kjeldahl nitrogen	Under investigation
Potassium (K+)	Level 2	Potassium	Under investigation
Selenium D	Level 2	Dissolved selenium	Under investigation
Sulphate (SO4-)	Level 2	Sulphate	Under investigation
Total Nitrogen (TN)	Level 2	Total nitrogen	Under investigation
Uranium D	Level 2	Dissolved uranium	Under investigation
Uranium T	Level 2	Total uranium	Under investigation

Parameter investigations to date show:

- Source areas occur both upstream of, and within the Lower Athabasca Region (LAR).
- Geographical gaps in monitoring preclude differentiating some important jurisdictions and tributaries.
- Monitoring enhancements and/or supplementary data could provide the additional resolution between:
  - The Clearwater River Basin and the oil sands region
  - The Athabasca River Basin upstream of the Athabasca town site at: Pembina River; McLeod River; Municipalities of Hinton and Whitecourt

8.1.2 Proposed and Ongoing Investigation Activities

A key component of the ongoing investigation is the continued spatial and temporal analysis of trends throughout the Athabasca River Basin. In the future, these analyses could be enhanced with data from the Oil Sands Monitoring Program and expanding monitoring within the provincial monitoring program. Key investigation activities are as follows:

Explore seasonal patterns in water quality trends

Description: Seasonal trend analyses to identify the temporal patterns in which undesirable trends develop. If an effect is known to be season-specific, then activities with known coincident impacts can be identified, evaluated, and prioritized. Seasonal trend analysis identifies the locations and timing of effects which, in turn, determine geographical areas of interest; by parameter and season.

Status: Ongoing

Progress: Seasonal trend analyses were compiled and presented in the previous report (AEP, 2020). However, new trigger exceedances in 2019 have expanded the list of parameters under investigation and an update to the analysis is underway.

Classification: Public

Leverage water quality data from the Oil Sands Monitoring Program.

Description: Procure and integrate surface water quality monitoring data from the Oil Sands Monitoring Program to support trend analyses. This information may also inform source-tracking or the development of mitigation strategies.

Status: Ongoing

Progress: Procurement and integration of Oil Sands Monitoring Data with provincial monitoring program data is underway.

Enhance geographical resolution in provincial water quality monitoring programs

Description: Within the Athabasca basin, the provincial water quality monitoring programs consist of regular monitoring at predetermined sites along the main stem and tributaries. Monitoring enhancements to better enable upstream source-tracking of contaminants would improve the capability of provincial water quality monitoring program data to inform mitigation efforts.

Status: Under evaluation

Progress: Enhanced monitoring to support investigations are considered by Alberta Environment and Parks via ongoing review and prioritization of the provincial monitoring program.

In parts of the Athabasca River basin where the above investigation activities determine that undesirable trends exist, additional activities will focus on understanding the potential cause of the observed changes in surface water quality. These activities may include the following.

Identify existing department-, stakeholder- and community-led management plans that may impact water quality and gather information on relevant land-use activities identified therein.

Description: The Water for Life Strategy supports planning on several scales, including the Alberta Water Council (provincial scale), Watershed Planning and Advisory Councils (watershed scale), and Watershed Stewardship groups (local scale). Municipalities also develop project specific and municipal plans that may impact water quality. In union with land use activity information and geographic information about trends in water quality, opportunities to work in partnership to mitigate area-specific, undesirable trends in water quality are sought at the appropriate level.

Status: Ongoing

Progress: Alberta Environment and Parks is currently compiling information about watershed management plans and partners that exist at various scales.

Procure and integrate relevant third party water quality and effluent monitoring data

Description: Itemize, compile, and integrate supplementary data and analysis from third parties other than the province. This could include water and effluent quality monitoring data or published research where it may inform source-tracking or the development of mitigation strategies.

Status: Planned

Progress: The electronic capture and storage of municipal and industrial effluent monitoring data from regulated facilities and stakeholders, reported to Alberta Environment and Parks, in machine-readable format is under evaluation.

Classification: Public

Compile and summarize qualitative land use activity information within potential source areas of undesirable trends

Description*:* Activities are categorical land use definitions used by Environment and Parks to group and track regulated developments on the landscape. Qualitative application information collected under the Water Act and Environmental Protection and Enhancement Act generally relate to hydrological changes and effluent discharges to the environment. This information may inform the assessment of the frequency and timing of regulated activities on the landscape, and the identification of stakeholders in the development of mitigation strategies.

Status: Planned

Progress: Ongoing investigations are revealing the geographical locations and timing of undesirable trends in water quality. Identification, compilation, and summarization of the relevant qualitative information depends on information from the ongoing investigations into trends and seasonality.

8.2 Identification of Management Actions

Understanding influences on water quality is critical to identifying effective management actions. Management actions are less likely to achieve significant improvements in surface water quality without this information. Knowledge of the source areas and seasonality of trends in water quality helps to narrow the range of possible influences. Investigations are underway to identify likely source areas and the seasonality of trend development. This information will inform where and when to focus mitigation efforts. One management action that has been initiated is as follows:

Encourage and/or include the monitoring of parameters under investigation in regulated water quality monitoring programs conducted by third parties.

Description: Monitoring programs conducted through Water Act and Environmental Protection and Enhancement Act approval and compliance processes provide data that link water quality and specific land use activities, in specific areas if relevant parameters are included in the monitoring program. Those not linked to undesirable trends in water quality can refine the prioritization of mitigation efforts elsewhere.

Status: Ongoing

Progress*:* Parameters under investigation have been included in some monitoring programs supporting approvals or renewals of existing approvals within the Lower Athabasca Region. An opportunity to improve efficiency exists in the electronic capture and aggregation of third party monitoring data submitted to the province.

Future management response reports will provide updates on the progress of investigation and any management actions undertaken.

9.0 Next Steps for Surface Water Quality

AEP will continue to oversee the implementation of the management response, including continuing preliminary assessment and investigation work. Specifically, AEP will update the seasonal Kendall trend analysis within the Athabasca basin to include the most recent data and all parameters currently under investigation. This information will be used to prioritize areas for further source attribution and management action.

Within these areas land use information, community led plans, and government led plans will be leveraged to identify opportunities to work in partnership to mitigate area-specific, undesirable trends in water quality. Once relevant plans are identified, AEP will plan appropriate engagement to communicate findings from analysis, identify stakeholders and Indigenous Peoples within the areas of interest and seek additional insight from the local knowledge when developing mitigation strategies

Progress updates on the work outlined in this report will be communicated to the public in subsequent Status of the Management Response Reports.

Classification: Public

Surface Water Quality References

Alberta Environment and Sustainable Resource Development (AESRD). 2012b. Lower Athabasca Region: Surface Water Quality Management Framework for the Lower Athabasca River. ISBN: 978-1-4601-0530-6 at https://open.alberta.ca/publications/9781460105306

Alberta Environment and Parks (AEP). 2020. Lower Athabasca Region Status of Management Response for Environmental Management Frameworks, as of October 2019. Government of Alberta. Available at https://open.alberta.ca/publications/9781460147740

Chung, C., & Kerr, J. 2021. 2019 Status of Surface Water Quality, Lower Athabasca Region, Alberta. Government of Alberta, Environment and Parks. Available at: https://open.alberta.ca/publications/9781460152270

Surface Water Quality Glossary

Contaminant/Pollutant	A substance in a concentration or amount that adversely alters the physical, chemical, or biological properties of the natural environment
Ecosystem Health	A healthy aquatic ecosystem is an aquatic environment that sustains its ecological structure, processes, functions, and resilience within its range of natural variability.
Indicator	Parameters that are measured to provide information about environmental condition; metrics are applied to the measurements to compare with defined triggers and limits.
Limits	Numerical thresholds at which the risk of adverse effects on health or environmental quality is becoming unacceptable.
Metric	A procedure for processing monitoring data to determine an indicator value to compare to triggers and limits. In the SWQualMF, metrics summarize parameter measurements over a specific timeframe at a specific location.
Non-point Source Pollutant	Pollution that enters a water body from diffuse or undefined sources and is usually carried by runoff.
Parameter	Chemical, biological or physical characteristics of water that are measured as part of monitoring for water quality.
Point Source Pollution	Pollution that originates from an identifiable cause or location, such as a sewage treatment plant.
Substance	From the framework, a 'substance' is defined as: i) Any matter that: a. Is capable of becoming dispersed in the environment, or b. Is capable of being transformed in the environment into matter referred to in a., ii) Any sound, vibration, heat, radiation or other form of energy, and iii) Any combination of things referred to in i) and ii).
Toxicity	The adverse effect on the growth, reproduction, or survival of an organism.
Triggers	Numerical thresholds set in advance of limits as early warning signals for evaluation and proactive management.
Wastewater	The liquid waste generated through various industrial and municipal processes.
Water Uses	For the purpose of the framework these include: protection of aquatic life, drinking water, recreation and aesthetics, agricultural, and industrial.

Classification: Public

Appendix D: Surface Water Quality Indicators for the Lower Athabasca Region

TABLE A8: LIST OF INDICATORS FOR LOWER ATHABASCA REGION: SURFACE WATER QUALITY MANAGEMENT FRAMEWORK FOR THE LOWER ATHABASCA RIVER (D = DISSOLVED; T = TOTAL).

	Indicators	
Aluminum D	Iron D	Sulphate (SO4-)
Aluminum T	Iron T	Thallium D
Antimony D	Lead D	Thallium T
Antimony T	Lead T	Thorium D
Arsenic D	Lithium D	Thorium T
Arsenic T	Lithium T	Titanium D
Barium D	Magnesium (Mg+)	Titanium T
Barium T	Manganese D	Total Ammonia (NH3+4-N)
Beryllium T	Manganese T	Total Dissolved Phosphorus (TDP)
Bismuth T	Mercury T	Total Nitrogen (TN)
Boron D	Molybdenum D	Total Phosphorus (TP)
Boron T	Molybdenum T	Uranium D
Cadmium D	Nickel D	Uranium T
Cadmium T	Nickel T	Vanadium D
Calcium (Ca2+)	Nitrate (NO3-N)	Vanadium T
Chloride (Cl-)	Potassium (K+)	Zinc D
Chromium D	Selenium D	Zinc T
Chromium T	Selenium T	
Cobalt D	Silver T	
Cobalt T	Sodium (Na+)	
Copper D	Strontium D	
Copper T	Strontium T	

Classification: Public

Appendix E: History of Exceedances

TABLE A9: HISTORY OF MEAN (M) AND PEAK (P) TRIGGER EXCEEDANCES FOR WHICH THERE IS A CURRENT MANAGEMENT RESPONSE.

Parameter	2012	2013	2014	2015	2016	2017	2018	2019	Current Status
Aluminum (dissolved)		P							Closed (2016)
Barium (dissolved)								M	Under investigation
Chloride									Under investigation
Cobalt (dissolved)			P		P			P	Closed (2016/2019)
Iron (dissolved)		M							Under investigation
Lithium (dissolved)	P				M/P	M/P			Under investigation
Lithium (total)		P							Closed (2016)
Nitrate (NO3-N)									Under investigation
Nitrite (NO2-N)									Under investigation
Nitrogen (total)	M	M							Under investigation
Nitrogen NO3+NO2									Under investigation
Nitrogen Total Kjeldahl (TKN)									Under investigation
Potassium			M			M	M	M	Under investigation
Selenium (dissolved)								M	Under investigation
Strontium (dissolved)				M					Closed (2016)
Sulphate			M	M	P				Under investigation
Uranium (dissolved)	M/P	M/P	P	M/P	M/P	M/P	M/P	M/P	Under investigation
Uranium (total)								M	Under investigation

Classification: Public

Appendix F: Trend Analyses Conducted under Preliminary Assessment

Barium D (dissolved barium)

There is no limit set for dissolved barium in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2019, no observations were above the peak trigger, which is set at 73.7 µg/L. The maximum value was 67.7 µg/L, which equals 91.9% of the peak trigger value. The 2019 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2018). The trend analysis for dissolved barium revealed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A9). Changes in flow-concentration relationships over time prevented the development of an adjustment model for dissolved barium. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and an investigation into this parameter will has been initiated.

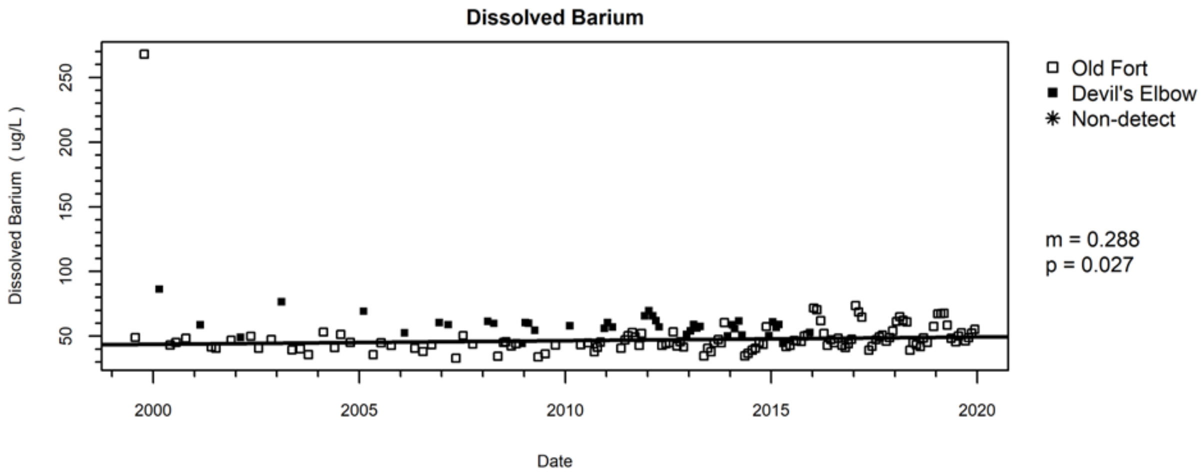


Figure A9: Dissolved barium concentrations at 'Old Fort' over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and Mann-Kendall p value (p).

Cobalt D (dissolved cobalt)

There is no limit set for dissolved cobalt in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2019, 3 occurrences were above the peak trigger, which is set at 0.11 µg/L. The maximum value was 0.191 µg/L, which equals 173.6% of the peak trigger value. In 2019, 3 measurements exceeded the range of historical values (before 2010), and none exceeded observed values during the interim (2010-2018). The trend analysis for dissolved cobalt revealed an increasing trend in un-adjusted concentration that was not statistically significant at 'Old Fort' (Figure A10). Changes in flow-concentration relationships over time prevented the development of an adjustment model for dissolved cobalt. Thus, no significant trend in dissolved cobalt was observed and standard regulatory practices will resume for the management of this parameter.

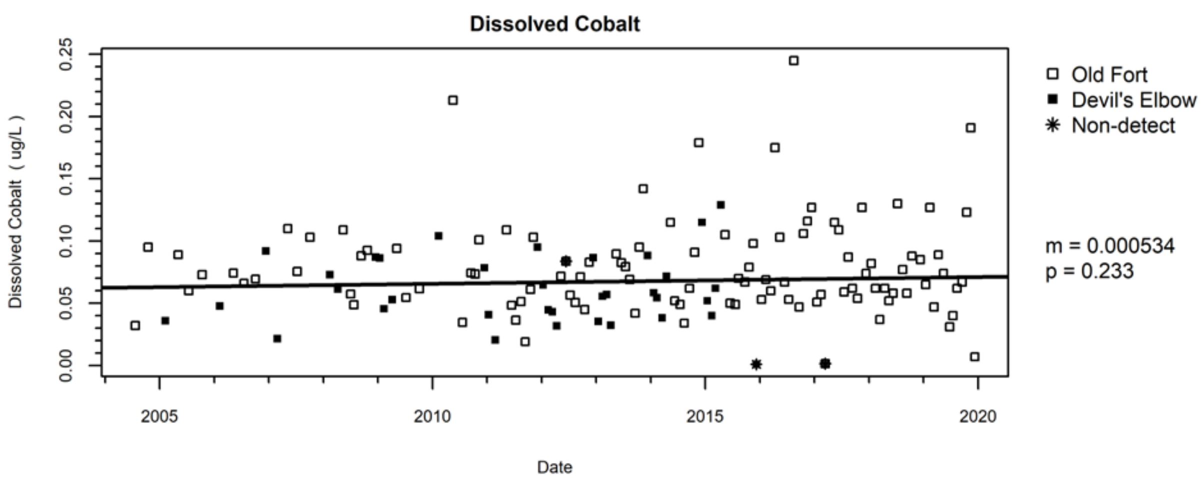


Figure A10: Dissolved cobalt concentrations at 'Old Fort' over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and censored Mann-Kendall p value (p).

Classification: Public

Selenium D (dissolved selenium)

There is no limit set for dissolved selenium in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2019, no observations were above the peak trigger, which is set at 0.409 µg/L. The maximum value was 0.3 µg/L, which equals 73.3% of the peak trigger value. The 2019 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2018). The trend analysis for dissolved selenium revealed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A11). The trend was also significant when adjusted for flow. Thus, dissolved selenium will proceed to investigation.

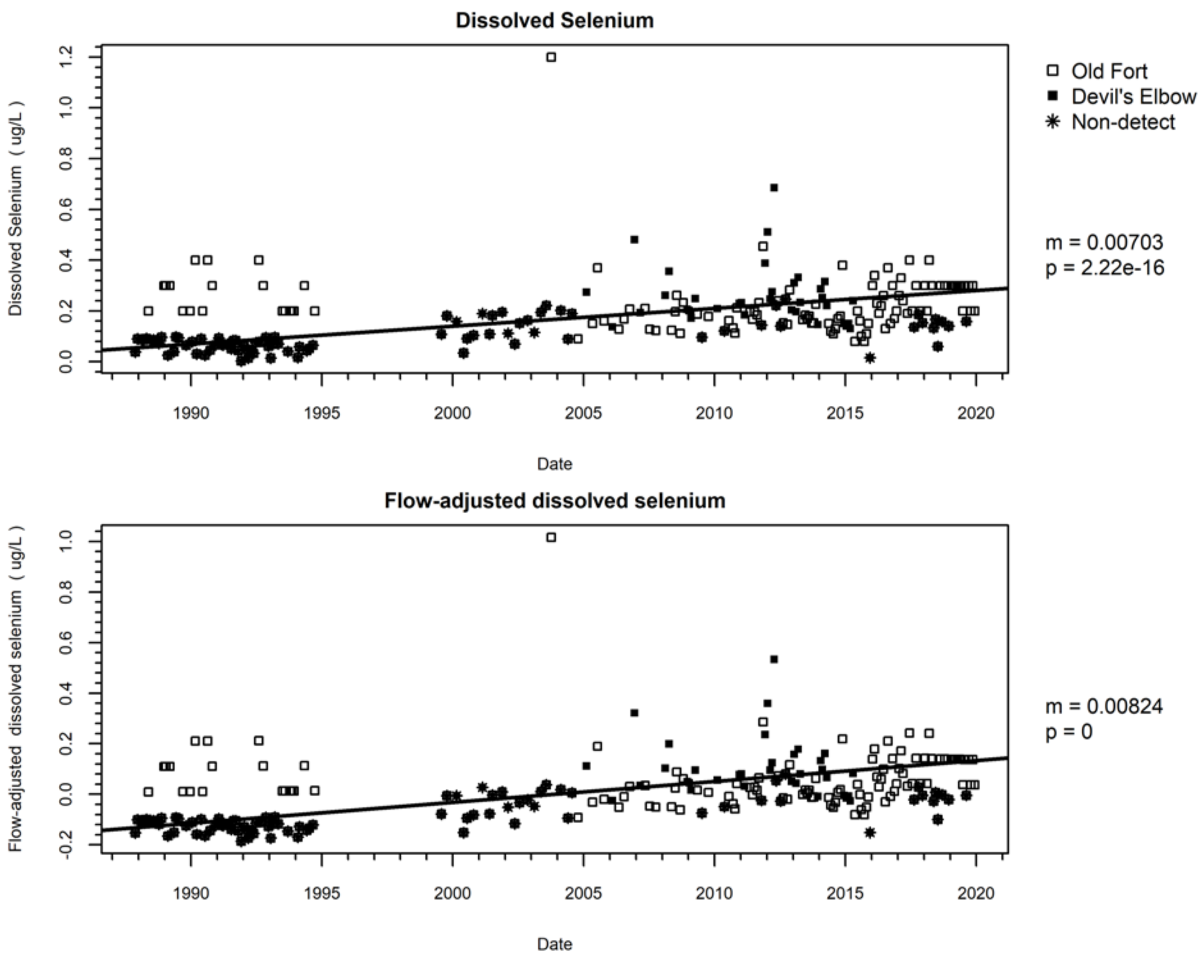


Figure A11: Dissolved selenium concentrations at 'Old Fort' over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentration are represented by Akritas-Thiel Sen lines, their slope (m), and censored Mann-Kendall p value (p).

Uranium T (total uranium)

The framework limit for total uranium is set at 10 µg/L and the peak trigger is set at 0.7 µg/L. In 2019, no observations were above the limit and 1 was above the peak trigger. The maximum value observed in 2019 was 0.924 µg/L which equals 132% of the peak trigger and 9.2% of the limit values. The 2019 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2018). The trend analysis for total uranium revealed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A12). Changes in flow-concentration relationships over time prevented the development of an adjustment model for total uranium. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and an investigation into this parameter will has been initiated.

Classification: Public

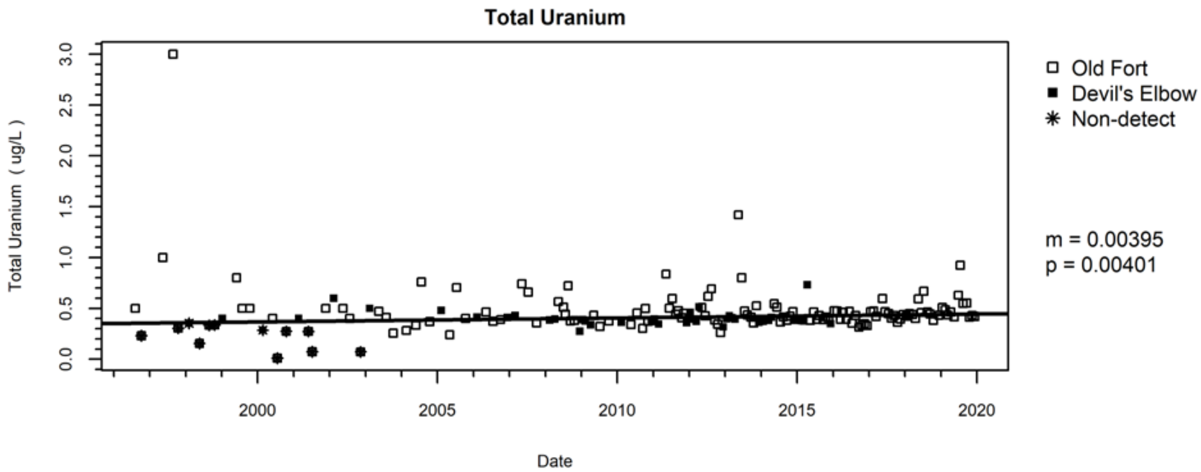


Figure A12: Total uranium concentrations at 'Old Fort' over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and censored Mann-Kendall p value (p).

Classification: Public

Appendix G: Trend Analyses Conducted under Investigation

Chloride

The framework limit for chloride is set at 100 mg/L and the peak trigger is set at 45 mg/L. In 2019, no occurrences were above the limit or above the peak trigger. The maximum value observed in 2019 was 30 mg/L which equals 66.7% of the peak trigger and 30% of the limit values. The 2019 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2018). The trend analysis for chloride revealed a decreasing trend in un-adjusted concentration that was not statistically significant at ‘Old Fort’ (Figure A13). In contrast, flow-adjustment revealed a significant increasing trend. Thus, chloride will continue to be investigated.

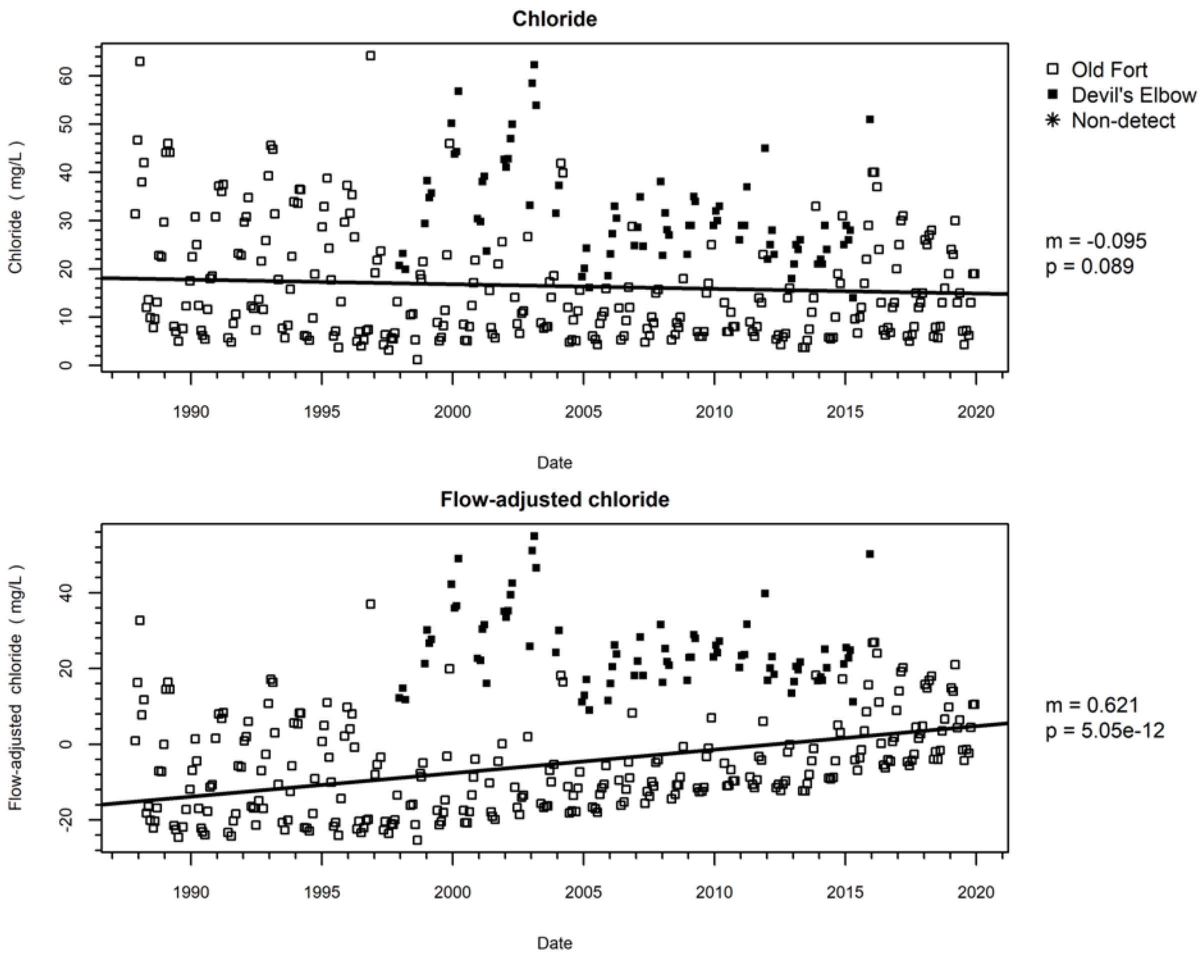
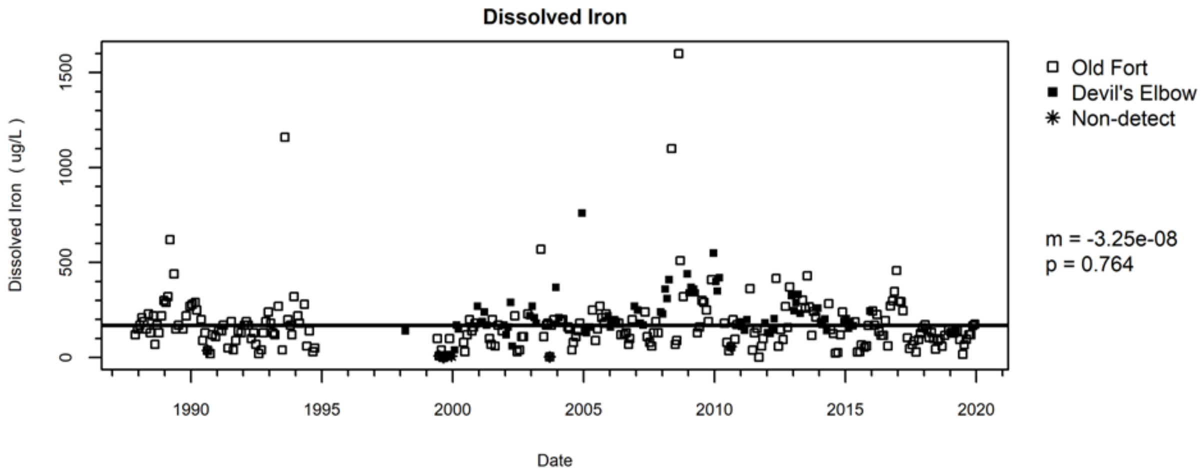


Figure A13: Chloride concentrations at ‘Old Fort’ over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentrations are represented by the Akritas-Thiel Sen line, their slopes (m), and Mann-Kendall p values (p).

Dissolved iron

There is no limit set for dissolved iron in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2019, no observations were above the peak trigger, which is set at 372 µg/L. The maximum value was 175 µg/L, which equals 47% of the peak trigger value. The 2019 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2018). The trend analysis for dissolved iron revealed a decreasing trend in un-adjusted concentration that was not statistically significant at ‘Old Fort’ (Figure A14). In contrast, flow-adjustment revealed a significant increasing trend. Thus, dissolved iron will continue to be investigated.

Classification: Public



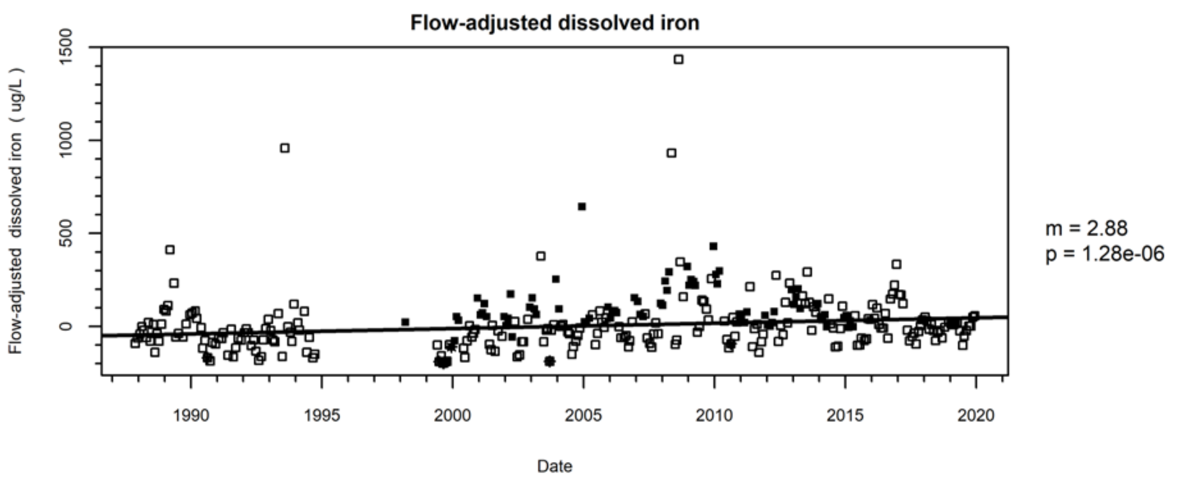


Figure A14: Dissolved iron concentrations at 'Old Fort' over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentrations are represented by the Akritas-Thiel Sen line, their slopes (m), and censored Mann-Kendall p values (p).

Dissolved lithium

There is no limit set for dissolved lithium in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2019, 2 occurrences were above the peak trigger, which is set at 9 µg/L. The maximum value was 9.57 µg/L, which equals 106.3% of the peak trigger value. The 2019 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2018). The trend analysis for dissolved lithium revealed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A15). Changes in flow-concentration relationships over time prevented the development of an adjustment model for dissolved lithium. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and investigation into this parameter will continue.

Classification: Public

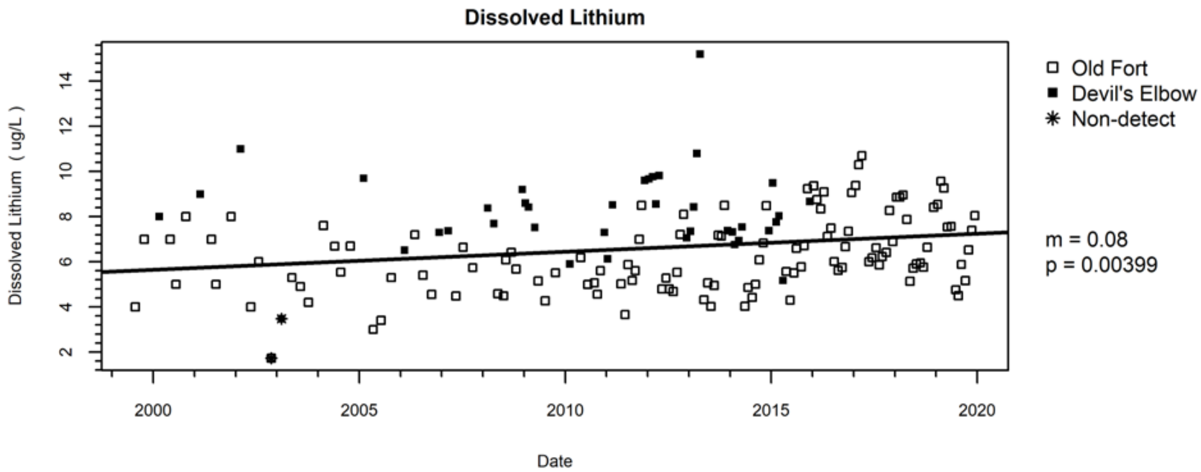


Figure A15: Dissolved lithium concentrations at ‘Old Fort’ over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and censored Mann-Kendall p value (p).

Nitrate plus nitrite

There is no limit set for nitrate plus nitrite in the Lower Athabasca Regional Surface Water Quality Management Framework. The maximum value was 0.29 mg/L. 2019 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2018). The trend analysis for nitrate plus nitrite revealed an increasing trend in un-adjusted concentration at ‘Old Fort’ (Figure A16). Changes in flow-concentration relationships over time prevented the development of an adjustment model for nitrate plus nitrite. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and investigation into this parameter will continue.

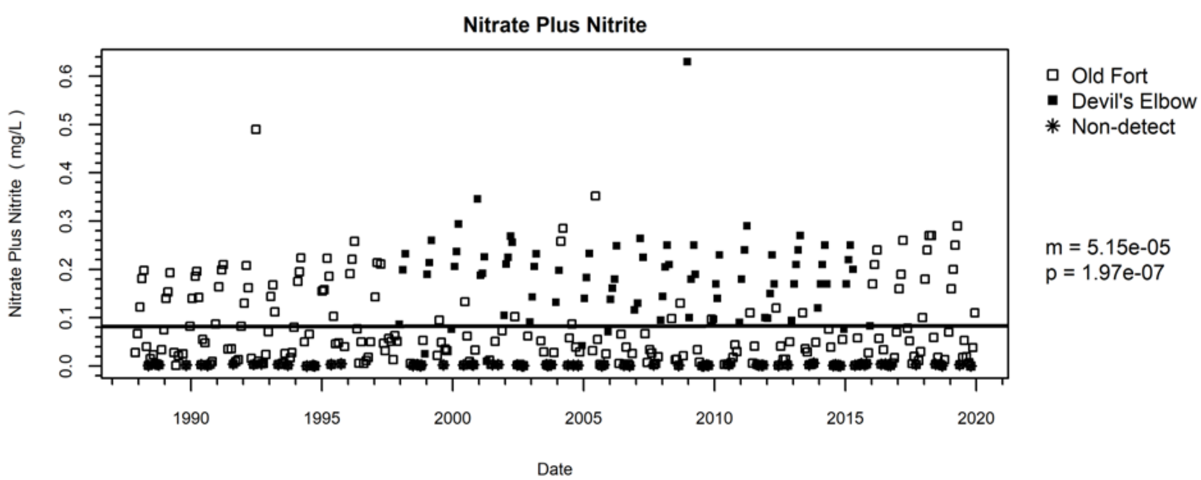


Figure A16: Nitrate plus nitrite concentrations at ‘Old Fort’ over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and censored Mann-Kendall p value (p).

Total Kjeldahl nitrogen

There is no limit set for total Kjeldahl nitrogen in the Lower Athabasca Regional Surface Water Quality Management Framework. The maximum value was 1 mg/L. 2019 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2018). The trend analysis for total Kjeldahl nitrogen revealed an increasing trend in un-adjusted concentration that was not statistically significant at ‘Old Fort’ (Figure A17). Changes in flow-concentration relationships over time prevented the development of an adjustment model for total Kjeldahl nitrogen. Thus, no significant trend in total Kjeldahl nitrogen was observed.

Classification: Public

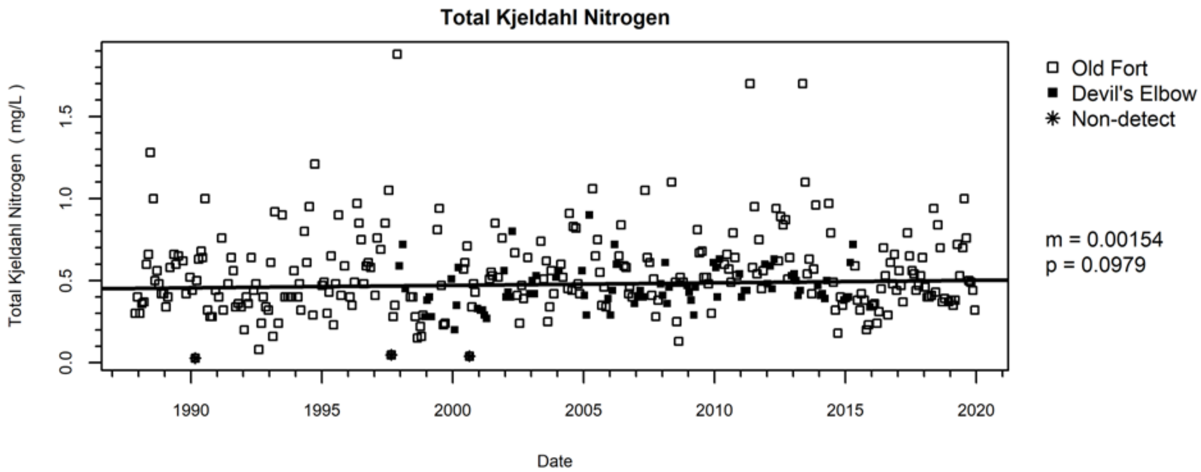


Figure A17: Total Kjeldahl nitrogen concentrations at 'Old Fort' over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and censored Mann-Kendall p value (p).

Total nitrogen

There is no limit set for total nitrogen in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2019, 1 occurrence was above the peak trigger, which is set at 1.041 mg/L. The maximum value was 1.1 mg/L, which equals 105.67% of the peak trigger value. The 2019 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2018). The trend analysis for total nitrogen revealed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A18). Changes in flow-concentration relationships over time prevented the development of an adjustment model for total nitrogen. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and investigation into this parameter will continue.

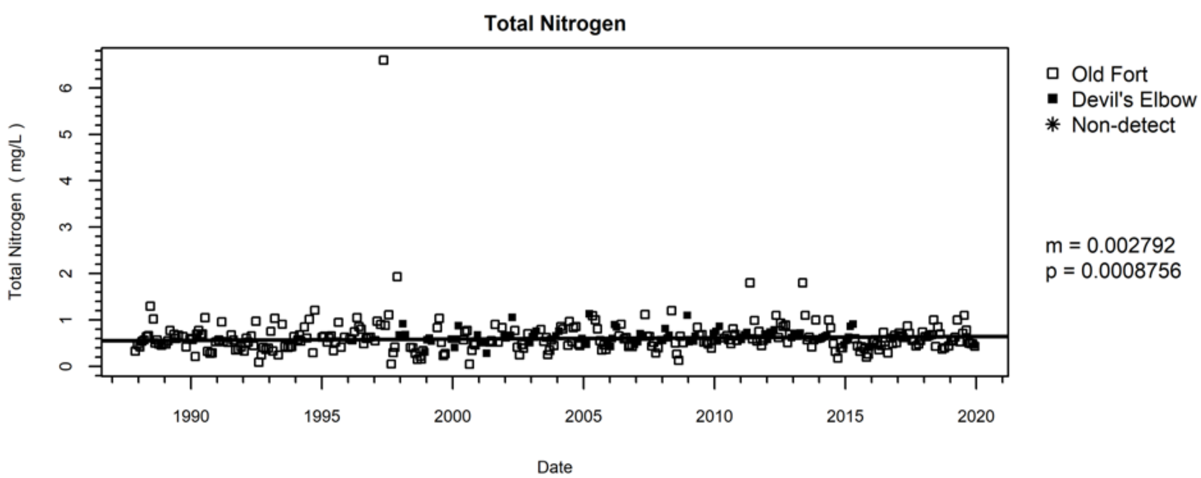


Figure A18: Total nitrogen concentrations at 'Old Fort' over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and Mann-Kendall p value (p).

Potassium

There is no limit set for potassium in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2019, 2 occurrences were above the peak trigger, which is set at 2.1 mg/L. The maximum value was 3.9 mg/L, which equals 185.7% of the peak trigger value. The 2019 measurements ranged within historical values (before 2010) and the trend analysis for potassium revealed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A19). The trend was also significant when adjusted for flow. Thus, potassium will continue to be investigated.

Classification: Public

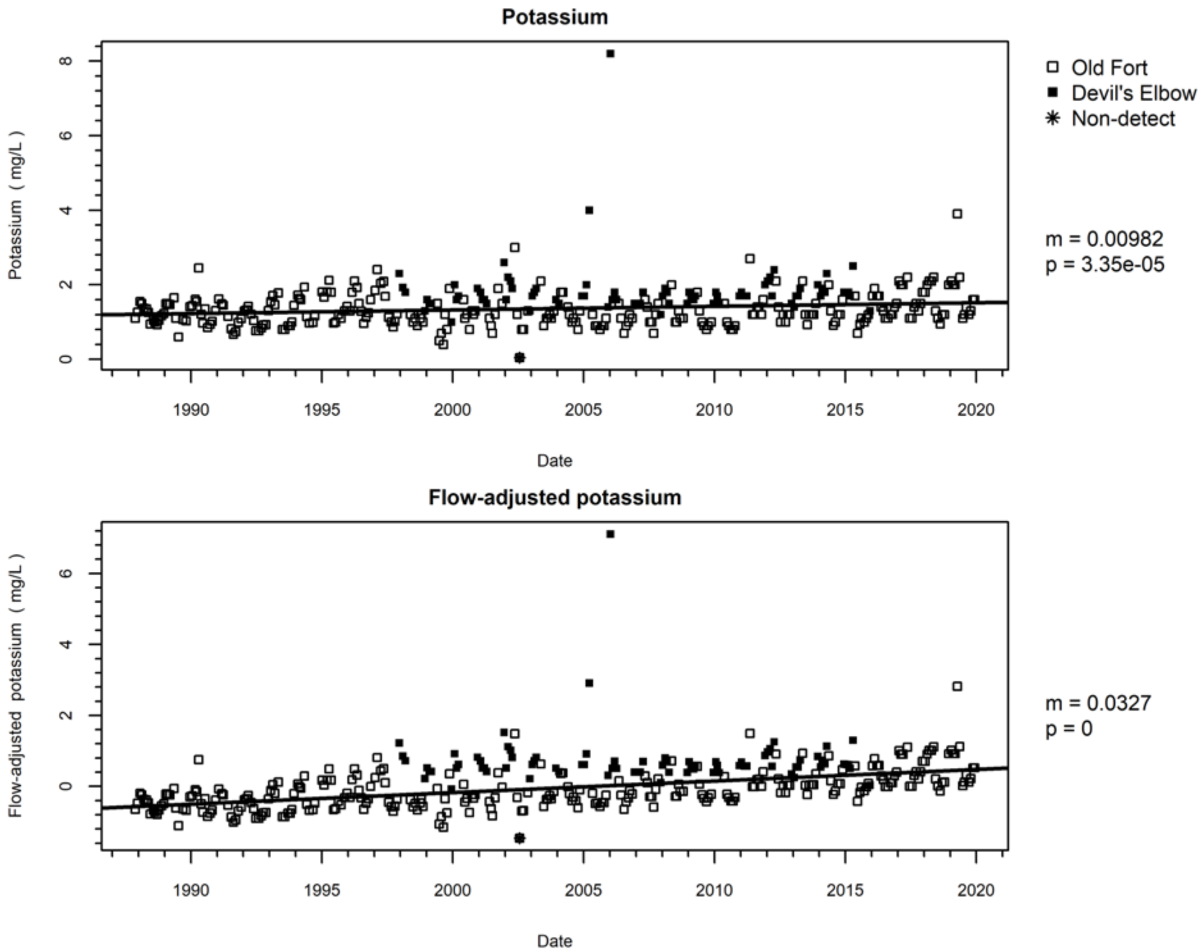


Figure A19: Potassium concentrations at 'Old Fort' over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentrations are represented by the Akritas-Thiel Sen line, their slopes (m), and censored Mann-Kendall p values (p).

Sulphate

The framework limit for sulphate is set at 500 mg/L and the peak trigger is set at 41.4 mg/L. In 2019, 0 occurrences were above the limit and 0 occurrences were above the peak trigger. The maximum value observed in 2019 was 36 mg/L which equals 87% of the peak trigger and 7.2% of the limit values. The 2019 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2018). The trend analysis for sulphate revealed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A20). The trend was also significant when adjusted for flow. Thus, sulphate will continue to be investigated.

Classification: Public

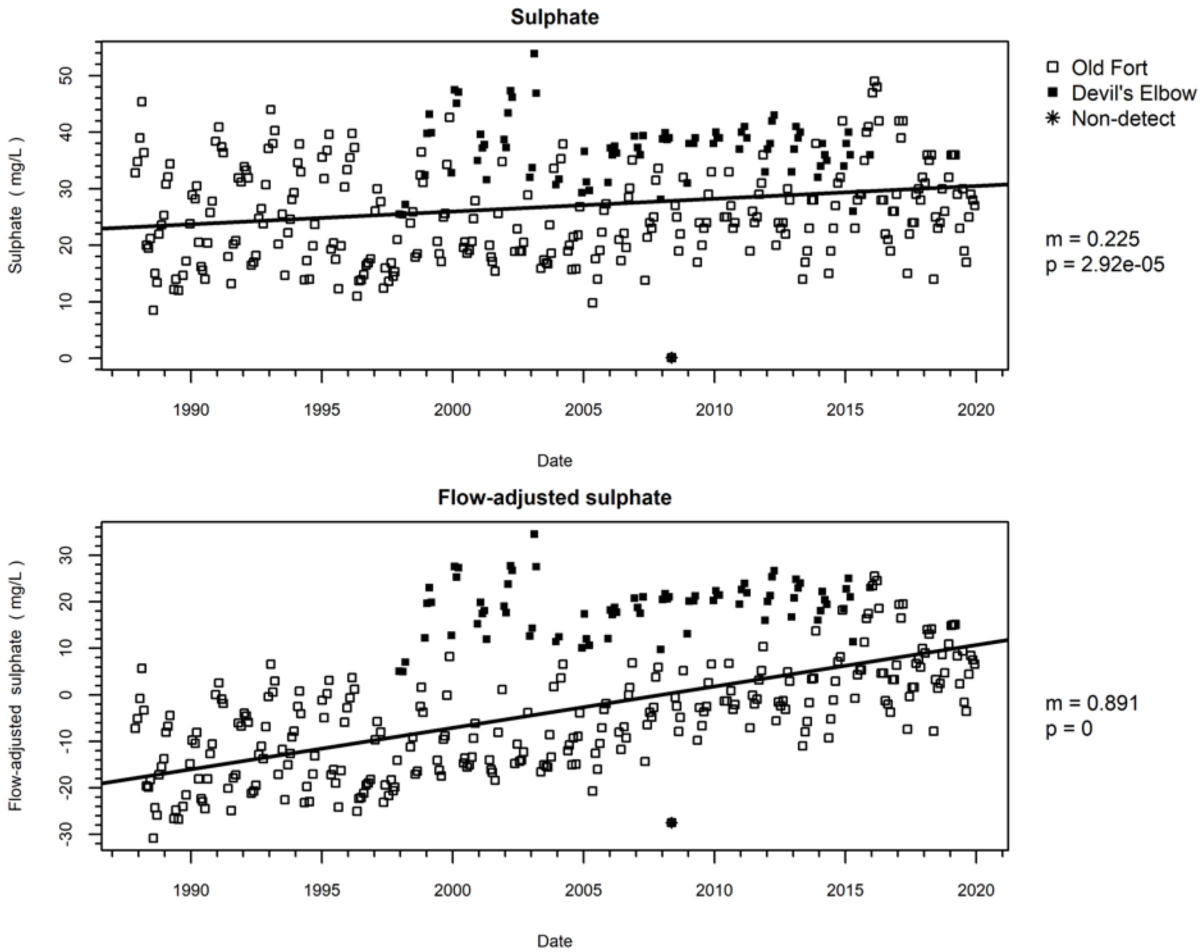


Figure A20: Sulphate concentrations at 'Old Fort' over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentrations are represented by the Akritas-Thiel Sen line, their slopes (m), and censored Mann-Kendall p values (p).

Dissolved uranium

There is no limit set for dissolved uranium in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2019, 11 occurrences were above the peak trigger, which is set at 0.381 µg/L. The maximum value was 0.498 µg/L, which equals 130.7% of the peak trigger value. The 2019 measurements ranged within historical values (before 2010) and the trend analysis for dissolved uranium revealed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A21). Changes in flow-concentration relationships over time prevented the development of an adjustment model for dissolved uranium. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and investigation into this parameter will continue.

Classification: Public

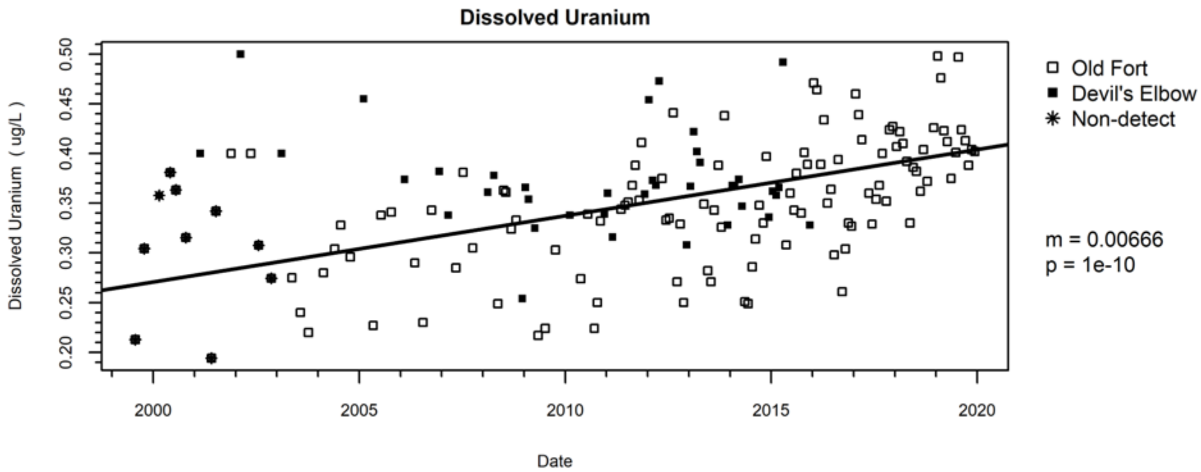


Figure A21: Dissolved uranium concentrations at 'Old Fort' over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and censored Mann-Kendall p value (p).

Classification: Public