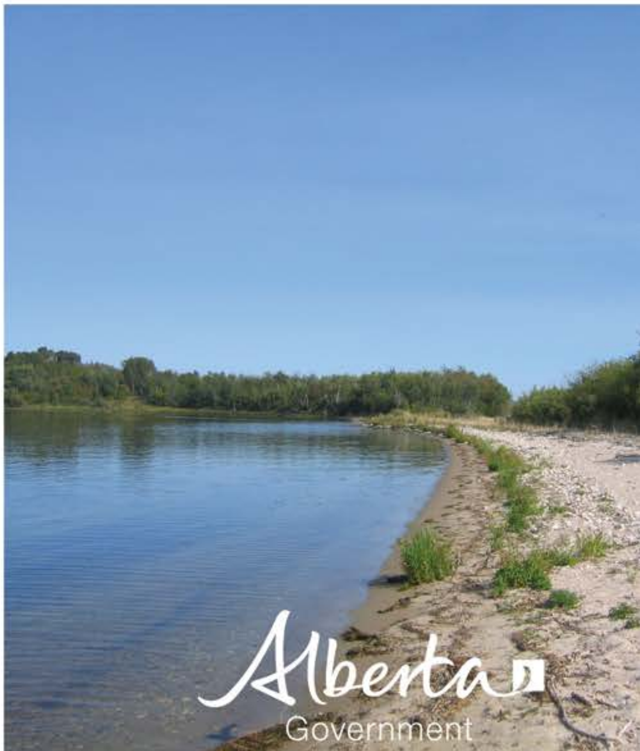
Lower Athabasca Region

Status of Management Response for Environmental Management Frameworks

- Air Quality Management Framework
- Surface Water Quality Management Framework

As of December 2016



Alberta Government

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Executive Summary

As part of the Integrated Resource Management System, this report communicates Alberta's management response to air and surface water quality triggers since 2012 in the Lower Athabasca Region. This fulfills commitments made to Albertans in the Lowere Athabasca Region Air Quality Management Framework for Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2) and the Lower Athabasca Region Surface Water Quality Management Framework for the Lower Athabasca River.

Since 2012, there were no limits exceeded for air and surface water quality indicators. This means that the state of the environmental health remains with the range of acceptable conditions, and that air and surface water quality objectives identified in the Lower Athabasca Regional Plan are being met.

However, some proactive triggers were exceeded. As a result, the Ministry of Environment and Parks is leading the required management response. This report communicates the status of the response to 2015 trigger exceedances, and includes an update on the management response to 2012, 2013 and 2014 trigger exceedances.

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

Air Quality

- A number of trigger exceedances were identified in 2012 & 2013. An investigation was completed and released in March 2016. Several management actions were identified based on the results of the investigation.
  I. Since 2012, the Syncrude Sulphur Emissions Reduction program has effectively changed the SO_2 emissions scenarios at Syncrude Operations. We are continuing to collect emissions and ambient monitoring data and assess the actions effect on regional air quality management.
  II. Work is continuing on a new trend assessment tool while work has been completed on improving emissions inventories and assessing the ambient air quality monitoring network.
- In 2014, noted increase in NO_2 at the Fort McMurray Athabasca Valley station. Investigation concluded that this was likely related to bridge construction. The temporary nature of the traffic-related disturbance influencing the site in 2013 and 2014 combined with declining NO_2 values in 2015 suggest no additional action required at this time.

- In 2015, Lower Camp station changed from Level 2 to Level 3 for the upper range of SO_2. While some preliminary work has been completed to understand why this station has transitioned, further investigative work is needed. Episode analyses will be conducted to review emissions conditions at regional facilities during the time of elevated events at the Lower Camp station. This might include looking at emissions sources such as flaring and venting and fugitive emissions that are not always well understood and may require some additional inventory and modelling work.

Surface Water Quality

- In 2015, three of the 38 water quality indicators exceeded a trigger. These included: sulphate (mean trigger), dissolved strontium (mean trigger), and dissolved uranium (mean and peak triggers).
- Management response activities undertaken in 2016 consisted of trend analysis to complete the preliminary assessment for indicators that first exceeded a trigger in 2013, 2014 and 2015. These include: potassium, sulphate, dissolved iron, dissolved aluminum, dissolved cobalt, total lithium, and dissolved strontium.
- Based on the preliminary assessment, a determination was made for each indicator to move into the investigation phase or to close the management response. From the trend analysis completed in 2016, potassium, sulphate, dissolved iron, total nitrogen and dissolved uranium showed significant increasing trends. Investigation for potassium, sulphate and dissolved iron will begin. No statistical temporal trends were observed for dissolved aluminum, dissolved cobalt, total lithium, and dissolved strontium. The management response is closed for these indicators.
- Seasonal trend analysis was also conducted in 2016 for nitrogen and dissolved uranium as part of their ongoing investigation. This was based on preliminary assessment completed in 2014 for indicators exceeding triggers in 2012 (dissolved lithium, nitrogen and dissolved uranium). The management response for dissolved lithium was closed while nitrogen and dissolved uranium were moved into investigation. Investigation for dissolved uranium and total nitrogen will continue.
- In 2017, the management response will focus on seasonal trend analysis for surface water quality data from monitoring stations upstream of ‘Old Fort’. This analysis will support the spatial and temporal delineation of trends and investigation of potential sources. Future steps may include higher resolution monitoring to refine the understanding of potential sources and processes contributing to trends. It is anticipated that this monitoring may be initiated in 2018.

Alberta Environment and Parks (AEP) will post updates to the status of the management response and supporting documents on the Ministry website.

Table of Contents

Status of Air Quality Management Response

Figures

Tables

1.0 Introduction

Under the Lower Athabasca Regional Plan, a management response must be initiated when a trigger or limit has been exceeded, as determined by the Minister of Environment and Parks. Part of the management response is determining the need for management action(s).

A management response was initiated when triggers were exceeded based on the 2012 ambient air quality data. As each annual report on condition becomes available, the management response is re-evaluated and updated based on new information.

This report is intended to provide an update on the management response since the last status report, in May 2015 and identify next steps for the management response based on the 2015 Status of Ambient Environmental Condition Report.

Environment and Parks is the lead coordinator in undertaking the management response and will work with other government organizations (e.g. Alberta Energy Regulator (AER)) and external parties as required to implement the identified management actions.

A full description of the management system is found in the Lower Athabasca Region Air Quality Management Framework. The management response is a set of seven steps that must be undertaken (in full or in part) when an ambient air quality trigger or limit is exceeded. Initial steps include verification, preliminary assessment and an investigation to determine the need for management actions.

There are seven steps in the management response:

- Verification
- Preliminary assessment
- Investigation
- Management Actions
- Oversight/Delivery of management actions
- Evaluation
- Communication

The management response for air will consider a variety of factors including (but are not limited to) the type and location of the monitoring station, averaging time (hourly or annual) and the ambient air quality trigger or limit that was exceeded.

Copies of the framework as well as all of the status of ambient environmental condition and management response reports can be found on the Environment and Parks website.

2.0

Summary of Ambient Levels Assigned

The Minister's Determination confirmed that no limits have been exceeded in the Lower Athabasca Region. However, air quality triggers have been exceeded at several monitoring stations, resulting in the assignment of ambient air quality levels described in the 2012, 2013, 2014 and 2015 Status of Ambient Environmental Condition Reports (Table 1, Figure 1).

Based on the 2015 ambient condition data, both Fort McMurray stations, Athabasca Valley and Patricia McInnes, fell below the trigger to Level 2 in 2015. In the case where a station is assigned to an air quality level and need management actions one year, then falls to a lower level the following year, management actions are still carried out but may be modified accordingly. One station, Lower Camp, which was at a Level 2, exceeded the trigger to Level 3 in 2015.

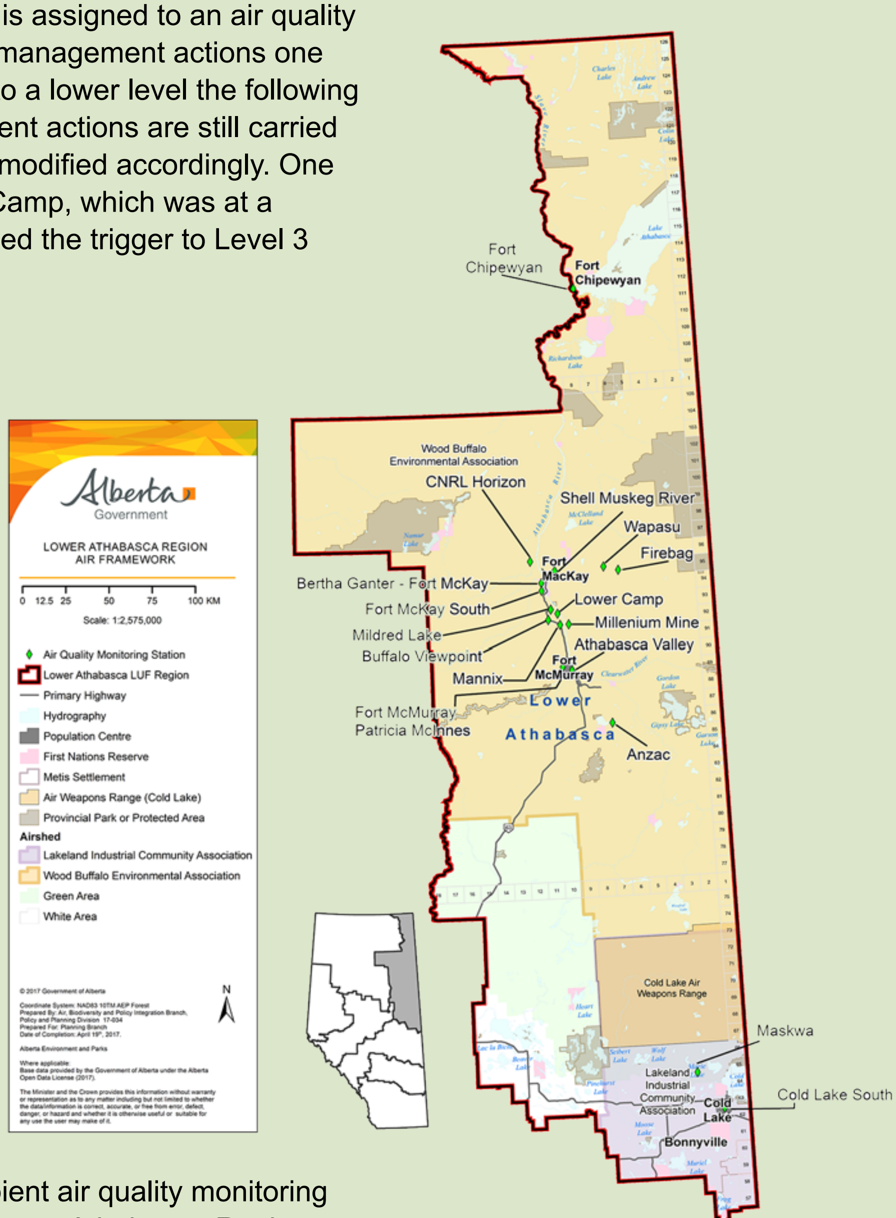

Figure 1.
Location of ambient air quality monitoring stations in the Lower Athabasca Region.

Table 1
Ambient levels assigned to air quality stations in the Lower Athabasca Region in 2012, 2013, 2014 and 2015 based on triggers established in the Air Quality Management Framework

Station Name (listed North to South)	Nitrogen Dioxide								Sulphur Dioxide							
	Annual Average				Upper Range				Annual Average				Upper Range			
	2012	2013	2014	2015	2012	2013	2014	2015	2012	2013	2014	2015	2012	2013	2014	2015
Fort Chipewyan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CNRL Horizon	1	1	1	1	2	2	2	2	1	1	1	1	2	2	2	1
Shell Muskeg River	2	2	2	2	2	2	2	2	1	1	1	1	2	2	2	2
Wapasu			1	1			1	1			1	1			1	1
Firebag				1				1				1				1
Bertha Ganter - Fort McKay	1	1	1	1	2	2	2	1	1	1	1	1	2	2	2	2
Fort McKay South	1	1	1	1	2	2	2	1	1	1	1	1	2	2	2	2
Mildred Lake									1	1	1	1	3	2	3	3
Lower Camp									1	1	1	1	2	2	2	3
Buffalo Viewpoint									1	1	1	1	2	2	1	1
Mannix									1	1	1	1	3	3	3	3
Millenium Mine	2	2	2	*	2	2	2	*	1	1	1	*	2	2	2	*
Fort McMurray Patricia McInnes	1	1	1	1	1	2	1	1	1	1	1	1	1	2	2	1
Fort McMurray – Athabasca Valley	2	2	2	1	2	2	2	1	1	1	1	1	1	1	1	1
Anzac	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Maskwa	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cold Lake South	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

* Millenium Mine station was decommissioned in August 2015. Therefore station did not meet completeness criteria.

3.0

Status of Management Response

The management response is a set of steps that must be taken (in full or in part) when an ambient air quality trigger or limit is exceeded. The management response will support the management intent associated with each trigger level or limit exceeded (Table 2). A full description of the management system is found in the Lower Athabasca Region Air Quality Management Framework for Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2).

Table 2
Annual ambient air quality description and management intent for each level

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

This section of the report summarizes progress made on the management response since the release of the Lower Athabasca Region Status of Management Response for Environmental Management Frameworks (as of May 2015).

At that time the following were identified as next steps:

- Oversight and delivery of management actions identified based on the 2012 management response including the implementation of the Syncrude Sulphur Emissions Reduction Plan, the development of an improved trend assessment methodology, actions to assess and improve the monitoring network and the compilation of information on non-point source emissions; and
- Continuing the investigation into the 2014 trigger exceedances to determine whether additional action is required.

In addition to providing updates on those items, this report provides initial investigation results for the 2015 trigger exceedances.

3.1 Verification and Preliminary Assessment

Verification and preliminary assessment are generally completed as part of preparing the Status of Ambient Environmental Condition report. In some cases, additional work may be completed in order to determine if rare events or natural circumstances (e.g. forest fires) contributed to trigger exceedances.

In this reporting cycle, verification and preliminary assessment were completed for the 2015 air quality data. The preliminary assessment suggests that no rare events or natural circumstances contributed to trigger exceedances in 2015.
Table 3 provides a summary of the status of verification and preliminary assessment for trigger exceedances since 2012.

Table 3 Status of verification and preliminary assessment for trigger exceedances since 2012

Year of Trigger Exceedance	Status	Report Title
2012	Complete	"Status of Ambient Environmental Condition – Air and Surface Water Quality 2012" released Aug 2014 by Environment and Parks
2013	Complete	"Status of Ambient Environmental Condition - Air and Surface Water Quality 2013" released July 2016 by Environment and Parks
2014	Complete	"Status of Ambient Environmental Condition – Air Quality 2014" released July 2016 by Alberta Environmental Monitoring Evaluation and Reporting Agency (AEMERA)
2015	Complete	"2015 Status of Air Quality- Lower Athabasca Region, Alberta for January 2015-December 2015" released March, 2017 by Environment and Parks.

3.2 Investigation Update (2014 & 2015)

The purpose of the investigation is to determine the influence for the performance of an indicator and inform the need for management action. The scale of the investigation will depend on the assigned management level as well as the complexity of the issue identified and whether or not conditions are trending or occurring in areas as anticipated. Table 4 provides a summary of the status of investigation for trigger exceedances since 2012.

Table 4
Status of investigation for trigger exceedances since 2012

Year of Trigger Exceedance	Status	Report Title
2012	Complete	2012 Technical Report for Lower Athabasca Region Air Quality Management Framework Management Response was released March 2016 by Environment and Parks
2013	Complete	Technical Addendum: Technical Supporting Document for the 2013 Air Quality Management Framework (AQMF) Management Response
2014	Complete	Results of the 2014 investigation are summarized in section 3.2 of this report
2015	Complete	Preliminary investigation results and next steps are reported in section 3.2 of this report

3.2.1 2014 Investigation - Nitrogen Dioxide (NO_2) - Level 2 stations

The 2014 investigation focused on the Fort McMurray-Athabasca Valley station where increases to both annual average and upper range levels of NO_2 were noted (Figure 2 and Figure 3). An NO_2 value of 165 ppb was recorded on February 23, 2014, exceeding the Alberta Ambient Air Quality Objectives (AAAQO) guideline of 159 ppb. Personal correspondence with Alberta Transportation and Wood Buffalo Environmental Association (WBEA) office confirmed the presence of bridge construction and truck idling near the Athabasca Valley air monitoring station.

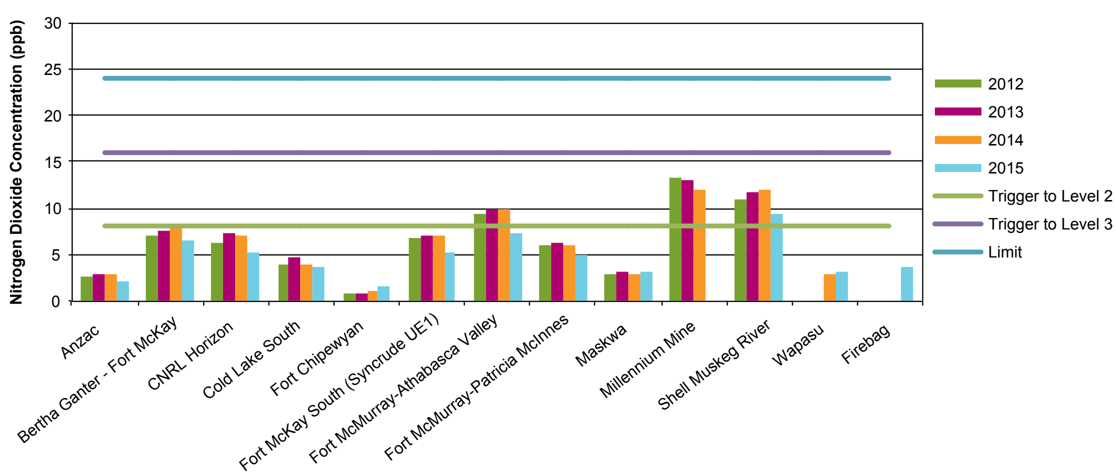

Figure 2
Annual Average of the Hourly Data for Nitrogen Dioxide for 2012 to 2015 from Air Monitoring Stations in the Lower Athabasca Region.

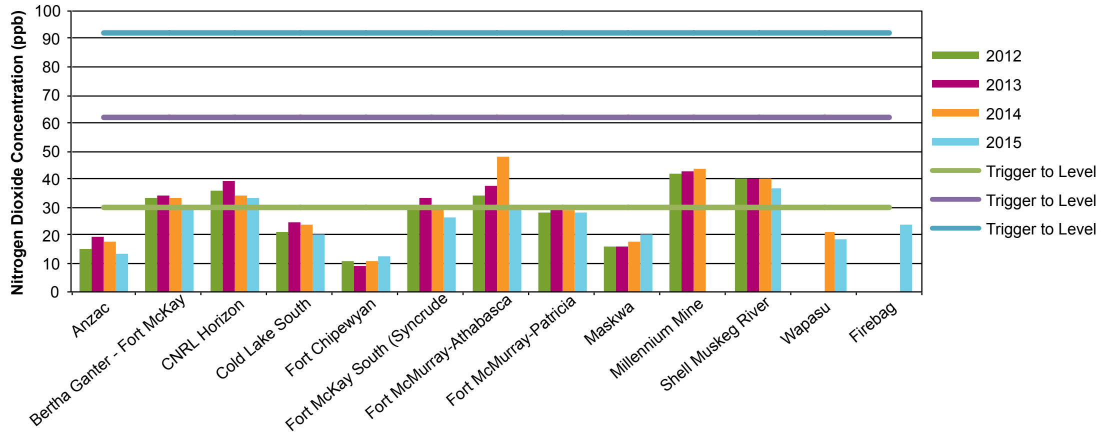

Figure 3
Upper Range of the Hourly Data[1] for Nitrogen Dioxide for 2012 to 2015 from Air Monitoring Stations in the Lower Athabasca Region.

In 2015, the annual average of NO_2 at the Fort McMurray - Athabasca Valley station declined to 7 ppb from 10 ppb in 2014; the 99th percentile of the upper limit declined to 30 ppb from 48 ppb in 2014. The temporary nature of the traffic-related disturbance influencing this site in 2013 and 2014, combined with the declining NO_2 values in 2015, suggests no additional action is required at this time.

3.2.2 Investigation - Sulphur Dioxide (SO_2) – Level 2 & Level 3 Stations

Figures 4 & 5 show the annual average and upper range SO_2 levels for stations in Lower Athabasca Region from 2012 – 2015.

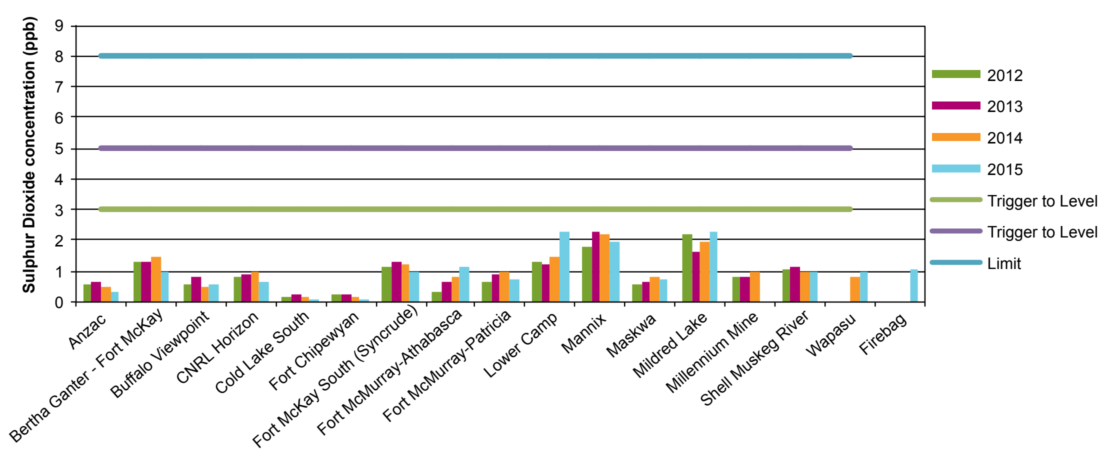

Figure 4. Annual Average of the Hourly Data for Sulphur Dioxide for 2012 to 2015 from Air Monitoring Stations in the Lower Athabasca Region.

[1] The Upper Range of Hourly Data is represented by the annual 99th percentile of the hourly average concentrations

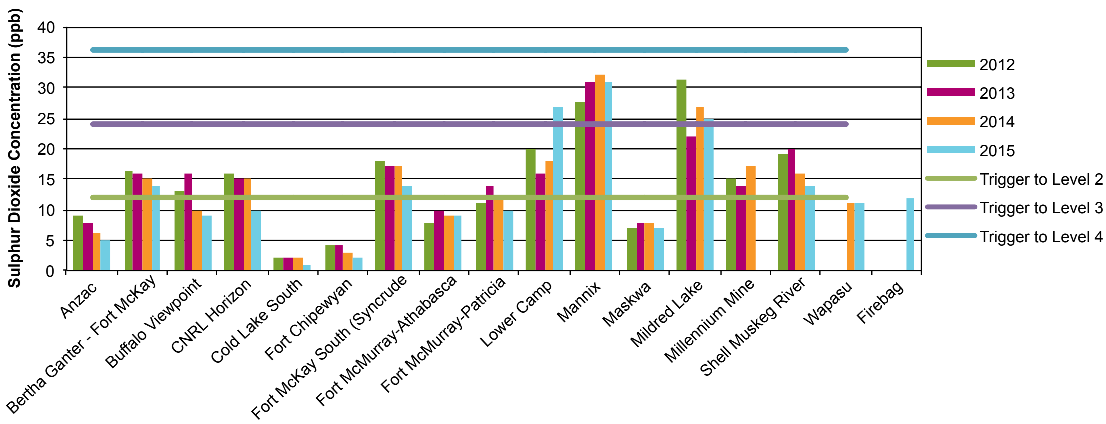

Figure 5.
Upper Range of the Hourly Data[2] for Sulphur Dioxide for 2012 to 2015 from Air Monitoring Stations in the Lower Athabasca Region.

In 2014, SO_2 concentrations were generally similar to 2012-2013. The 2012 investigation found that at Level 3 stations, SO_2 concentrations occurred at higher wind speed and at stations in close proximity to operations and were assumed to be the result of plume downwash following emissions from the upgrader stacks. At Level 2 stations, elevated SO_2 concentrations were appeared to be influenced by SO_2 emissions from the near large upgraders.

Annual average conditions were also fairly similar from 2014 to 2015, an exception being the Lower Camp station where SO_2 increased. In 2015, almost all the Level 1 and 2 stations had upper range concentrations lower than in previous years. Again, the exception to this being Lower Camp where increases caused the station to move from a Level 2 to Level 3. Management actions that include analysing regional data using an improved trend assessment methodology and also evaluating the influence of SO_2 emissions reductions at Syncrude on regional air quality have already been identified and will be continued over the next reporting cycle.

The 2015 investigation was focused on the Lower Camp station and understanding the reasons for the change at this station.

Wind roses reflect the relative frequency of the wind direction at a particular place over a period of time and can be used to identify the emission source(s) of ambient concentrations. Wind data collected at 10 m level (Figure 6) indicated that during 2014-15, wind from SE dominated the stations within the valley area. During 2015, wind data at 90 m level at Mannix indicated that wind was more prominent from W, SW and SE (Figure 7).

[2] The Upper Range of Hourly Data is represented by the annual 99th percentile of the hourly average concentrations

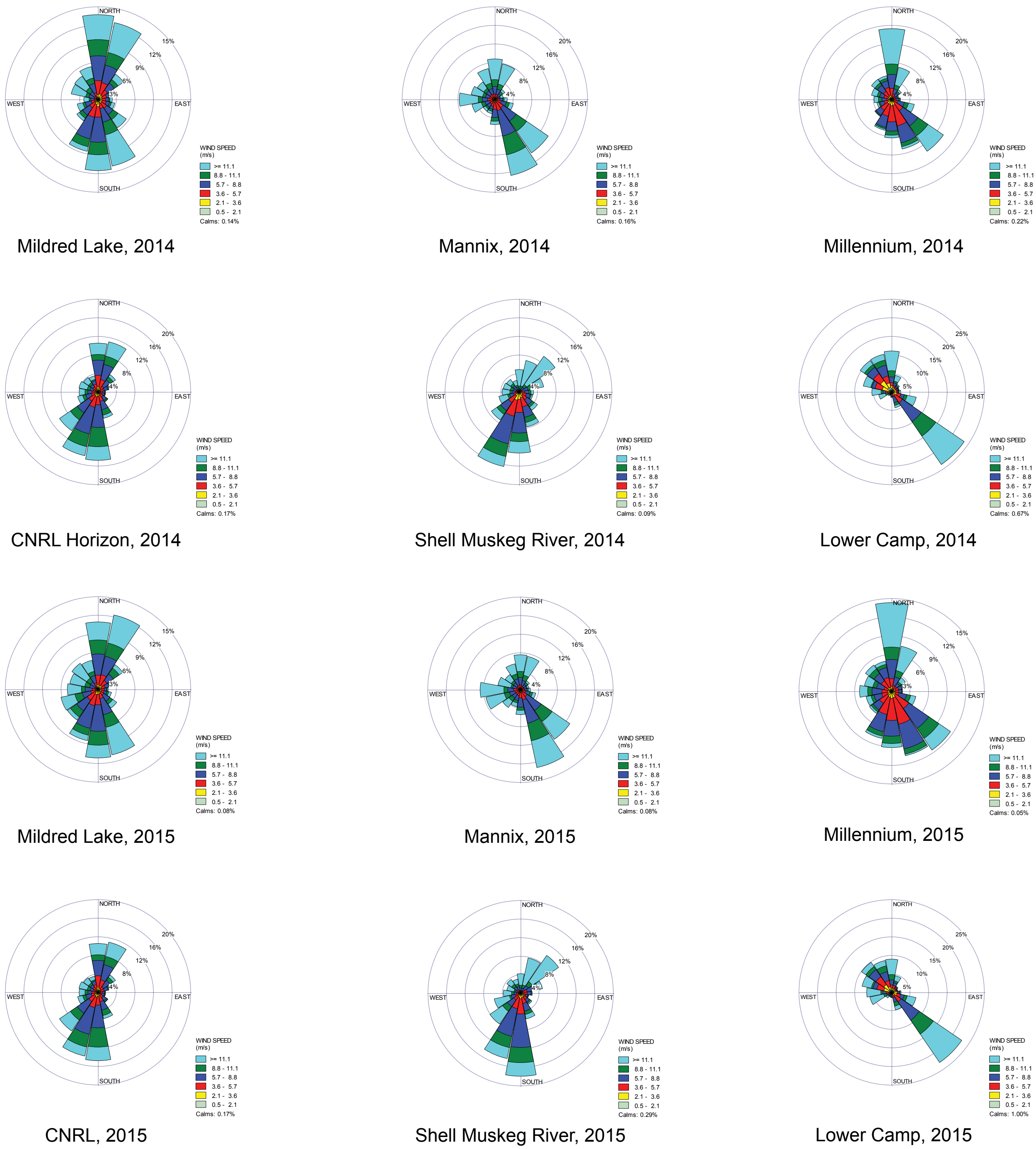

Figure 6
Wind Roses at 10 m level for stations near major industrial operations and Lower Camp in 2014 and 2015.

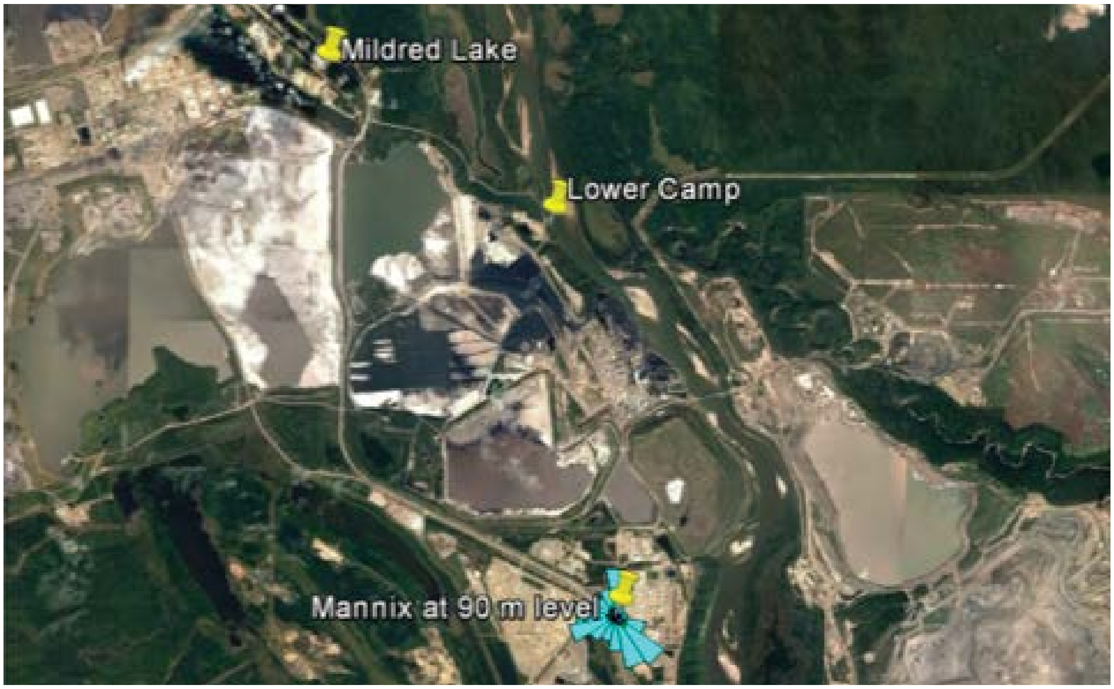

Figure 7.
Wind rose in 2015 at 90 metre height for Mannix.

While the wind rose for Lower Camp shows that winds were not frequently blowing from the southwest, there appears to be some source of SO_2 in this quadrant, particularly in 2015. This is illustrated by a greater quantity of higher SO_2 hourly readings emanating from 180 degrees (south) to 270 degrees (west) in 2015 (Figure 8b) than in 2014 (Figure 8a). Stacks on SE and and SW of Lower Camp station might play bigger role in influencing higher SO_2 hourly readings at lower wind speed at this station. Figure 8 (a, b) also shows elevated SO_2 readings originating from a source at approximately 130 to 140 degrees (southeast) for both 2014 and 2015.

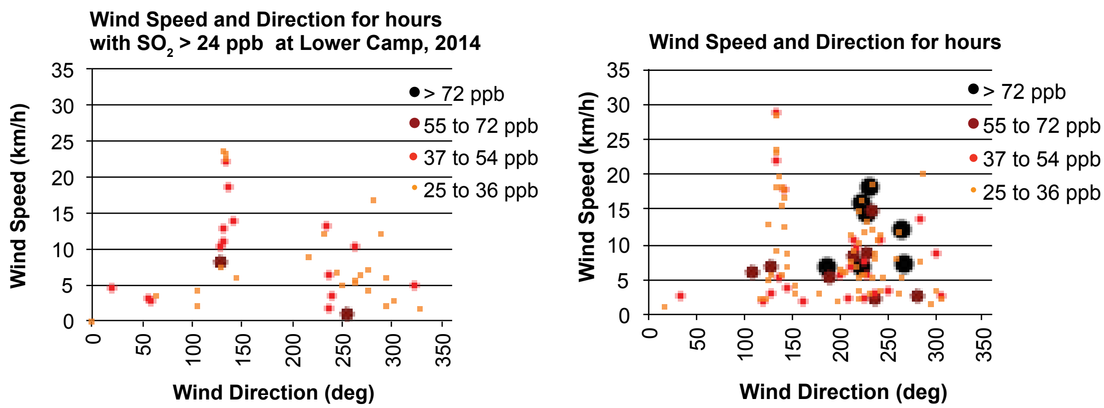

Figure 8.
SO_2 concentration and meteorology (wind speed and wind direction) at Lower Camp station in a) 2014 and b) 2015.

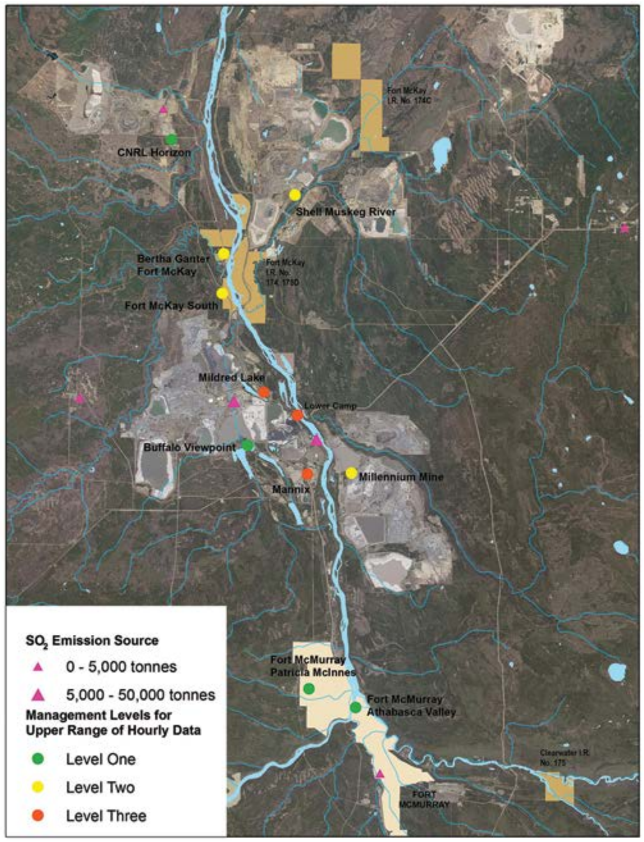

Figure 9.
Map of major SO_2 emission sources in the LAR relative to the management levels for upper range of hourly data at air monitoring stations in 2015

To check the influences from industrial operations, the highest SO_2 peaks at Lower Camp station were compared with readings from other industrial stations such as Mannix, Mildred lake, CNRL and Shell Muskeg River and assumed close relationships with Mannix (Appendix A). There was no relationship between SO_2 peaks and forest fire smoke or any other natural factors.

Further study is required to determine what other factors could be contributing to the transition of Lower Camp from level 2 to level 3. Episode analyses will be conducted to review emissions conditions at regional facilities during the time of elevated events at the Lower Camp station. This might include looking at emissions sources such as flaring and venting and fugitive emissions that are not always well understood and may require some additional inventory and modelling work.

3.3 Identification of Management Actions

Following the investigation, the next step of the management response is the identification of management actions. Some management actions have been identified and are underway. The need for additional management actions will be considered as part of the investigation.

Table 5
Status of Identified Management Actions

Year of Trigger Exceedance	Status	Notes
2012	Complete	A series of actions was identified in 2014; see section 3.4 for an update on the status of those actions.
2013	Complete	Based on investigation, no actions required beyond those identified in 2012.
2014	Complete	No additional actions required.
2015	Proposed	The results of the 2015 investigation will help inform whether additional actions are required.

3.4 Oversight/Delivery of Management Actions

A series of recommended management actions was identified based on analyses of the 2012 and 2013 monitoring data and subsequent investigations. These actions take into account ongoing initiatives that are being developed or are in place to reduce emissions in the region.

3.4.1 Sulphur Emissions Reduction

The Syncrude Sulphur Emission Reduction Program was identified as a key measure to achieving a reduction of SO_2 in the Lower Athabasca Region. The major action included the commissioning of a sulphur recovery system on the main stack. This action, and others, has effectively changed the emissions scenarios of Syncrude operations. Between 2013 and 2015, Syncrude recorded a reduction of SO_2 emission from Main Stack (29-1) of more than a 50 per cent, contributing to a drop in SO_2 emissions of nearly 58 per cent from all sources during the same period (Figure 10).

Environment and Parks will work with the Alberta Energy Regulator to continue to monitor the progress of this program and evaluate the effectiveness of this project on reducing regional SO_2 concentrations.

Table 6
Status of Delivery of Management Actions

Action	Lead	Status	Notes
Level 3 Stations – Sulphur Dioxide (Upper Range) Management Intent: Proactively maintain air quality below Level 4 trigger			
Emissions Management – Sulphur Emissions Reduction	AER/ Environment and Parks	Complete	Evaluation of management action will continue through 2018.
Level 2 Stations – Sulphur Dioxide (Upper Range) and Nitrogen Dioxide (Annual Average and Upper Range) Management Intent: Improve knowledge and understanding and plan			
Develop improved trend assessment methodology	Environment and Parks	Underway	
Assess and improve monitoring network	Environment and Parks	Ongoing	Report submitted by third party contractor and is under consideration by Environment and Parks.
Compile information on non-point source emissions	Environment and Parks	Complete	The Joint Oil Sands Monitoring Program Emissions Inventory Compilation Report was published by Environment Canada and Environment and Parks in June 2016.

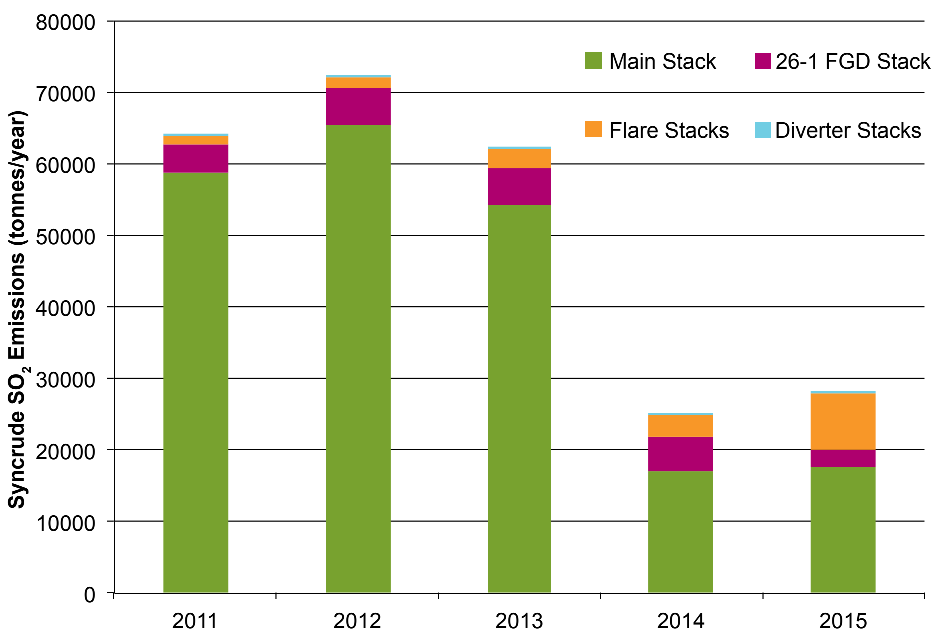

Figure 10. Temporal variations of SO_2 emission sources in Syncrude (tonnes/year)[3].

[3] Table was adapted from information provided in the Syncrude Air Emissions Annual Report for 2015.

3.4.2 Develop Improved Trend Assessment Methodology

Trends in NO_2 and SO_2 concentrations are calculated from the hourly concentrations of monitoring data and reporting for the State of Environment reporting for all years since the air monitoring stations went into operation. Since the stations became operational in different years, the reported trends at different stations cannot be compared directly. Also, at stations with long time series data, the trend could reflect changes that occurred early in the time series, but may yield little information about more recent years. Developing a tool suitable for calculating both short term and long term trends in SO_2 and NO_2 concentrations in the Lower Athabasca Region was identified as a management action to fill gaps in our knowledge and understanding and is being developed by the Environmental Monitoring and Science Division (EMSD) of Environment and Parks that will be used for the next year assessment.

3.4.3 Assess and Improve Monitoring Network

The Oil Sands Monitoring (OSM) network assessment was initiated to provide recommendations on adjustments to the monitoring network to improve characterization and understanding of ambient air quality in the Lower Athabasca Region in 2015. A third-party report with recommendations has been submitted to Environment and Parks and is currently under review by EMSD.

3.4.4 Compile information on non-point source emissions

In June 2016, Environment Canada and Environment and Parks released the Joint Oil Sands Monitoring (JOSM) Program Emissions Inventory Compilation Report based on a synthesis of the best available information from several existing emissions inventories and related sources. The inventory work did identify several data gaps that are still being addressed by ongoing inventory development at Environment Canada and Climate Change.

4.0 Next Steps

Environment and Parks will continue to oversee the delivery of the identified management actions while also continuing the investigation into 2015 trigger exceedances, working with other government organizations (e.g. Alberta Energy regulator (AER)) and external parties as required.

A report updating the status of the management response will be made publicly available within one year.

5.0

References

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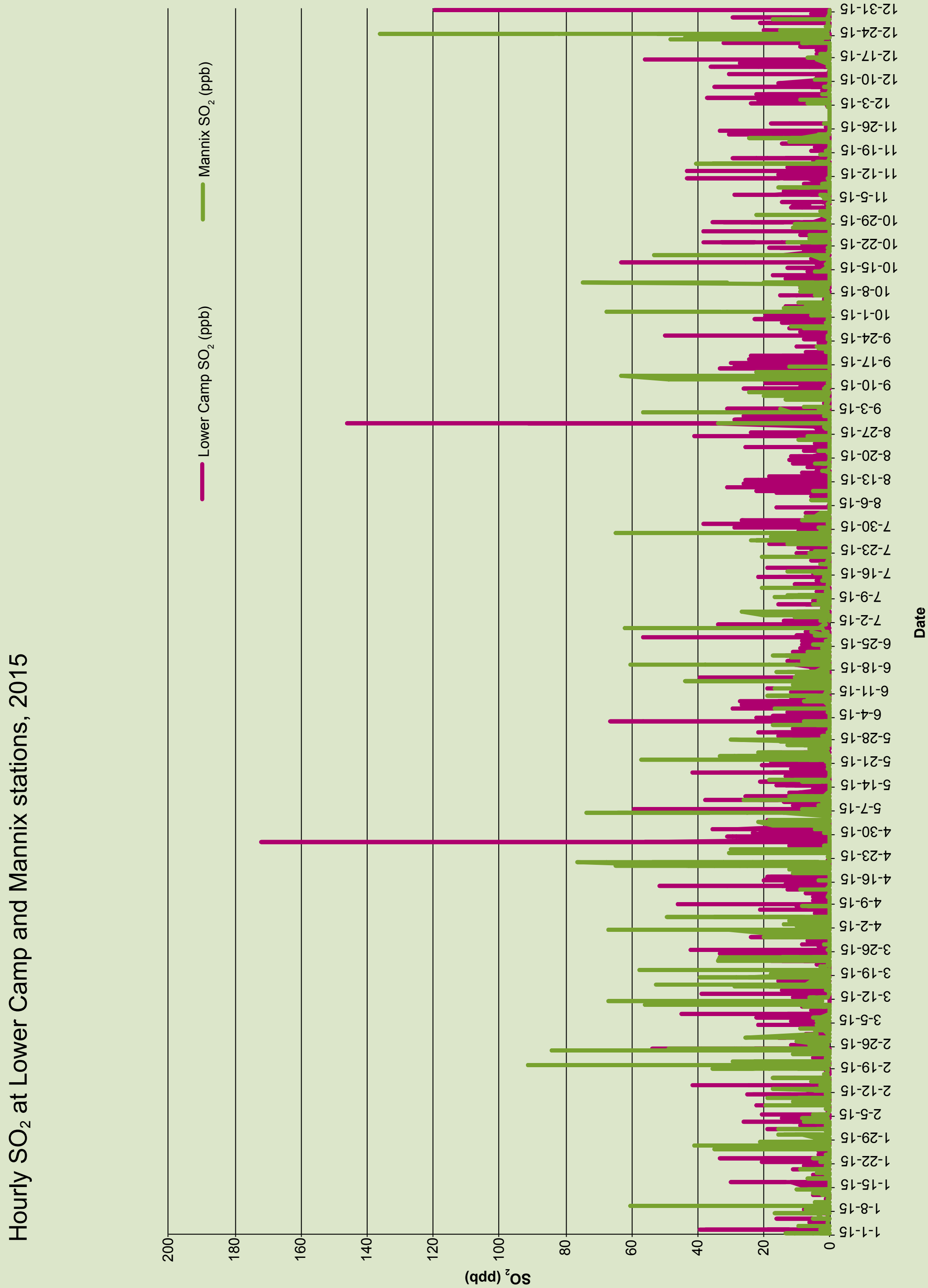
Government of Alberta. 2017. 2015 Status of Air Quality Lower Athabasca Region, Alberta for January 2015-December 2015. Environmental Monitoring and Science Division, Alberta Environment and Parks.

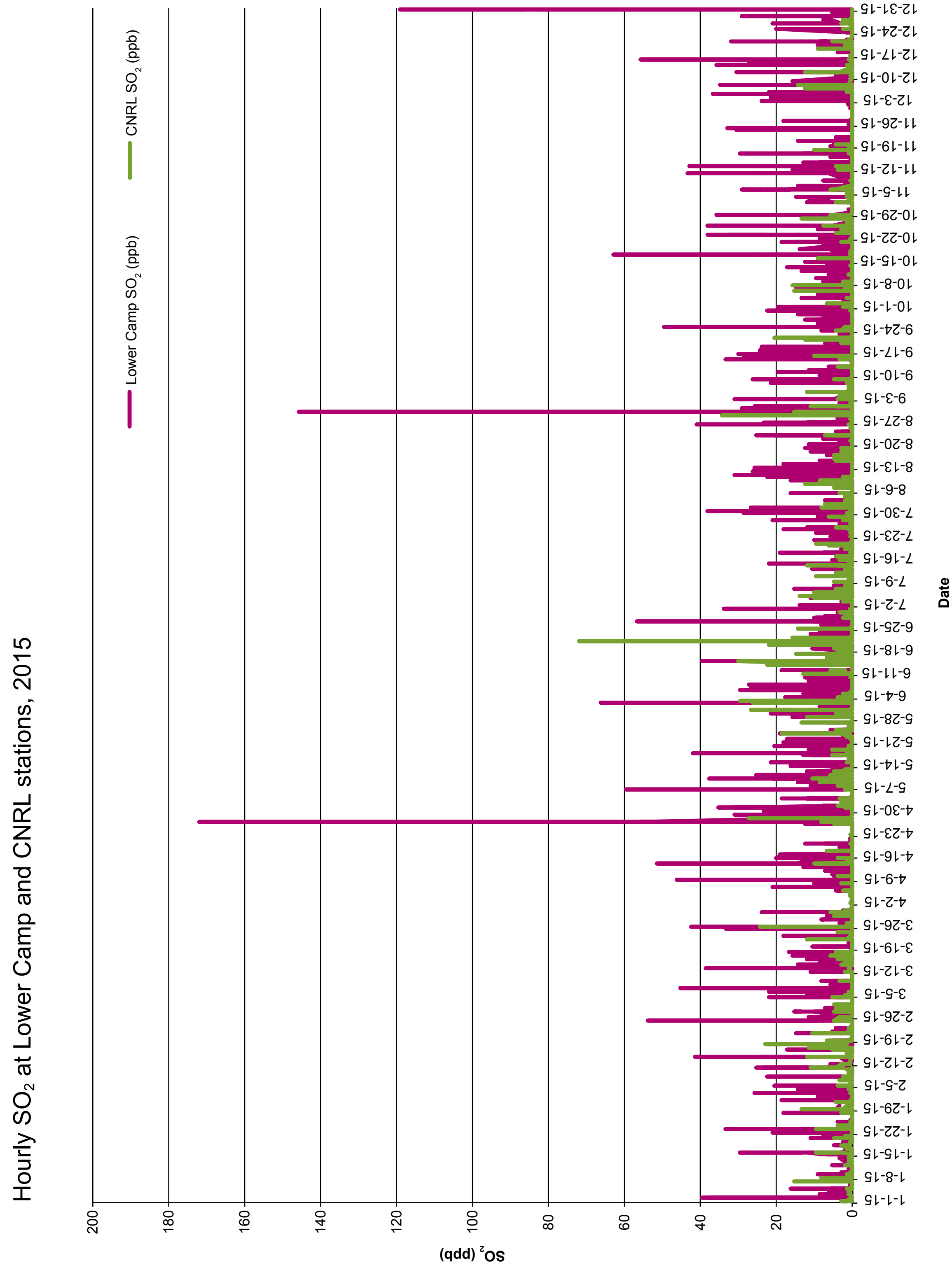
Liu, Y., M. Mazur and C. Adams. 2015, Technical Supporting Document for the 2012 Air Quality Management Framework Management Response. Alberta Environment and Parks.

Syncrude. 2016. Syncrude Air Emissions Annual Report for 2015.

Appendices

Appendix A - Hourly Concentrations of SO_2 at Lower Camp and other stations, 2015




Hourly SO_2 at Lower Camp and CNRL stations, 2015
Lower Camp SO_2 (ppb)
CNRL SO_2 (ppb)
SO_2 (ppb)
0
20
40
60
80
100
120
140
160
180
200
Date
1-1-15
1-8-15
1-15-15
1-22-15
1-29-15
2-5-15
2-12-15
2-19-15
2-26-15
3-5-15
3-12-15
3-19-15
3-26-15
4-2-15
4-9-15
4-16-15
4-23-15
4-30-15
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11-5-15
11-12-15
11-19-15
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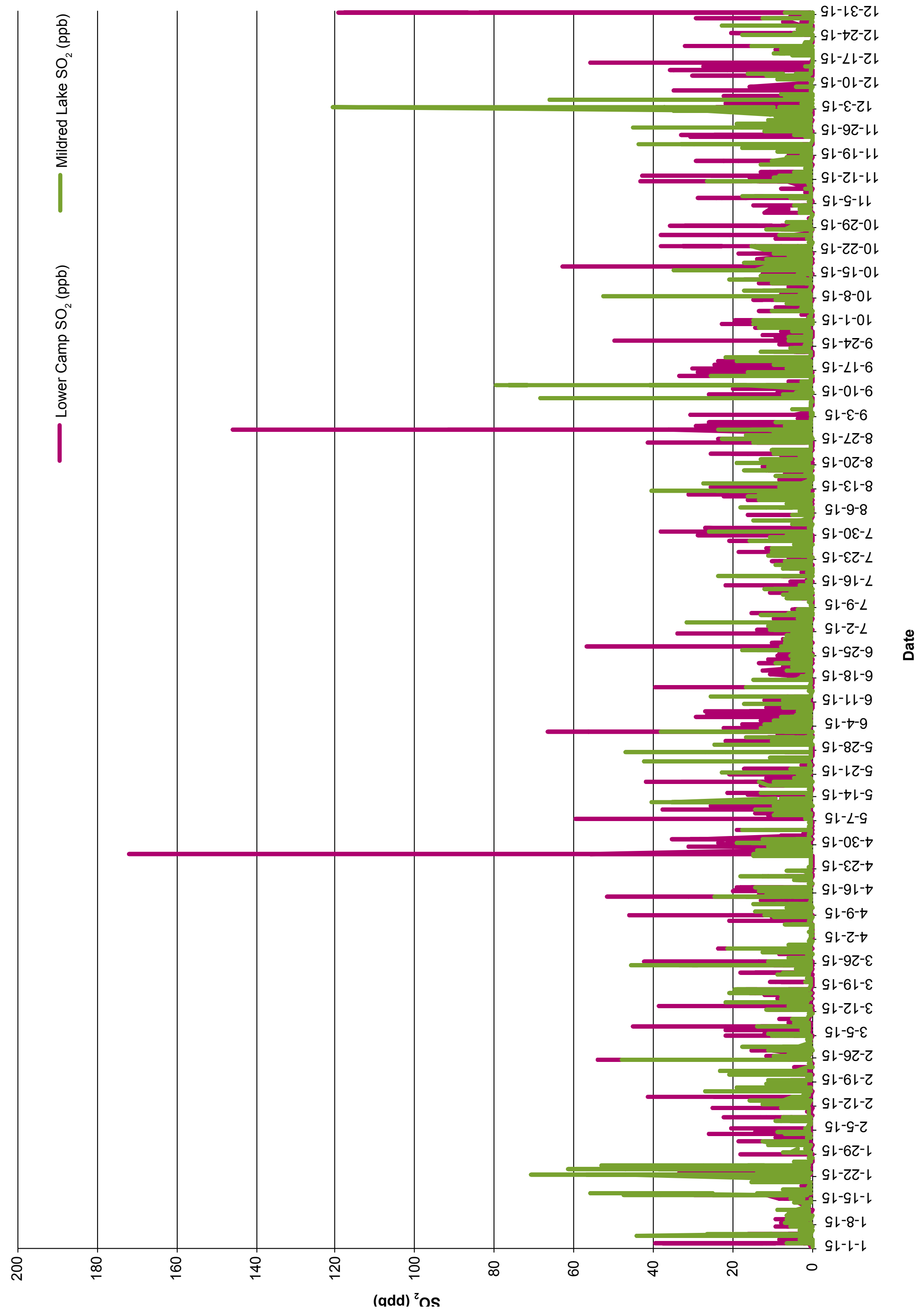
Hourly SO_2 at Lower Camp and Mildred Lake stations, 2015



Hourly SO_2 at Lower Camp and Shell Albian Muskeg River stations, 2015

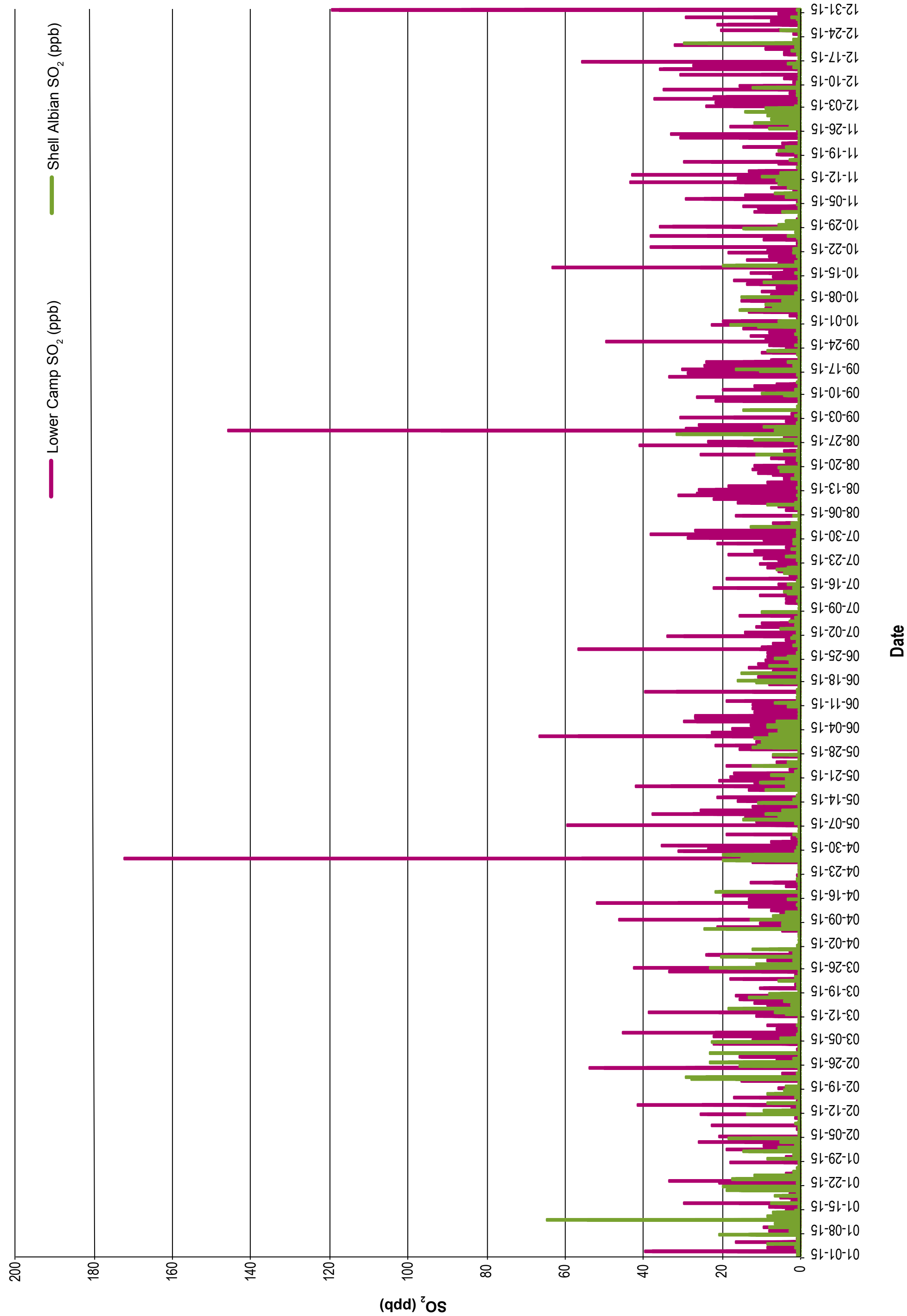


Table of Contents

Status of Surface Water Quality Management Response

Figures

Tables

1.0

Introduction

Under the Lower Athabasca Regional Plan, a management response must be initiated when a trigger or limit has been exceeded, as determined by the Minister of Environment and Parks. Part of the management response is determining the need for management action(s).

The first management response was initiated when triggers were exceeded based on the 2012 surface water quality data. As each annual report on condition becomes available, the management response is re-evaluated and updated based on new information. New management responses are initiated for new exceedances. Annual status of ambient condition and status of management response reports can be found on Alberta Environment and Park's website.

This report is intended to provide an update on ongoing management responses to previously identified trigger exceedances, since the last status report, in May 2015 and describe any new management response to exceedances identified in the 2015 Status of Ambient Environmental Condition Report. The report also identifies next steps for the overall management response.

Environment and Parks is the lead coordinator in undertaking the management response and will work with other government organizations (e.g. Alberta Energy Regulator) and external parties as required to undertake investigation and implement identified management actions.

There are six steps in the management response:

- Verification
- Preliminary assessment
- Investigation
- Management Actions
- Evaluation
- Communication

A full description of the management system is found in the Lower Athabasca Region Surface Water Quality Management Framework. The management response is a set of six steps that must be undertaken (in full or in part) when an ambient surface water quality trigger or limit is exceeded. Initial steps include verification, preliminary assessment and an investigation to determine the need for management actions.

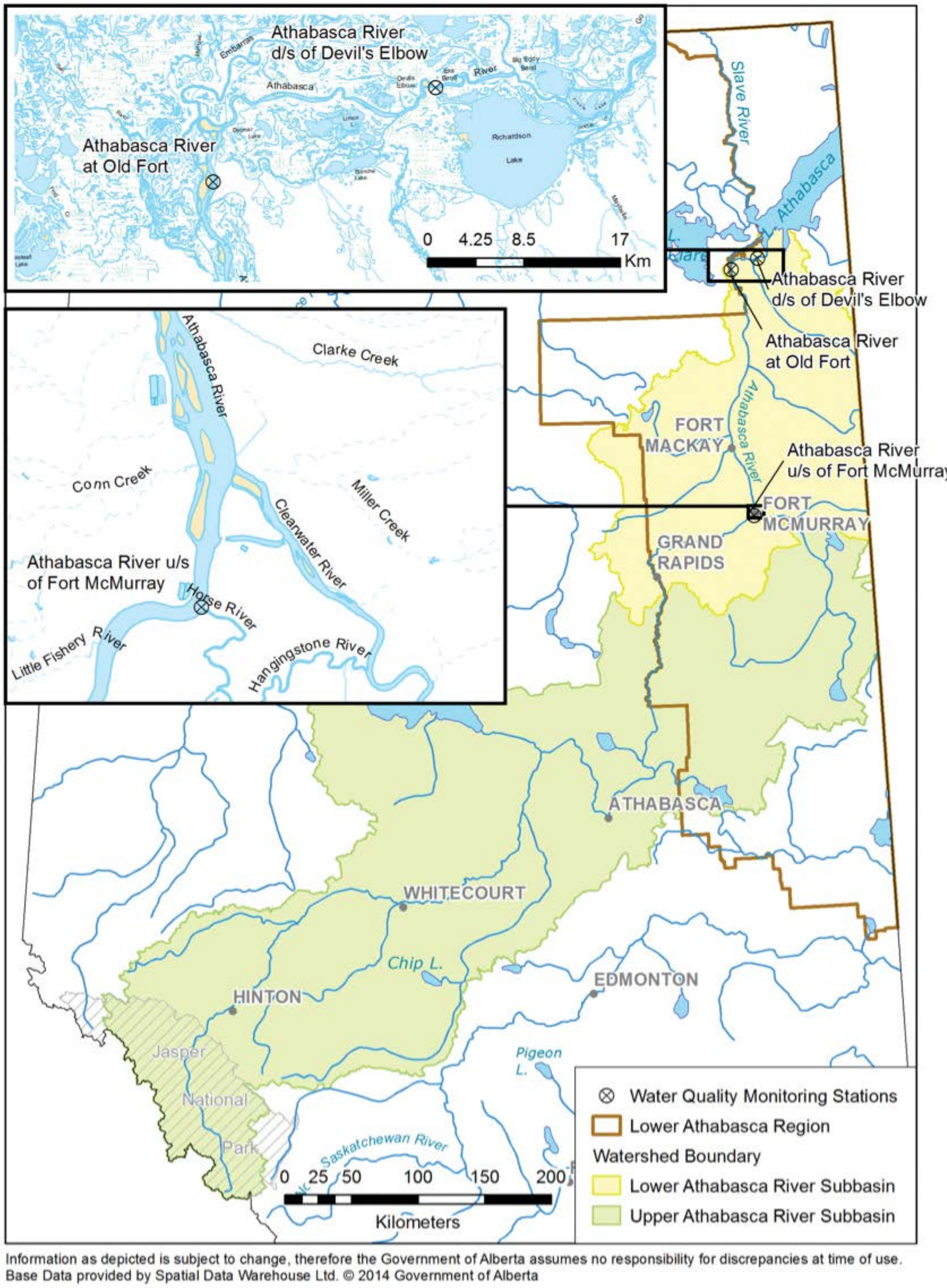


Figure 1
Map of the Athabasca River Basin and Lower Athabasca Region surface water quality monitoring stations. (Note: the 'Old Fort' dataset is comprised of surface water quality data from both Athabasca River at Old Fort and Athabasca River d/s of Devil's Elbow monitoring stations.)

2.0

Summary of Trigger Exceedances and Status of Management Response

To date, surface water quality indicators in the lower Athabasca River have not exceeded any limits. Trigger exceedances; however, have been observed each year since the framework was first implemented in 2012. Table 1 identifies the trigger exceedances described in the 2012, 2013, 2014 and 2015 Status of Ambient Condition reports and the status of their respective management response.

Table 1.
History of trigger exceedances for surface water quality indicators at 'Old Fort' and status of Management Response.

Indicator	2012	2013	2014	2015	Status of management response as of December 2016
Potassium			Mean		Investigation
Sulphate			Mean	Mean	Investigation
Iron (dissolved)		Mean			Investigation
Nitrogen (total)*	Mean	Mean			Investigation
Uranium (dissolved)*	Mean/Peak	Mean/Peak	Peak	Mean/Peak	Investigation
Aluminum (dissolved)		Peak			Closed
Cobalt (dissolved)			Peak		Closed
Lithium (dissolved)*	Peak				Closed
Lithium (total)		Peak			Closed
Strontium (dissolved)				Mean	Closed

*Preliminary assessment completed in 2015.

Of the trigger exceedances observed in 2015, dissolved uranium has exceeded triggers each year since 2012; sulphate exceeded triggers in the last two consecutive years; and dissolved strontium exceeded a trigger for the first time in 2015.

The last management response report, Status of Management Response for Environmental Management Frameworks as of May 2015, identified the following next steps for the management response:

- trend analysis of flow-adjusted and unadjusted data to complete the preliminary assessment for indicators that first had exceedances in 2013 and 2014, and
- analysis of the winter synoptic survey results to advance the investigation for total nitrogen and dissolved uranium.

3.0

Status of Management Response

This report is the third Status of Management Response Report for the Lower Athabasca Region. A summary of all activities undertaken and reported on in the previous two Status of Management Response Reports is provided in Appendix A.

The following section provides a description of the activities undertaken to advance the management response since the last Status of Management Response Report. It addresses all previous trigger exceedances (with the exception of dissolved lithium, whose management response was closed) in 2015, as well as indicators that exceeded a trigger for the first time (Table 1 in 2015).

In 2016, the management response focused on completing statistical trend analysis on both flow-adjusted and unadjusted data from 'Old Fort', using surface water quality data and flow data to 2015. This trend analysis supports the preliminary assessment for potassium, sulphate, dissolved iron, dissolved aluminum, dissolved cobalt, total lithium, and dissolved strontium, and the investigation of total nitrogen and dissolved uranium. Investigation for total nitrogen and dissolved uranium also included analysis of the seasonality of trends, considering the year-over-year trend for each month, as well as analysis of the synoptic survey results.

3.1 Verification

Verification of data occurs each year as new annual datasets are available and includes the calculation of mean and peak metrics to compare to trigger values established in the framework. This work has been completed by Alberta Environment and Parks for the 2015 data from 'Old Fort' and indicators with trigger exceedances are shown in Table 1. Management response continues to preliminary assessment for these indicators.

Table 2 provides the status of verification for all indicators that have exceeded a trigger since 2012 and identifies the relevant report documenting the verification phase of the management response.

Table 2
Status of verification for trigger exceedances since 2012.

Year of Exceedance	Status of Verification	Report Title
2012	Complete	"Status of Ambient Environmental Condition – Air and Surface Water Quality 2012" released Aug 2014 by Environment and Parks
2013	Complete	"Status of Ambient Environmental Condition - Air and Surface Water Quality 2013" released July 2016 by Environment and Parks
2014	Complete	"Status of Ambient Environmental Condition – Surface Water Quality 2014" released July 2016 by Alberta Environmental Monitoring Evaluation and Reporting Agency (AEMERA)
2015	Complete	"2015 Status of Water Quality for the Athabasca River, Alberta at the Old Fort Monitoring Station" released April 2017 by Environment and Parks

3.2 Preliminary Assessment

The purpose of the Preliminary Assessment is to determine if an investigation is required or if the management response may be closed. A key component of this assessment is analyzing for emerging trends in water quality over time. If a trend is detected, the indicator is moved into the investigation phase of a management response. If a trend is not detected, the management response may be closed. Appendix B provides further explanation of trend analysis, including how the influenence of flow is accounted for.

Table 3 provides the status of the preliminary assessment for all indicators that have exceeded a trigger since 2012 and identifies the relevant report documenting the preliminary assessment phase of the management response.

Table 3
Status of preliminary assessment for trigger exceedances since 2012.

Year of Exceedance	Status of Verification	Report Title
2012	Complete	"Status of Management Response for Environmental Management Frameworks, as of May 2015", released July 2016 by Environment and Parks
2013	Complete	"Status of Management Response for Environmental Management Frameworks, as of May 2015", released July 2016 by Environment and Parks Section 3.2 of this report.
2014	Complete	"Status of Management Response for Environmental Management Frameworks, as of May 2015", released July 2016 by Environment and Parks Section 3.2 of this report.
2015	Complete	Section 3.2 of this report.

The preliminary assessment conducted in 2016 consisted of a statistical trend analysis for indicators first exceeding triggers in 2013, 2014 and 2015.

3.2.1 Dissolved iron (mean trigger exceeded in 2013)

The trend analysis for dissolved iron showed increasing concentrations at 'Old Fort' (Figure 2). The trends in concentrations were also significant when adjusted for flow. Thus, dissolved iron has been moved into the investigation phase of the management response.

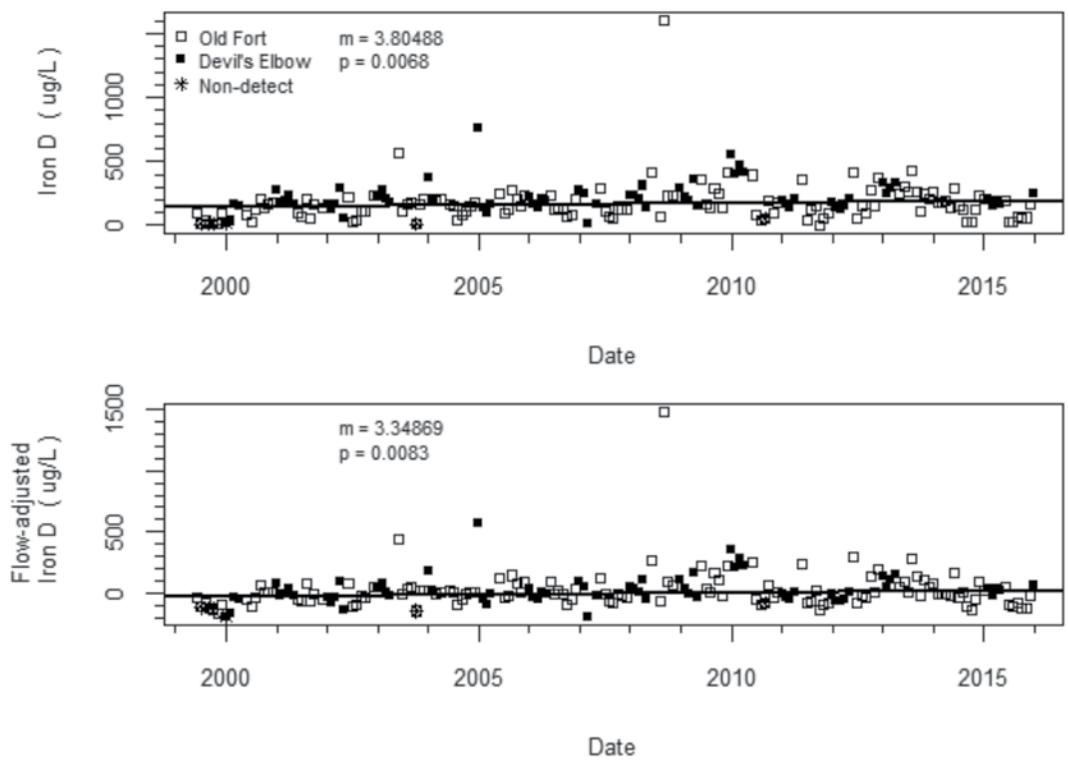


Figure 2
Time series plots of unadjusted concentrations (top) and flow-adjusted concentrations (bottom) from the Athabasca River at 'Old Fort'. Trend lines represent Akritas-Theil-Sen line and Turnbull intercept.

3.2.2 Dissolved aluminum (peak trigger exceeded in 2013)

The trend analysis did not show any changes over time in the concentration of dissolved aluminum at 'Old Fort' (Figure 3). Therefore, the management response for dissolved aluminum is closed.

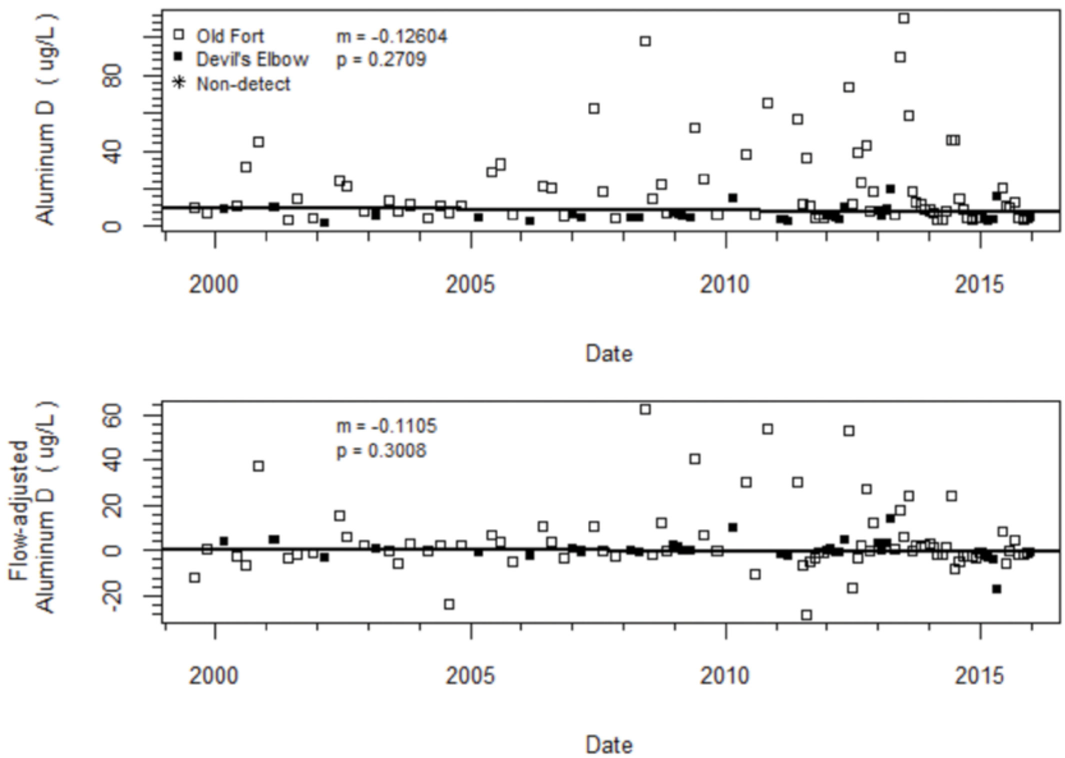


Figure 3
Time series plots of unadjusted concentrations (top) and flow-adjusted concentrations (bottom) from the Athabasca River at 'Old Fort'. Trend lines represent Akritas-Theil-Sen line and Turnbull intercept.

3.2.3 Total lithium (peak trigger exceeded in 2013)

The trend analysis did not show any changes over time in the concentration of total lithium at 'Old Fort' (Figure 4). Therefore, the management response for total lithium is closed.

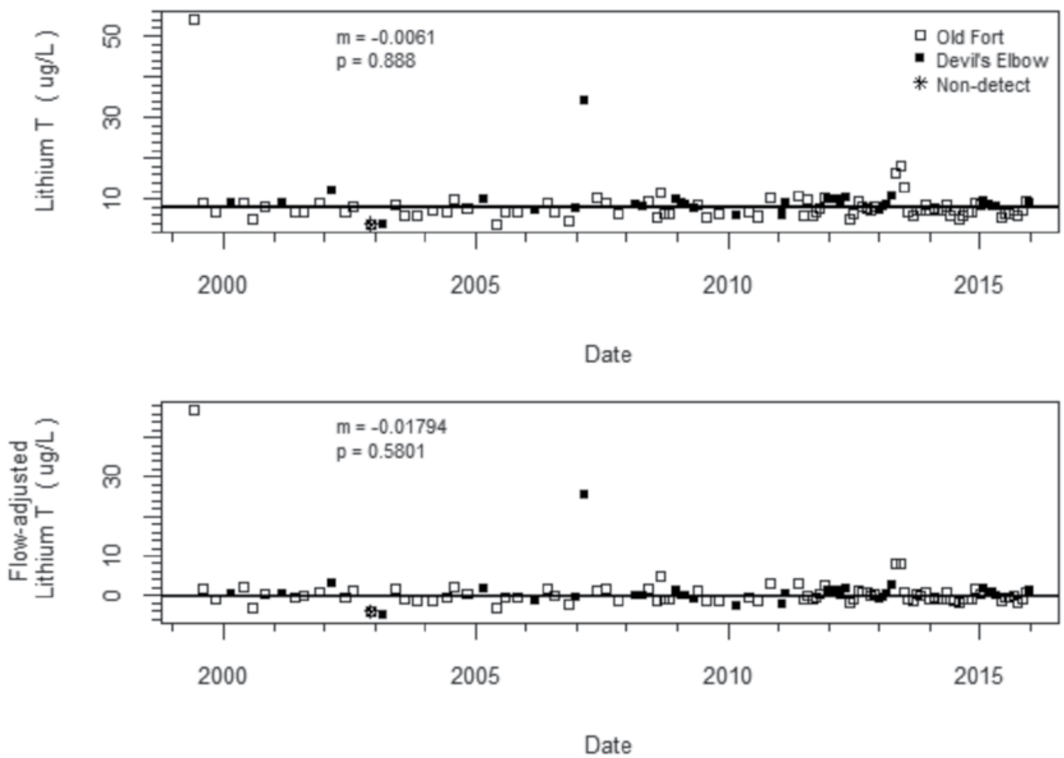


Figure 4
Time series plots of unadjusted concentrations (top) and flow-adjusted concentrations (bottom) from the Athabasca River at 'Old Fort'. Trend lines represent Akritas-Theil-Sen line and Turnbull intercept.

3.2.4 Potassium (mean trigger exceeded in 2014)

Trend analysis showed increasing trends in concentration for potassium (Figure 5). Trends were significant and also observable when adjusted for flow. Thus, potassium has been moved into the investigation phase of the management response.

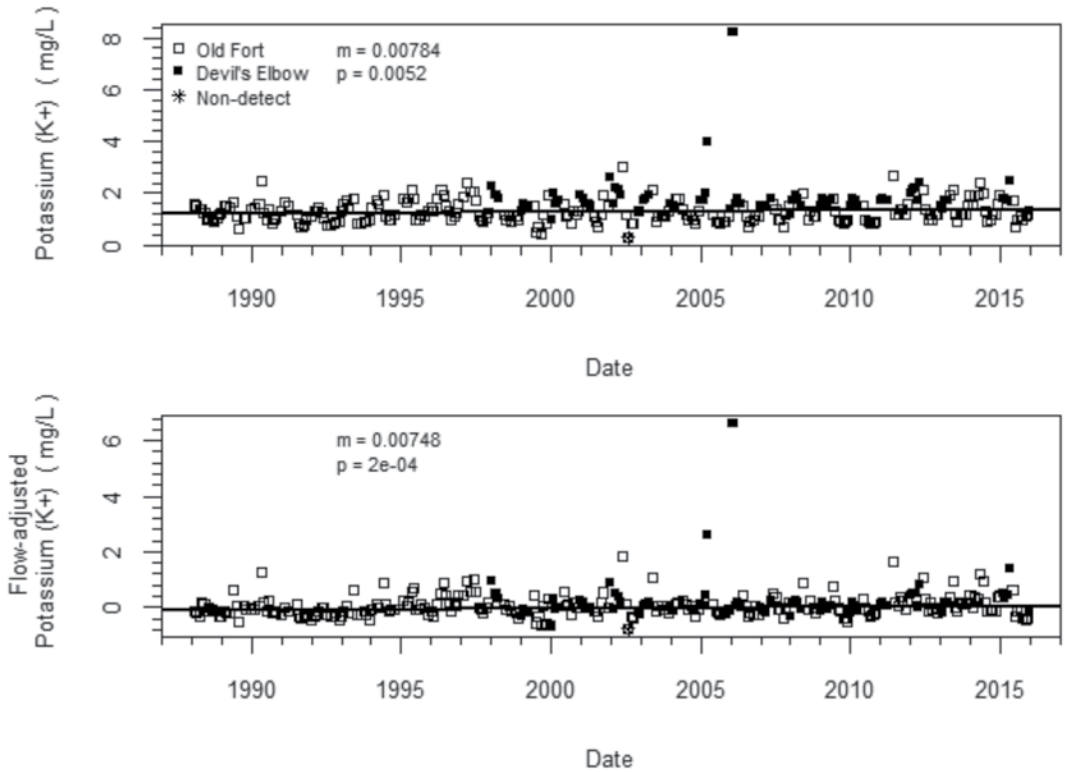


Figure 5
Time series plots of unadjusted concentrations (top) and flow-adjusted concentrations (bottom) from the Athabasca River at 'Old Fort'. Trend lines represent Akritas-Theil-Sen line and Turnbull intercept.

3.2.5 Dissolved cobalt (peak trigger exceeded in 2014)

The trend analysis did not show any changes over time in the concentration of dissolved cobalt at ‘Old Fort’ (Figure 6). Therefore, the management response for dissolved cobalt is closed.

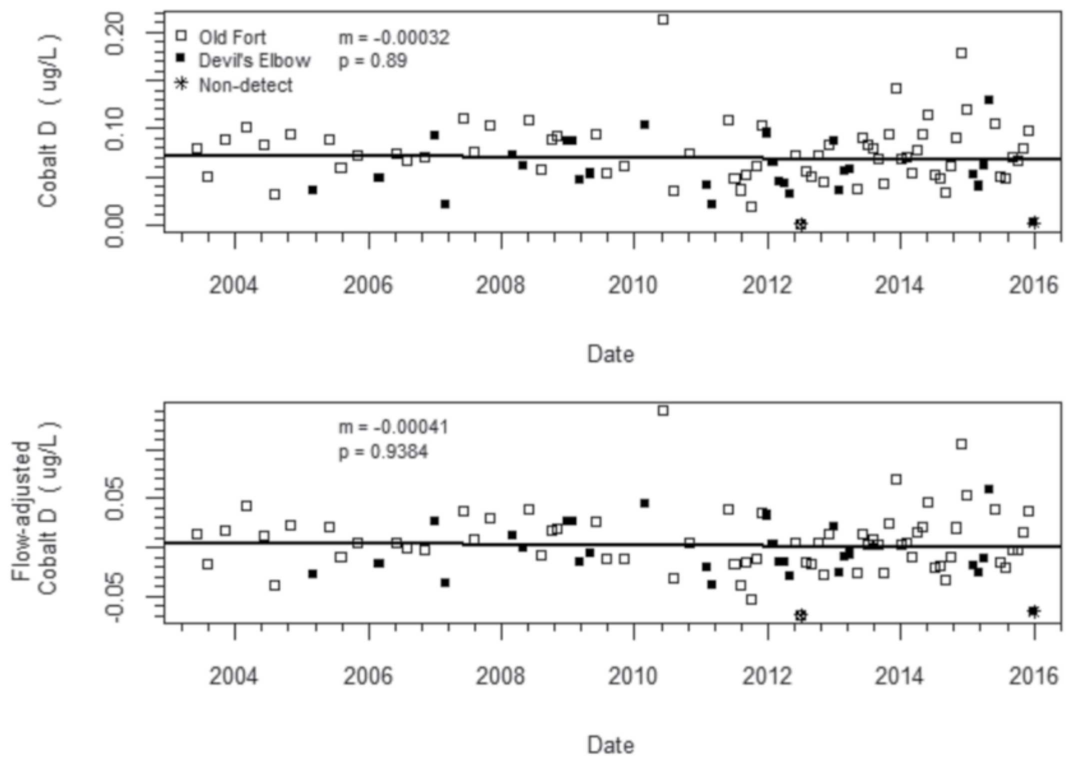


Figure 6
Time series plots of unadjusted concentrations (top) and flow-adjusted concentrations (bottom) from the Athabasca River at ‘Old Fort’. Trend lines represent Akritas-Theil-Sen line and Turnbull intercept.

3.2.6 Sulphate (mean trigger exceeded in 2014 and 2015)

A trend analysis identified increasing concentrations of sulphate from 1988 to 2015 (Figure 7). Trends were significant and observable when adjusted for flow. Thus, sulphate has been moved into the investigation phase of the management response.

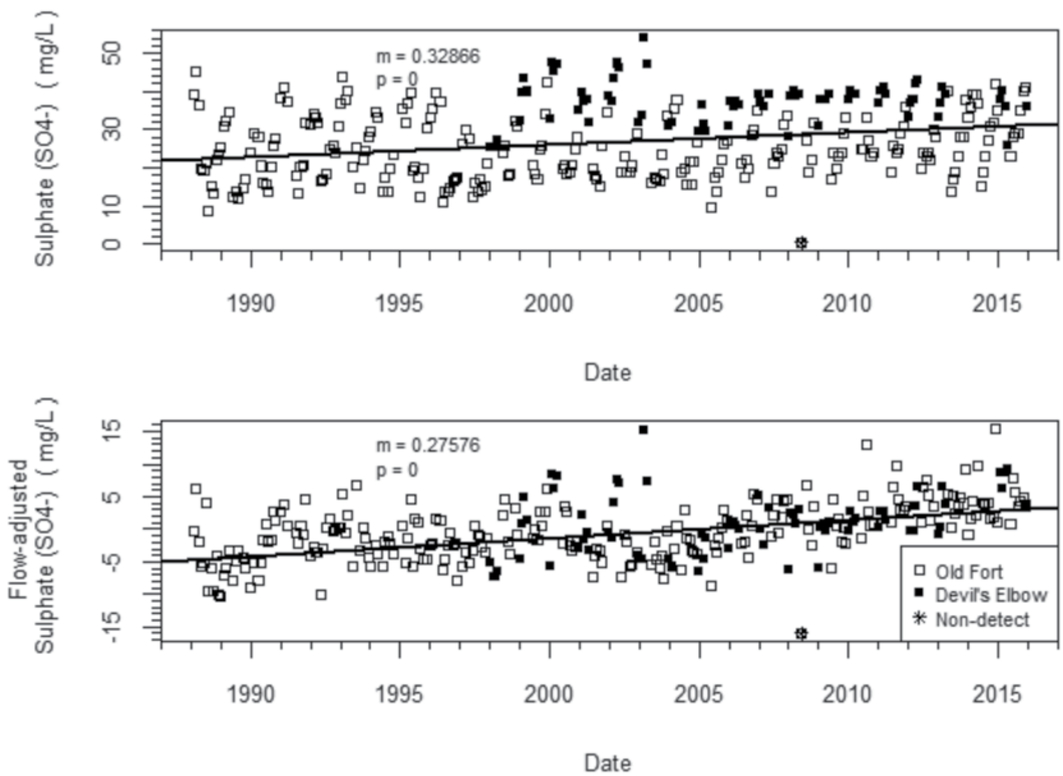


Figure 7
Time series plots of unadjusted concentrations (top) and flow-adjusted concentrations (bottom) from the Athabasca River at 'Old Fort'. Trend lines represent Akritas-Theil-Sen line and Turnbull intercept.

Potential causes of increased sulphate concentrations over time include changes in the proportion of base flows (i.e., groundwater) to tributary inputs and additional unknown sources. In previous studies, concentrations were relatively high in the headwaters of the Athabasca River and got diluted with tributary input (Noton & Saffran 1995). Sulphate was also seasonally variable.

3.2.7 Dissolved strontium (mean trigger exceeded in 2015)

The trend analysis did not show any changes over time in the concentration of dissolved strontium at 'Old Fort' (Figure 8). Therefore, the management for dissolved strontium is closed.

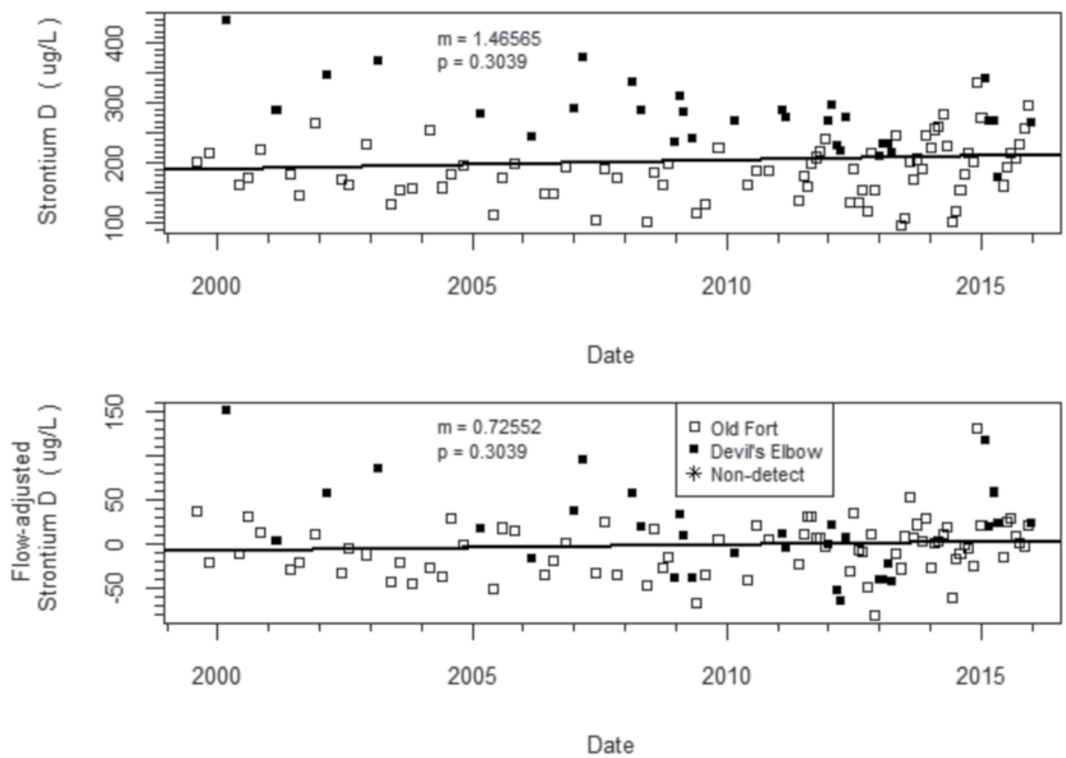


Figure 8
Time series plots of unadjusted concentrations (top) and flow-adjusted concentrations (bottom) from the Athabasca River at 'Old Fort'. Trend lines represent Akritas-Theil-Sen line and Turnbull intercept.

3.3 Investigation

The purpose of the investigation is to identify sources and/or processes that contribute to trends in surface water quality. Determining the temporal and spatial scope of observed changes to surface water quality is a key component of the investigation. Seasonal trend analysis at surface water quality monitoring stations both upstream and downstream of the location of an observed trend can help achieve this. Appendix B describes seasonal trend analysis.

Table 4 provides the status of the investigation for all indicators that have exceeded a trigger since 2012 and have been moved into the investigation phase, and identifies the relevant report.

Table 4
Status of investigation for trigger exceedances since 2012.

Year of Exceedance	Status of Investigation	Indicators	Report Title
2012	Ongoing	total nitrogen dissolved uranium	"Status of Management Response for Environmental Management Frameworks, as of May 2015", released July 2016 by Environment and Parks McKenzie, H., K. Westcott and C. Cooke. 2015. Analysis of Water Quality Conditions and Trends for Indicators Triggering in 2012 under the Surface Water Quality Framework for the Lower Athabasca River. Alberta Environment and Parks. Section 3.3 of this report.
2013	Initiated	dissolved iron	Section 3.2 and 3.3 of this report.
	Ongoing	total nitrogen dissolved uranium	see 2012 exceedences.
2014	Initiated	potassium sulphate	Section 3.2 and 3.3 of this report.
	Ongoing	dissolved uranium	see 2012 exceedences.
2015	Ongoing	dissolved uranium	see 2012 exceedences.
		sulphate	Section 3.2 and 3.3 of this report.

A seasonal statistical trend analysis was completed as part of the investigation for indicators that first exceeded triggers in 2012 and were moved into the investigation phase in 2014 (ie. total nitrogen and dissolved uranium). Indicators that were moved into the investigation phase in 2016 will be subjected to this analysis in 2017.

Components of Investigation:

1. Scope timing of the issue
   - Perform seasonal trend analysis where exceedances occurred
2. Scope spatial extent of the issue
   - Perform trend analyses on upstream water quality data
3. Identify potential sources
   - Characterize the sources and sensitivities

3.3.1 Total nitrogen (mean trigger exceeded in 2012 and 2013)

The 2016 trend analysis confirms that there is a weak increasing trend in the concentration of total nitrogen (Figure 9). The trends are more significant when the flow is adjusted. From previous study, Mckenzie et al. (2015) noted that total nitrogen concentrations upstream of Fort McMurray were trending towards higher concentrations. This is consistent with an upstream source of nitrogen.

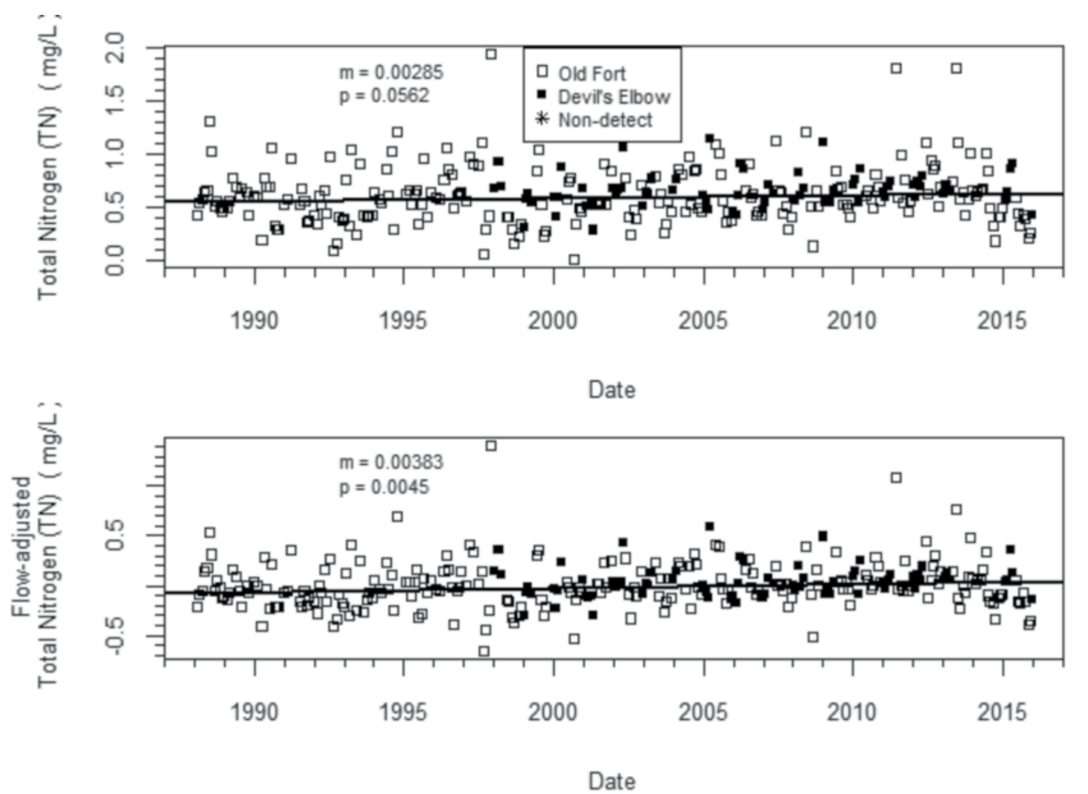


Figure 9
Time series plots of unadjusted concentrations (top) and flow-adjusted concentrations (bottom) from the Athabasca River at 'Old Fort'. Trend lines represent Akritas-Theil-Sen line and Turnbull intercept.

Seasonal Kendall trend analysis conducted at 'Old Fort' indicated that the trends in total nitrogen are only significant in certain months (Figure 10, in boxplot). The most significant increases happened in August, when concentrations are typically at their lowest (Figure 10, in bar charts). Similar conclusions were reached using flow-adjusted concentrations (Figure 11), revealing trends in both August and May. As the 2014 synoptic survey was conducted during winter (Tondu, 2017), it is unlikely that synoptic data would accurately represent the processes contributing to increasing trends in total nitrogen concentration at 'Old Fort'.

Investigation for total nitrogen will continue , as described in Section 6.1.

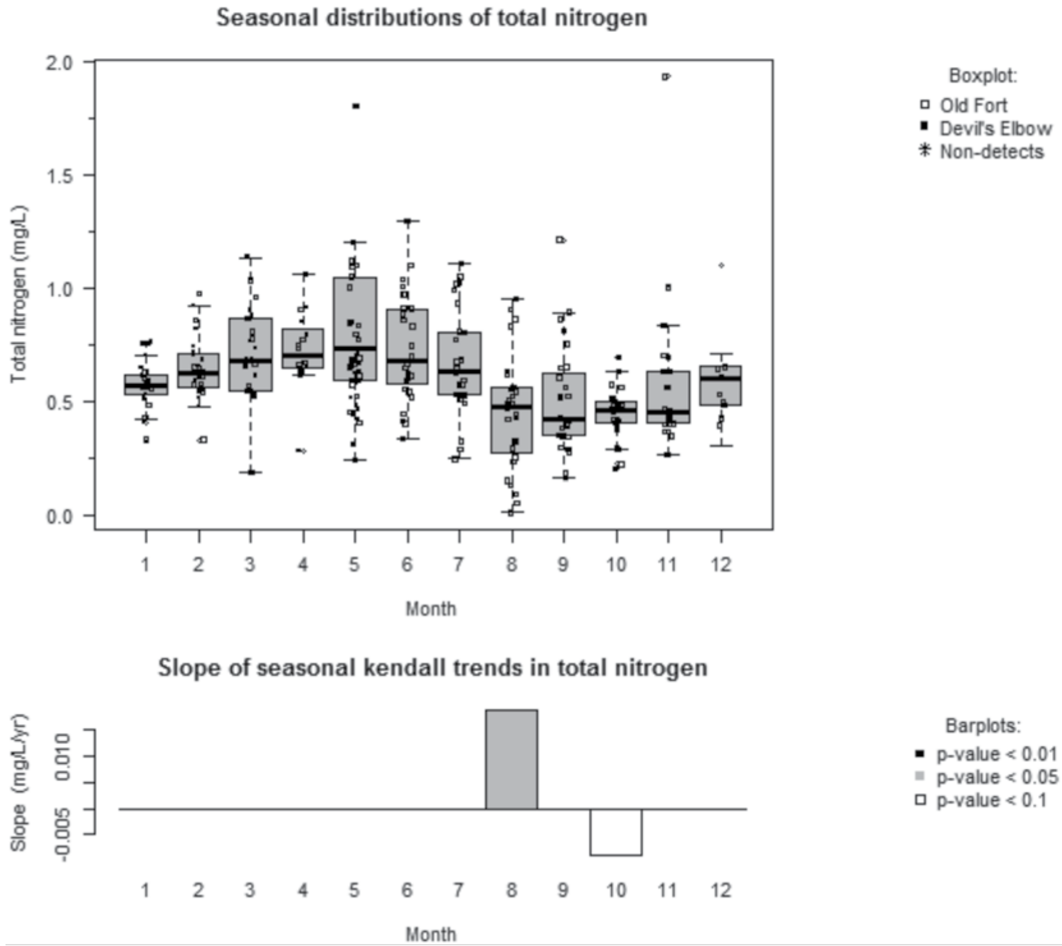


Figure 10
Boxplots of total nitrogen concentrations in the Athabasca River at 'Old Fort' (top).
Barplots of seasonal kendall trend slopes (bottom).

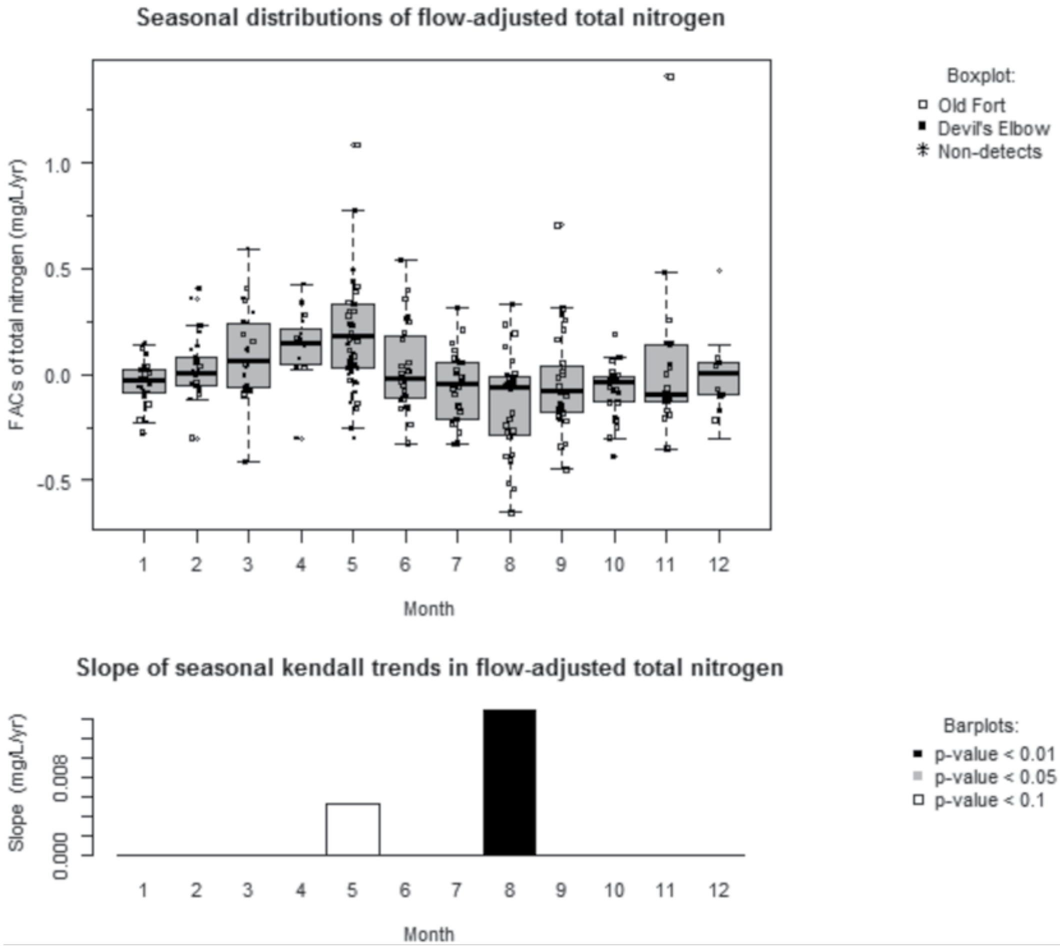


Figure 11
Boxplots of flow-adjusted total nitrogen concentrations in the Athabasca River at 'Old Fort' (top). Barplots of seasonal kendall trend slopes (bottom).

3.3.2 Dissolved uranium (mean trigger exceeded in 2012, 2103 and 2105; peak trigger exceeded 2012-2105, inclusive)

The 2016 trend analysis confirms increasing concentrations over time of dissolved uranium (Figure 12). Trends are also significant and observable in flow-adjusted concentrations (FACs).

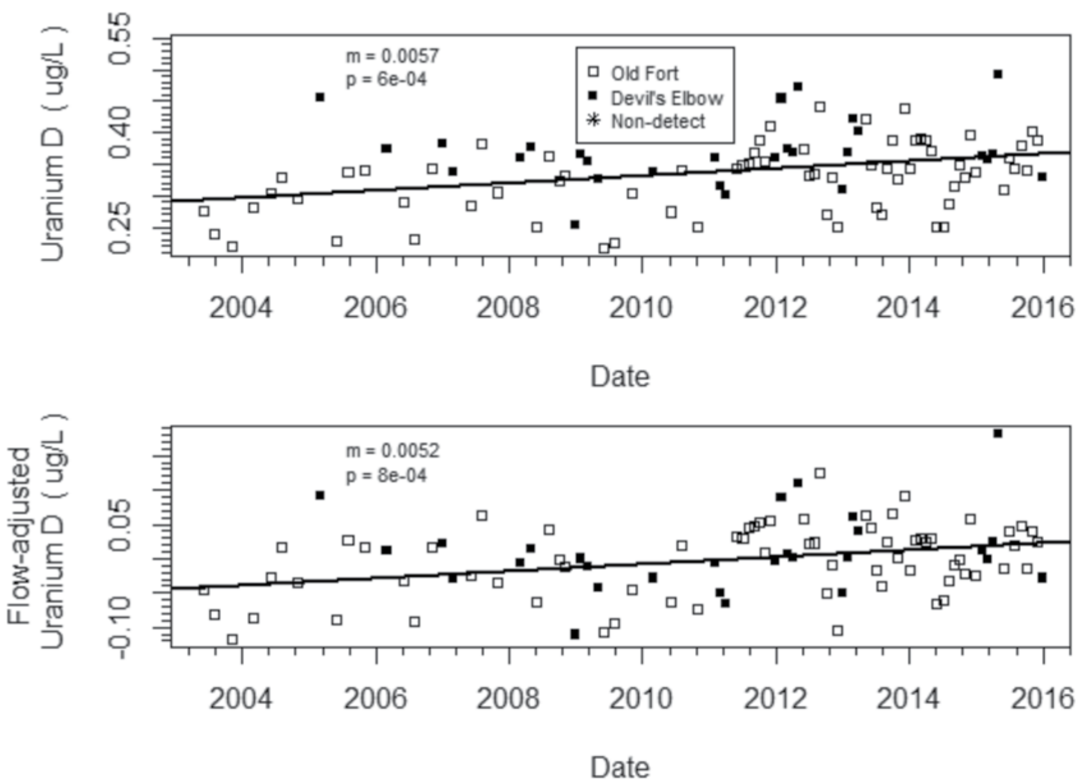


Figure 12
Time series plots of unadjusted concentrations (top) and flow-adjusted concentrations (bottom) from the Athabasca River at 'Old Fort'. Trend lines represent Akritas-Theil-Sen line and Turnbull intercept.

Dissolved uranium concentrations vary seasonally (Figure 13, in box plot). However, overall trends in concentration were not unique to any time of year (Figure 13, in bar chart). Analyses of flow-adjusted data lead to identical conclusions (Figure 14). Therefore, trends in dissolved uranium do not appear to be sensitive to seasonal factors. Alternatively, small sample sizes may have been a factor in the detection of seasonal trends.

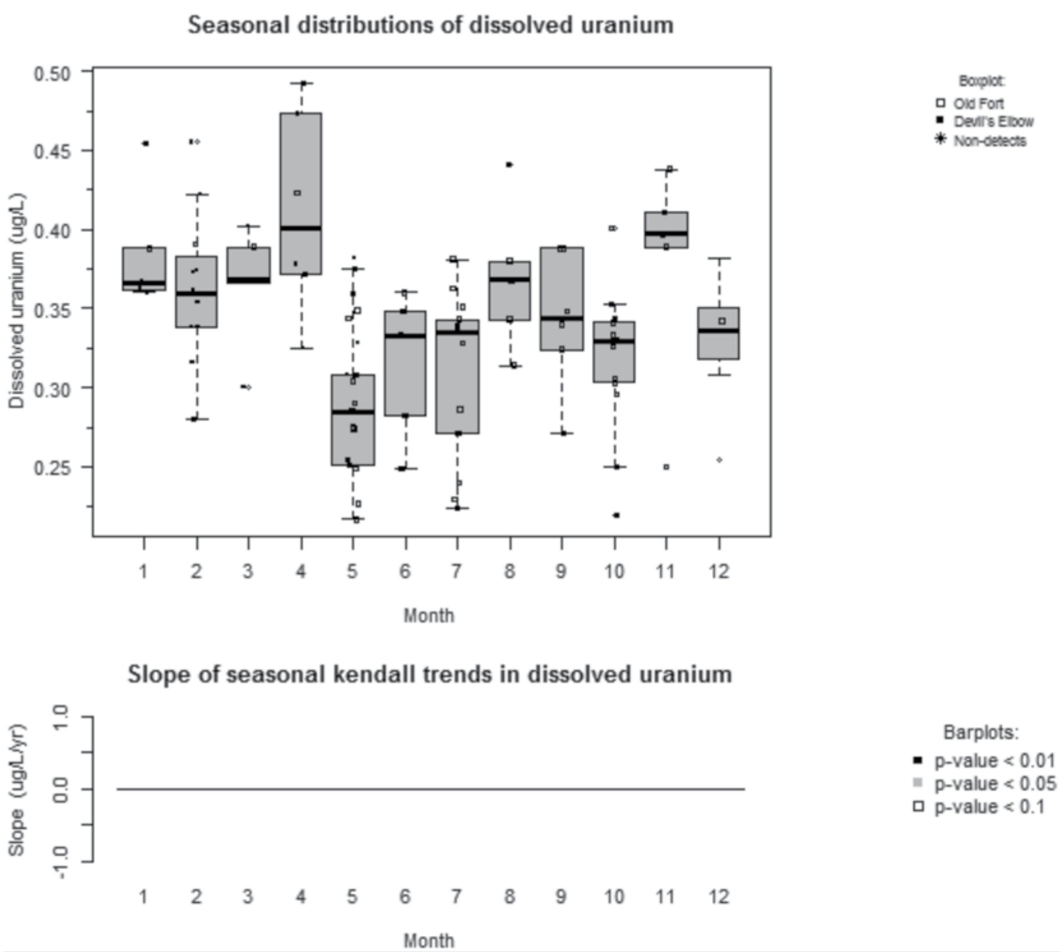


Figure 13
Boxplots of dissolved uranium concentrations in the Athabasca River at ‘Old Fort’ (top). Barplots of seasonal kendall trend slopes (bottom).

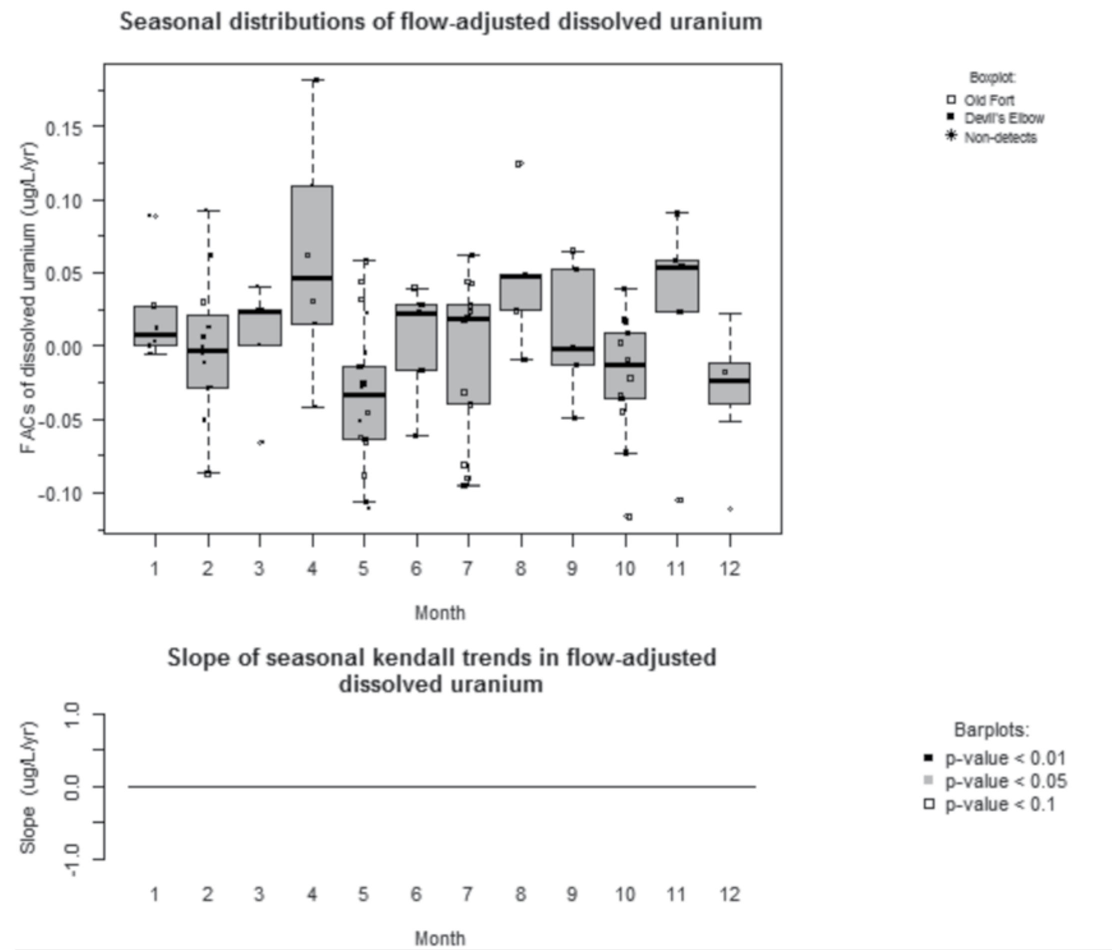


Figure 14
Boxplots of flow-adjusted dissolved uranium concentrations in the Athabasca River at ‘Old Fort’ (top). Barplots of seasonal kendall trend slopes (bottom).

The synoptic survey showed that higher concentrations of dissolved uranium tend to occur in the upstream reaches of the Athabasca River (Tondu, 2017). As one travels downstream, dissolved uranium typically becomes more dilute. Thus, dilution by tributaries and runoff are likely factors affecting dissolved uranium concentrations. In keeping with this, dissolved uranium was more concentrated upstream of Fort McMurray than at ‘Old Fort’ (AEP 2016b). However, concentrations have increased at both sites. Therefore, either a decline in tributary inflows (dilution) or additional sources upstream of Old Fort could contribute to changes in concentration at ‘Old Fort’.

The investigation of dissolved uranium will continue, as described in Section 6.1.

3.4 Management Actions

The need for management actions and the selection of appropriate management actions will be determined based on the results of the investigation phase of the management response.

3.5 Status of Management Response

As of December 2016, the status of management response is as follows:

- Total nitrogen and dissolved uranium remainin the investigation phase;
- Potassium, sulphate and dissolved iron have been moved into the investigation phase;
- Management response for dissolved strontium, total lithium, total aluminum and dissolved cobalt have been closed after the preliminary assessment; and
- The management response for dissolved lithium is closed (as of May, 2015).

4.0 Next Steps

4.1 Indicators under Investigation

Total nitrogen, dissolved uranium, potassium, sulphate and dissolved iron are under investigation. In 2017, the investigation will focus on delineating the spatial extent of the observed trends by conducting statistical trend analysis on flow-adjusted and unadjusted data from monitoring stations upstream of ‘Old Fort’. The seasonality of observed trends at ‘Old Fort’ and other stations will also be assessed to better understand the temporal patterns of the concentration of each indicator and support the identification of potential sources. Following the spatial and temporal scoping of potential sources, future steps may include higher resolution monitoring to refine the understanding of potential sources and processes contributing to trends. It is anticipated that this monitoring may be initiated in 2018.

Understanding the influence of hydrology on water quality regime requires an understanding of the various flow contributions from the tributaries. Archived data from the Regional Aquatics Monitoring and Oil Sands Monitoring programs provides extensive, subregional dataset at higher spatial resolution and could be leveraged during the investigation phase of the management response. Analyses of historical discharge within some tributaries are possible. The GOA also has data from past winter synoptic surveys along the Athabasca River. Investigations will use data from these sources where relevant.

4.2 Indicators whose Management Response is Closed

Trend assessment determined that trigger exceedances for dissloved aluminum, cobalt, lithium, strontium, and total lithium do represent long term change in surface water quality condition. No investigation will be conducted and the management response for these indicators is closed.

A report updating the status of management response will be made publically available within one year.

5.0 References

Alberta Environment and Parks (AEP). 2016b. Lower Athabasca Region: Status of Management Response for Environmental Management Frameworks as of May 2015. ISBN: 978-1-4601-2711-1.

Alberta Environment and Parks. 2017. 2015 Status of Water Quality for the Athabasca River, Alberta at the Old Fort Monitoring Station.

Alberta Environment and Sustainable Resource Development (AESRD) 2012. Lower Athabasca Region: Surface Water Quality Management Framework for the Lower Athabasca River.ISBN: 978-1-4601-0530-6.

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McKenzie, H., K. Westcott and C. Cooke. 2015. Analysis of Water Quality Conditions and Trends for Indicators Triggering in 2012 under the Surface Water Quality Framework for the Lower Athabasca River. Alberta Environment and Parks.

Noton, L.A., Saffran, K.A. 1995. Water quality in the Athabasca River system 1990-93, Edmonton: Alberta Environment.

Tondu, J.M.E. 2017. Winter spatial water quality patterns in the Athabasca River: synoptic survey results. Alberta Environment and Parks. Draft.

6.0

Appendices

Appendix A: Summary of Previous Status of Management Response Reports

1. Status of Management Response as of March 2014

The first Status of Management Response Report for the Lower Athabasca Region was released in 2014 (AESRD 2014b). This report summarized the initial work undertaken as part of the preliminary assessment of the management response to the trigger exceedences observed in 2012, which were reported in the first Status of Ambient Conditions Report (AESRD 2014a). Initial work undertaken as part of the preliminary assessment was a comparison of the 2012 data to historical datasets, both at the 'Old Fort' station and the upstream of Fort McMurray station.

1.1 Preliminary Assessment

1.1.1 Comparison of Historical and Upstream Data for 2012 Trigger Exceedances

Total nitrogen
A 26 per cent increase in the annual mean (compared to historical mean) was found for total nitrogen at both the 'Old Fort' and upstream of Fort McMurray stations. The 2012 mean was higher than all but one other year in the historical data set at the 'Old Fort' station, and higher than all but two other years at the upstream of Fort McMurray station. From 1988 to 1999 annual means were higher at the upstream of Fort McMurray station 58 per cent of the time; but since 2000 the annual mean has consistently been higher at the 'Old Fort' station. This suggests either decreases in total nitrogen loading upstream of Fort McMurray, or increases in nitrogen loading downstream of Fort McMurray, since 2000.

Dissolved uranium
The annual mean concentration of dissolved uranium was 15 per cent and 12 per cent higher than historical means at the 'Old Fort ' and upstream of Fort McMurray stations, respectively. The 2012 mean was higher than all annual means in the historic dataset (2003-2009) at 'Old Fort', and third highest at the upstream of Fort McMurray station. The concentration of dissolved uranium has been consistenly higher at the upstream of Fort McMurray station than at the 'Old Fort' station. This may suggest that significant sources of dissolved uranium are not present downstream of Fort McMurray.

Three out of 12 samples were above the historical 95th percentile at ''Old Fort', while five out of 12 samples were above the historical 95th percentile at the upstream of Fort McMurray station.

Dissolved lithium
Three out of 12 dissolved lithium samples from 2012 were above the historical 95th percentile at ''Old Fort', while no samples were above the historical 95th percentile at the upstream of Fort McMurray station. The occurrance of samples above the 95th percentile at 'Old Fort' was considered unusual as only four samples in the historical data set (1999-2009) exceeded the 95th percentile.

1.2 Status of Management Response and Next Steps

As of March 2014, the preliminary assessment for total nitrogen, dissolved uranium and dissolved lithium was ongoing. Trend assessment for flow-adjusted and unadjusted data was identified as a next step to complete the preliminary assessment.

2. Status of Management Response as of May 2015

The second Status of Management Response Report for the Lower Athabasca Region was released in 2016, current to May, 2015 (AESRD 2016b). This report summarized: 1) the trend analysis undertaken to complete the preliminary assessment for 2012 trigger exceedences; and 2) initial steps of the preliminary assessment of the management response to the trigger exceedences observed in 2013 and 2014. The latter included a comparison of 2013 and 2014 data with the historical dataset at both 'Old Fort' and the upstream of Fort McMurray station. Trigger exceedances for 2013 and 2014 were identified in AEP (2016a) and AEMERA (2015), respectively, and are shown in Table 1. A technical report, describing the trend analysis, is provided by McKenzie et al. (2015).

2.1 Preliminary Assessment

2.1.1 Trend Analysis for 2012 Trigger Exceedances

Total nitrogen
Trend assessments showed increasing trends in total nitrogen concentrations (flow adjusted and unadjusted) at 'Old Fort'. Other studies of nitrogen have documented nutrient enrichment in, and downstream of the Athabasca River (Hebben 2009; Glozier et al. 2009). Similar trends were also found at the upstream of Fort McMurray station. A trigger exceedance was again observed for total nitrogen in 2013. Total nitrogen was therefore moved from preliminary assessment into investigation.

Dissolved uranium
The initial trend analysis found weak trends in unadjusted concentrations of dissolved uranium, but not in flow-adjusted ones (Mckenzie et al. 2015). The analysis of data from upstream of the Fort McMurray station found no significant trends in concentrations (flow adjusted and unadjusted) at the time. Thus, variability in dissolved uranium was thought to originate between Fort McMurray and 'Old Fort'.

However, since 2012 conditions have continued to change at 'Old Fort'. Dissolved uranium has exceeded water quality triggers in both 2013 and 2014 and was therefore moved from preliminary assessment into investigation.

Dissolved lithium
No trends were observed for dissolved lithium at the 'Old Fort' or the upstream of Fort McMurray stations for either flow-adjusted or unadjusted data. Concentrations are highly (inversely) correlated with flow. The management response for dissolved lithium was therefore closed.

2.1.2 Comparison of Historical and Upstream Data for new 2013 and 2014 Trigger Exceedances

Dissolved iron (mean exceedance in 2013) – annual mean concentration of dissolved iron was higher than the historical mean at 'Old Fort', but not at the upstream of Fort McMurray station. The 2013 mean was the third highest in the historical dataset. With the exception of 1999, annual mean concentrations have been higher at Old Fort than the upstream of Fort McMurray station.

Total lithium (peak exceenance in 2013) – three of the 2013 monthly samples exceeded the 95th percentile of the historical data set at 'Old Fort'; whereas only one sample exceeded the historical 95th percentile at the the upstream of Fort McMurray station. The 2013 mean concentration did not exceed the maximum historical mean concentration.

Total aluminum (peak exceedance in 2013) - three of the 2013 monthly samples exceeded the 95th percentile of the historical data set at 'Old Fort'; whereas no samples exceeded the historical 95th percentile at the the upstream of Fort McMurray station. The 2013 mean concentration exceeded the maximum historical mean concentration by 13 per cent.

Sulphate (mean exceedance in 2014) – The 2014 annual mean for sulphate was higher than the historical mean at 'Old Fort'; however, this is known to occur routinely. Annual mean concentrations were slightly higher than the historical mean at the upstream of Fort McMurray station; however samples were not collected in March or April of 2014 due to unsafe conditions, therefore the annual mean is temporally biased.

Potassium (mean exceedance in 2014) - The 2014 annual mean for potassium was higher than the historical mean at 'Old Fort'; however, this is known to occur routinely. Annual mean concentrations were slightly higher than the historical mean at the upstream of Fort McMurray station; however samples were not collected in March or April of 2014 due to unsafe conditions, therefore the annual mean is temporally biased.

Dissolved cobalt (peak exceedance in 2014) - Three of the 2013 monthly samples for dissolved cobalt exceeded the 95th percentile of the historical data set at 'Old Fort'; whereas no samples exceeded the historical 95th percentile at the the upstream of Fort McMurray station. These three values were all above the maxiumum historical concentration. The 2013 mean concentration exceeded the maximum historical mean concentration by 13 per cent.

2.2 Status of Management Response and Next Steps

As of May 2015, the status of management response was as follows:

- The management response for dissolved lithium was closed;
- Total nitrogen and dissolved uranium were moved into the investigation phase of the management response; and
- Dissolved iron, total lithium, total aluminum, sulphate, potassium and dissolved cobalt remained in the preliminary assessment phase of the management response.

The next steps identified for the management response were trend analysis of flow-adjusted and unadjusted data to completed the preliminary assessment for indicators that first had exceedances in 2013 and 2014, and the analysis of the winter synoptic survey results to advance the investigation for total nitrogen and dissolved uranium.

3.0 References

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Appendix B: Description of trend analysis and flow-adjustment

Trend Analysis

Trend analysis, with respect to the Framework, is a test performed using linear regression on a time series of water quality observations. In the trend analysis, the date of sample collection is the independent variable, and the concentration (of flow-adjusted concentration) is the dependent variable. The analysis determines if a trend is stable, increasing, or decreasing by calculating the slope and significance of the regression line.

The Seasonal Kendall trend test (Hirsch et al. 1982; Hirsch and Slack 1984) tests for trends in data collected over time. The analysis isolates data from each month and performs a trend analysis over several years. Thus, trend analyses are conducted using data only from January, then February, and so on for each month separately. The analysis returns the slope of trends for each month, over all the years in the dataset. Figures in this report present only seasonal trend slopes with a 10 per cent or less probability of resulting from random chance.

Flow Adjustment

Water quality measurements from rivers capture (some portion of) both suspended solids and dissolved ions. Flow provides the energy that suspends solids in water. Therefore, changes in flow often influence water quality measurements from rivers. This influence is accounted for by undertaking flow-adjustment of the sampled water quality concentrations. Flow adjustment simply means that the effects of flow on the changes in water quality over the period of analysis are accounted for.

In flow-adjustment of the sampled water quality concentrations, residuals are calculated by subtracting concentrations typically observed over a range of flow rates. These residuals, known as flow-adjusted concentrations (FAC), exclude the temporal (monthly or seasonal) influence of flow. In doing so, FACs highlight chemical changes caused by other factors such as effluent and land use changes within the watershed or regional boundary under assessment.

If a trend in the sampled water quality concentration does not also occur in FACs, the trend likely reflects the natural effect of flow. However, if trends detected in the sampled water quality concentrations are also observed in FACs, then the seasonal or monthly changes in streamflow flow cannot account for the observed trend. This eliminates changes in the streamflow regime as a potential cause of change in surface water quality and necessitates further investigation under the framework.

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