technical supporting document for the capital region air quality management framework

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1 Introduction

This *Technical Supporting Document* reports on the scientific and technical work conducted during the development of the *Capital Region Air Quality Management Framework* (*The Framework*). *The Framework* was prepared by a multi-stakeholder Steering Committee composed of representatives from municipalities, industry, non-governmental organizations, airsheds and federal and provincial governments. The stakeholders relied on the technical support described in this report as they developed their shared vision of ambient air quality management in the Capital Region. That shared vision is based on cumulative effects management and the triple-bottom line approach to balancing social and economic development with environmental protection. For *The Framework* and *Technical Supporting Document*, the Capital Region is defined by the boundary of the Edmonton Capital Region Board including Elk Island National Park and encompassing 25 municipalities.

The Steering Committee began its collaborative work to develop *The Framework* in January 2011 and in April 2011 assigned the role of providing scientific and technical support to a Technical Work Group. This group was comprised of scientific and technical experts, and was supported by *The Framework's* secretariat. Members shared expertise in interpreting monitoring information and air quality modelling. The Technical Work Group met regularly to:

- review data and bring analysis, findings and recommendations back to the Steering Committee
- interpret and use air quality modeling data to answer questions posed by the Steering Committee
- interpret and understand methodology regarding the development of triggers and limits
- review current standards and their achievement determination
- interpret air monitoring data in relation to triggers and limits
- identify gaps and future requirements for analysis to refine *The Framework*.

The group prepared Appendix C of *The Framework* as well as this *Technical Supporting Document*, which provides the scientific and technical methodologies, assessments and evaluations related to managing ambient air quality. The work is presented as follows:

- characterization of monitoring in the Capital Region (Chapter 2)
- evaluation and development of triggers for The Framework and assessment of current monitoring data against developed triggers (Chapter 3)
- examination of the importance of transboundary and naturally occurring nitrogen dioxide (NO_2) for the Capital Region (Chapter 4)
- review of air quality modelling conducted for the Capital Region and identification of additional work (Chapter 5).

The Framework describes a cumulative effects management approach to four contaminants of concern: nitrogen dioxide (NO_2), sulphur dioxide (SO_2), fine particulate matter ($PM_{2.5}$) and ozone (O_3). *The Framework* adopted particulate matter and ozone trigger values set by the Clean Air Strategic Alliance's *Particulate Matter and Ozone Management Framework.* This *Technical Supporting Document* describes the setting of trigger values for nitrogen dioxide and sulphur dioxide.

2 Review: Current Standards and Methods

The factors affecting air quality monitoring in the Capital Region vary according to the location of the monitoring station in the largely urban environment. Peak periods of vehicle traffic impact air quality at specific times of the day. Additional factors include other emission sources, topography, land cover, meteorology, amount of atmospheric chemical reactions, and mixing or amount of deposition.

Some areas in the region have well-established ambient monitoring networks that collect data for a number of contaminants. Monitoring organizations located in the Capital Region make information about ambient air concentrations available on their websites as follows.

- Alberta Environment and Sustainable Resource Development: www.environment.alberta.ca
- Fort Air Partnership: www.fortair.org
- Lehigh Station: www.lehighinland.com/inland
- Strathcona Industrial Association: www.sia.ab.ca
- West Central Airshed Society: www.wcas.ca

Ambient air concentration information is also available on the Clean Air Strategic Alliance's data warehouse website at:

- CASA Data Warehouse: www.casadata.org

The two methods widely used for monitoring the four contaminants of concern in the Capital Region are passive air samplers and continuous air analyzers. Passive air samplers are inexpensive and have fewer logistical challenges than continuous air analyzers, such as a need for ongoing electrical power and mobility. Passive air samplers provide monthly average concentrations and are best used as an indicator for spatial information of pollutant concentrations. Passive air samplers are not used to measure fine particulate matter concentrations within the Capital Region. In contrast, continuous air analyzers provide higher temporal resolution that is typically reported as one-hour averages. These analyzers, however, have more limited deployment opportunities as they require more maintenance, are costly and have logistical constraints. The distribution of continuous monitoring in the Capital Region is illustrated in Figure 1.

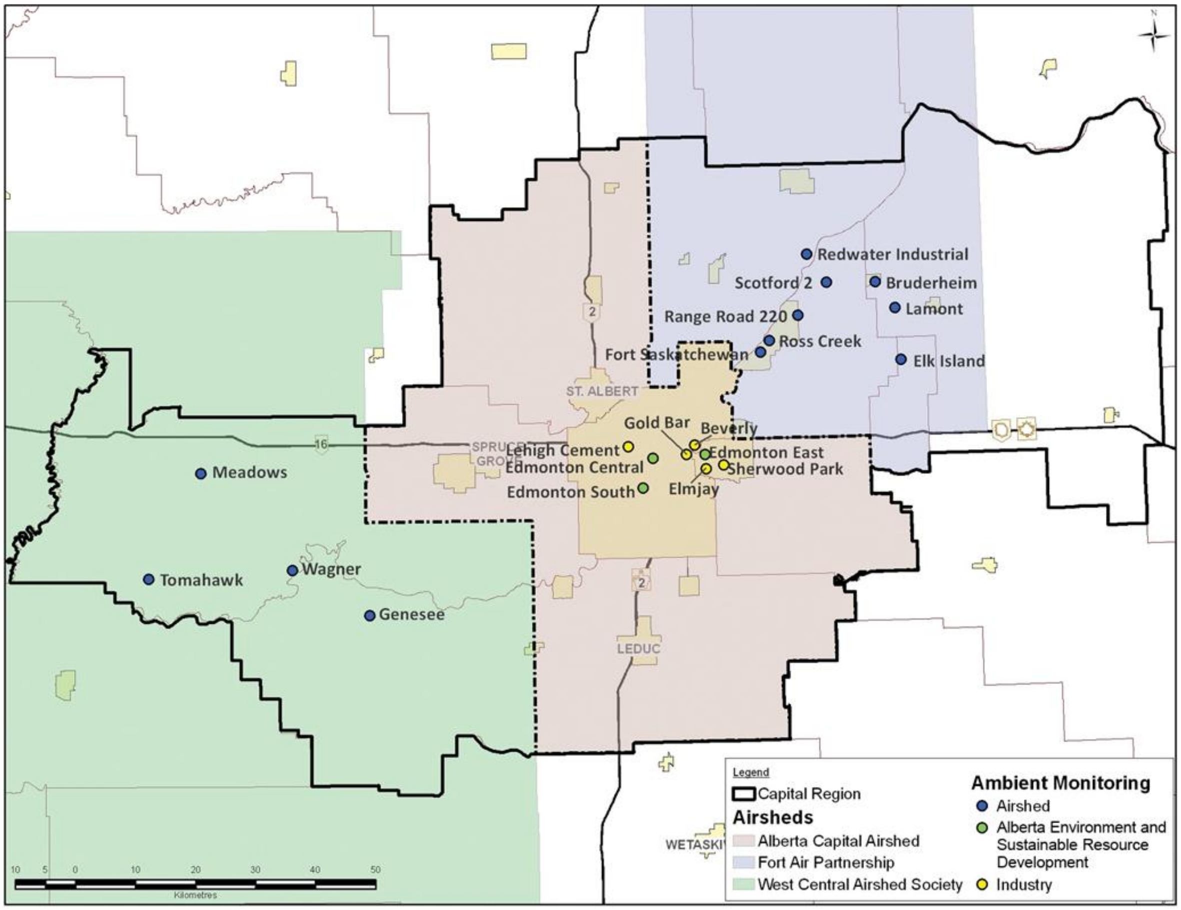


Figure 1: Location of Air Monitoring Stations Equipped with Continuous Analyzers

2.1 Characterization of Continuous Monitoring

The *Draft Lower Athabasca Region Air Quality Management Framework* classified ambient air monitoring stations in that region to determine which management tool would be most effective for each station type (i.e., industrial or community monitoring stations). The Technical Work Group was asked to determine whether ambient air monitoring stations within the Capital Region could also be classified by type.

Classification of monitoring stations within the Capital Region was not as straightforward as it was for the Lower Athabasca Region. The task of the Technical Work Group was to examine methodologies for classifying stations within the Capital Region relative to the measured substances that were the focus of *The Framework*. The intent was to assign management actions as a function of the type of station (community or industrial).

To characterize monitoring and gain a better understanding of monitored data in the Capital Region, an analysis of the most recent seven years of data (2004-2010) for NO_2 and SO_2 was conducted.

Although data from the Power monitoring station operated by West Central Airshed Society was included for this characterization analysis, the station was subsequently determined to be outside the Capital Region boundary. Data from the Power monitoring station was not considered in the final development of the triggers or the regional assessment. Additional criteria used for excluding data are outlined in Section 3.1.

2.2 Ambient NO_2 Concentrations

There were notable variations in the one-hour average NO_2 concentrations measured within the Capital Region (Figure 2). Lower NO_2 concentrations were typically measured at monitoring stations farther out from the Edmonton area with one-hour average NO_2 concentrations at Elk Island station among the lowest measured for the region. The Elk Island monitoring station is located within Elk Island National Park where there are limited NO_2 sources in the immediate vicinity.

The highest NO_2 concentrations were generally measured at stations affected by vehicle emissions, namely stations within Edmonton and Fort Saskatchewan. The median (50^{th} percentile) one-hour NO_2 concentrations at these stations for the period examined were greater than or equal to 8 parts per billion (ppb). Although elevated NO_2 concentrations were more frequently observed at the Edmonton and Fort Saskatchewan stations, resulting in higher median concentrations, peak one-hour average NO_2 concentrations (99^{th} percentile) greater than 30 ppb were observed at a number of the other stations within the region.

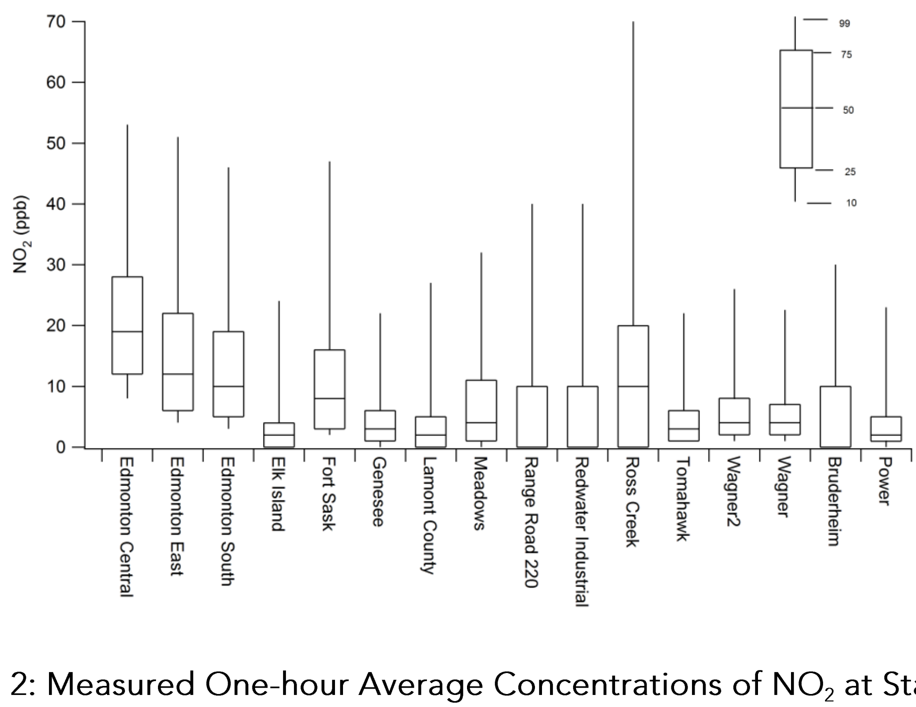


Figure 2: Measured One-hour Average Concentrations of NO_2 at Stations Located within the Capital Region

Note: The box plot was generated using data collected between 2004 and 2010.
The legend indicates percentiles associated with the figure.

Examination of the diurnal trend of one-hour average NO_2 concentration for the seven years studied (2004-2010) revealed that a number of the stations had diurnal variations indicative of impact from commuter traffic emissions. That is to say, an increase in NO_2

concentrations was observed in the early morning, peaking between 7 to 9 am (local time) and decreasing mid-morning with the onset of the breakup of the nocturnal boundary layer inversion. This variation was observed for the full dataset, but was more clearly defined during the winter months. Figure 3 illustrates diurnal variation for the winter months.

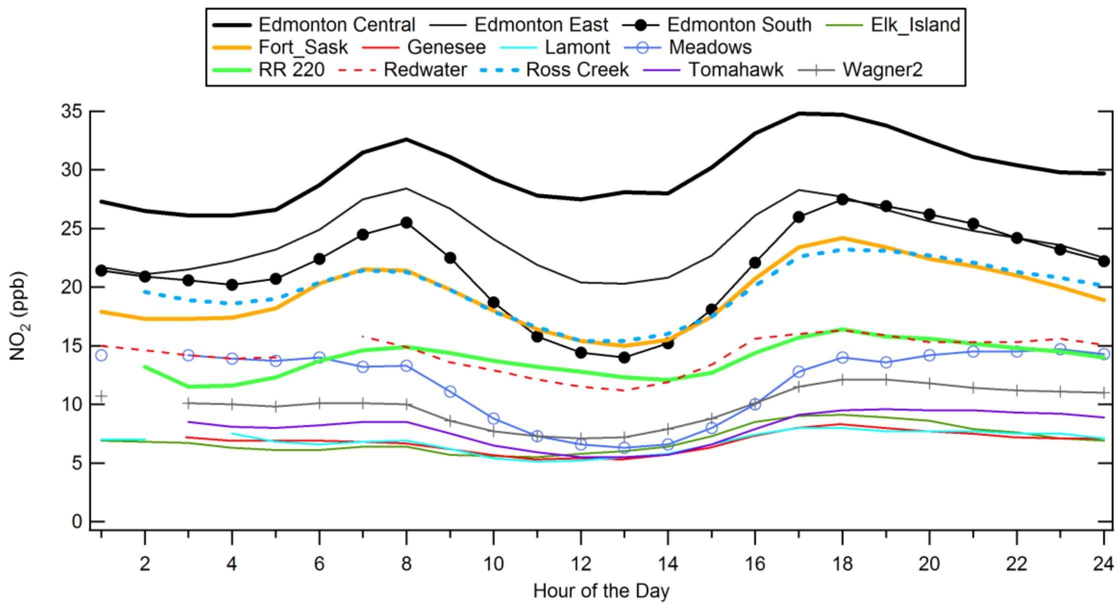


Figure 3: Diurnal Variation of NO_2 Measured at Stations within the Capital Region

Note: Data represents winter months between January 2004 and December 2010.

The height of the morning peak (*H*) was used to identify those stations that exhibited the commuter traffic profile and was calculated using Equations 1 to 3.

$$H = P - T \qquad \text{Equation 1}$$

$$P = \max\left([NO_2]_a, \ldots, [NO_2]_b\right) \qquad \text{Equation 2}$$

$$T = \frac{1}{n}\sum_{i=1}^{n}[NO_2]_i \qquad \text{Equation 3}$$

Where:
P is maximum measured NO_2 concentration between 6 am and 11 am
T is the average NO_2 concentration measured between 2 am and 5 am
n is the number of hours between 2 am and 5 am
$[NO_2]_i$ is the NO_2 concentration for each of the hours.

Peak heights calculated for the various monitoring locations are presented in Table 1. Peak heights greater than 4 ppb were considered to be affected by commuter traffic emissions. Heights of less than 4 ppb were considered to have been impacted minimally, and those stations with no clearly evident peaks were thought to have limited or no impact from commuter traffic.

Table 1. Morning Peak Height Analysis of NO_2 Concentrations

Station	Morning Trough (ppb)	Peak Height (ppb)	Amplitude (ppb)	Class
Lamont County	7	7	0	M
Elk Island	7	6	0	M
Power	7	7	0	M
Genesee	7	7	0	M
Meadows	14	14	0	M
Wagner2	10	10	0	M
Tomahawk	8	9	0	M
Redwater Industrial	14	16	2	L
Ross Creek	19	21	2	L
Range Road 220	12	15	3	L
Gold Bar	23	27	4	T
Fort Saskatchewan	17	21	4	T
Edmonton South	21	25	5	T
Sherwood Park	16	22	6	T
Edmonton Central	26	33	6	T
Edmonton East	22	28	7	T
Comparison Stations				
Calgary Central 2	28	35	6	
Calgary Northwest	19	25	6	
Calgary East	29	39	10	

Note: *Bruderheim and Lehigh Cement did not have one full year of data for analysis

M= Minimal effect by urban transportation
L = Limited effect by urban transportation
T = Peak effect by urban transportation

2.2.1 Data Distribution Assessment

The distribution of one-hour NO_2 concentrations measured in the Capital Region was examined. Figure 4 illustrates the distributions for the region as a whole and grouped according to the effects of urban transportation – as minimal (M), limited (L) or peak (T), as indicated in Table 1. All distributions were log normal. The distribution of one-hour average NO_2 concentration for the region as a whole was very similar to the areas characterized as having limited transportation impact. At those stations considered to have minimal impact from commuter vehicles, the measured one-hour average NO_2 concentrations were generally less than 5 ppb.

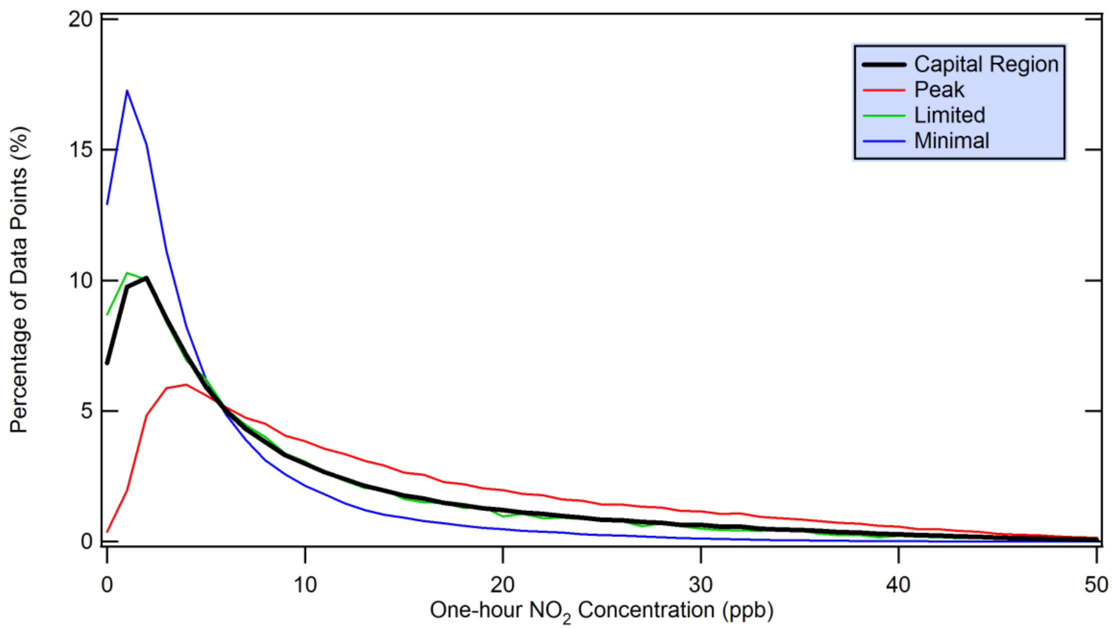


Figure 4: Distribution of One-hour Average NO_2 Concentrations in the Capital Region

2.3 Ambient SO_2 Concentrations

A review of one-hour average SO_2 concentrations collected at monitoring stations within the Capital Region indicated that ambient SO_2 concentrations are low. As illustrated in Figure 5, the 75th percentile SO_2 concentrations at all stations within the Capital Region for the seven years examined were lower than 2 ppb. However, elevated one-hour concentrations greater than 10 ppb were measured at a number of stations. The highest SO_2 99th percentile concentration of 77 ppb was measured at Redwater Industrial. This station is known to measure episodic elevated SO_2 concentrations linked to dispersion being impeded by building downwash.

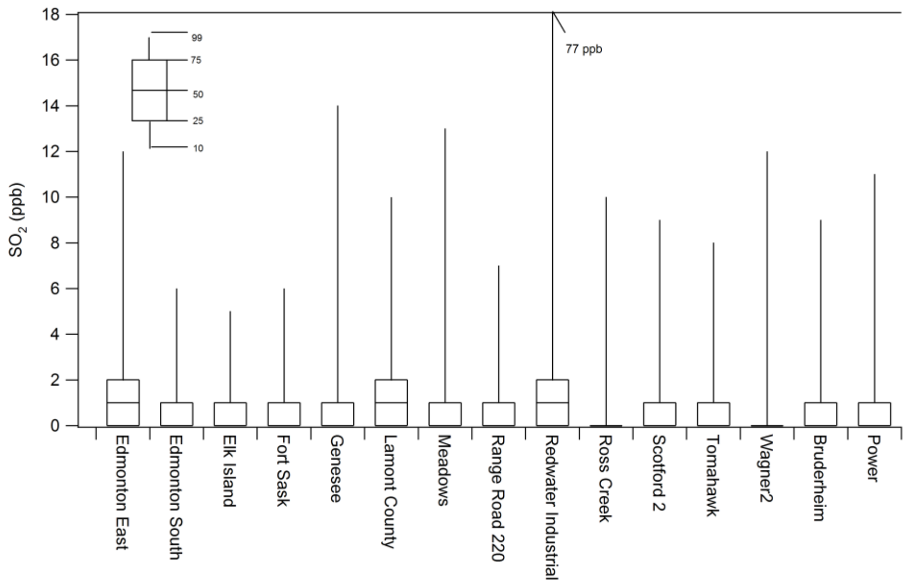


Figure 5: One-hour Average Concentrations of SO_2 at Stations Located within the Capital Region

Note: The box plot was generated using data collected between 2004 and 2010. The legend indicates percentiles used in the figure.

Diurnal average concentration for the seven years under review illustrated that, at most stations, one-hour average SO_2 concentrations have a small but well defined increase between 8 am and 10 am (see Figure 6). The increase in concentration is likely due to downward mixing associated with the breakup of the nocturnal boundary layer inversion.

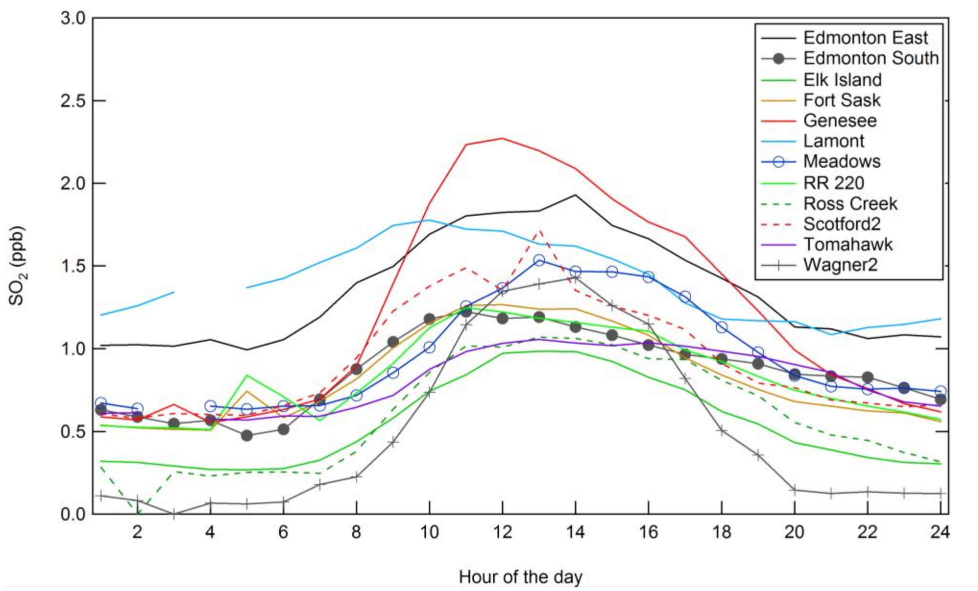


Figure 6: Diurnal Variation of SO_2 Measured at Stations within the Capital Region

Note: Data was collected between January 2004 and December 2010. The diurnal trend for Redwater industrial station was notably different and is not included.

2.4 Relating Meteorology and Peak Concentrations

The previous section looked at general observations for ambient one-hour average concentrations of SO_2 and NO_2. Conditional probability functions (CPF) were used to examine elevated concentration of NO_2 in the region. CPFs illustrate the likelihood of observing elevated concentration for a given wind sector for the period being examined. Elevated concentrations were defined as having a measured value greater than the 75th percentile for the seven years of data collected at a site. Data collected during wind speeds less than 3 km/hr (calm winds) were omitted from the analysis. CPFs were calculated using Equation 4.

$$CPF = \frac{m_{\Delta\theta}}{n_{\Delta\theta}} \qquad \text{Equation 4}$$

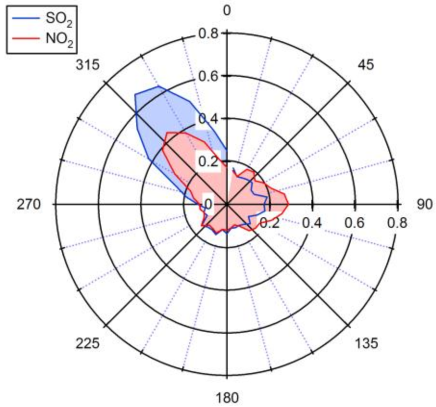
Where:

$m_{\Delta\theta}$ is the number of times NO_2 and SO_2 concentration exceeded the 75th percentile threshold for a given 10° wind sector ($\Delta\theta$), and

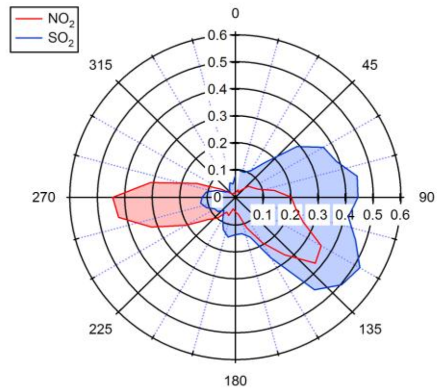
$n_{\Delta\theta}$ is the total number of times the wind direction was from a given 10° wind sector.

CPFs for each monitoring station within the region are presented in Figure 7 and Figure 8. In most cases peak concentrations of SO_2 and NO_2 are predominantly associated with one or two specific wind directions. For example, at the Fort Saskatchewan monitoring station, peak NO_2 and SO_2 concentrations were observed approximately 70 per cent of the time during southwesterly winds and to a lesser extent during northeasterly winds. At the Genesee station, both SO_2 and NO_2 peak concentrations are associated with the same or similar wind direction. These CPFs illustrate that ambient monitoring at the various monitoring stations within the region is likely impacted by multiple sources.

Genesee



Meadows



Tomahawk

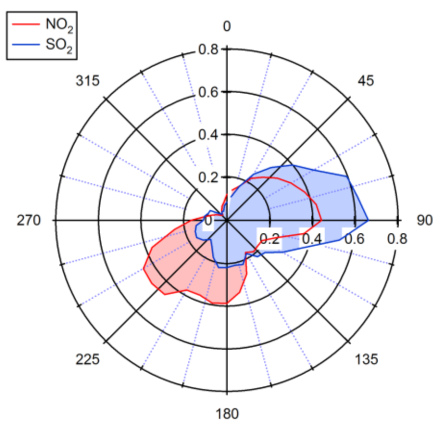


Figure 7: Conditional Probability Functions (CPFs) for Peak One-hour NO_2 and SO_2 Concentrations West of Edmonton.

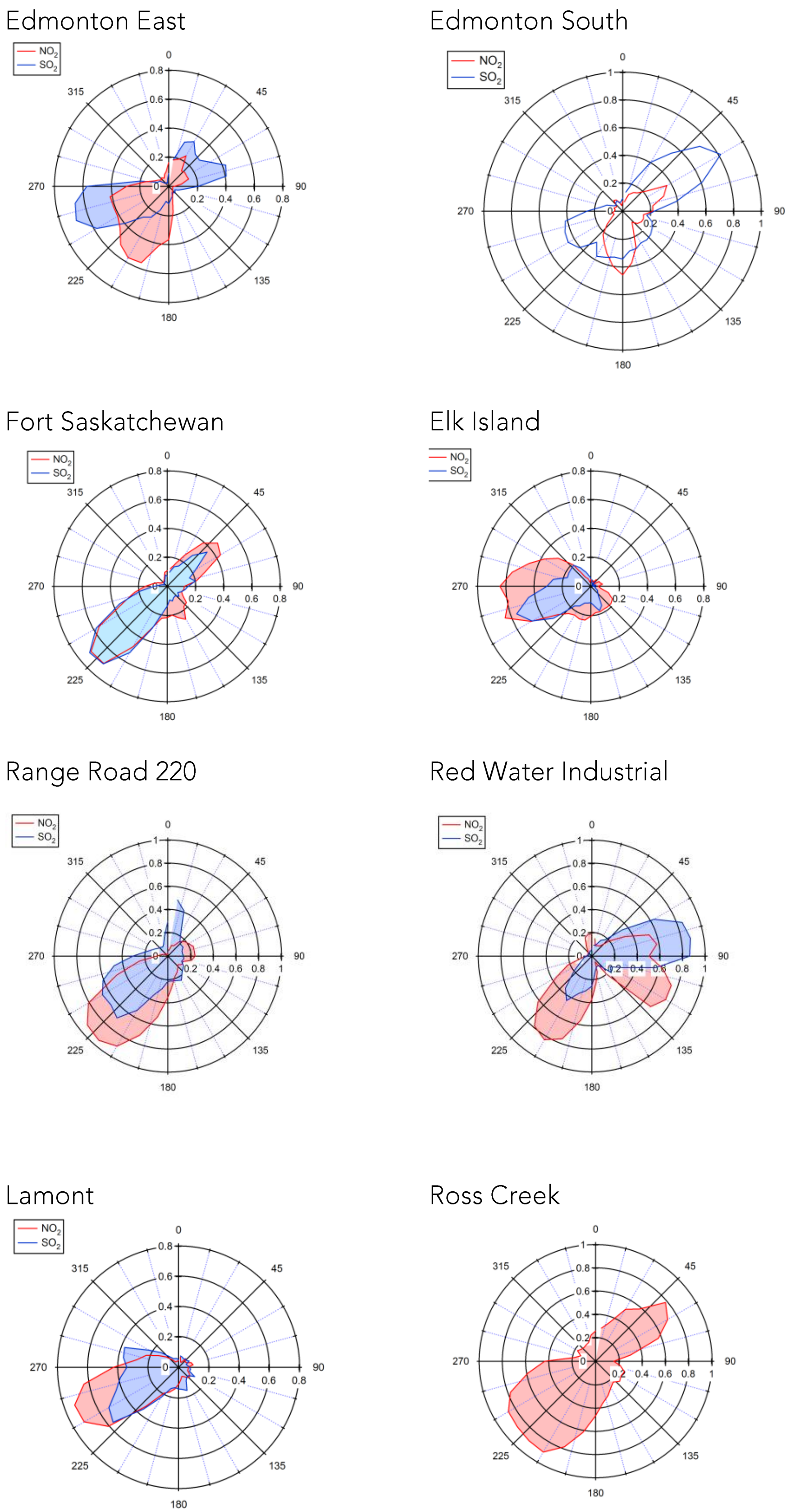


Figure 8: Conditional Probablity Functions (CPFs) for Peak One-hour SO_2 and NO_2 Concentrations within and East of Edmonton.

2.5 Associating Monitoring Stations with Management Actions

The exercise of examining monitoring data collected within the region was initiated in an effort to classify monitoring stations into subgroups. This classification was thought to be necessary as *The Framework* intended to assign different approaches for implementing management actions as a function of the type of station (e.g., community or industrial). This latter approach is recommended in the *Air Quality Management Framework* under the *Draft Lower Athabasca Regional Plan*. The findings of this exercise indicated that emissions affecting ambient monitoring at the various locations in the Capital Region are complex and likely from a number of different sources. As a result of this complexity, monitoring stations within the Capital Region were not classified by the Technical Work Group for *The Framework*. Sources impacting the stations are therefore considered on a station-by-station basis.

Recommendation: That framework management actions be assigned in response to the measured impact of NO_2 or SO_2 at each monitoring station.

Decision of the Steering Committee: The Steering Committee accepted the above recommendation.

3 Methodology: Trigger and Limit Development

The *Draft Lower Athabasca Region Air Quality Management Framework* uses a specific methodology to determine trigger values for its management system. The Steering Committee tasked the Technical Work Group to examine the implications of applying the same methodology to establish triggers in the Capital Region and to identify gaps and challenges when applying this methodology.

3.1 Criteria for Data Completeness

Ambient air quality monitoring stations occasionally have disruptions in data acquisition due to planned maintenance, power outages or equipment failures. In addition, monitoring requirements may change over time resulting in monitoring stations being decommissioned, moved or added. Due to these circumstances, the ambient air quality data set may not be 100 per cent complete for any given calendar year of operation at a single monitoring site. Therefore the Technical Work Group developed data completeness criteria to be able to work with available data and develop triggers for the Capital Region.

An annual data set of one-hour average concentrations at a station is considered complete when each season contains valid hourly data at least 75 per cent of the time. This completeness criteria is the same as that described in Alberta Environment and Sustainable Resource Development's *Air Quality Model Guideline* (2009). Completeness criteria are calculated using Equation 5.

$$CR_s = \frac{V}{T} \times 100\% \qquad \text{Equation 5}$$

Where:
CR_s is completeness criteria for each season
V is the number of hours with valid data points
T the total number of hours in the season.

For each individual station, a data set for a season is considered complete when CR_s is greater than 75 per cent. If all four seasons meet this criterion, then data from that station for the particular year is considered complete. The seasons are identified as follows:

Spring: March, April and May

Summer: June, July and August

Fall: September, October and November

Winter: December, January and February

This assessment criterion was applied to each individual station in the Capital Region. Stations no longer in operation were removed from consideration. If a station had been moved to a new location, the data from the new location were used if the station met the completeness criteria.

3.2 Trigger Levels

The Framework has adopted the four-level management approach from the *Draft Lower Athabasca Region Air Quality Management Framework*. This approach applies to each contaminant of concern being managed. Between each level there exists a trigger or limit. When a trigger or limit is exceeded, the management level is upgraded to the next level.

The four-level trigger management approach is illustrated in Figure 9. The trigger or limit between Level 3 and 4 is used to determine the other trigger values. The methodology used to determine the lower triggers is outlined in the following sections.

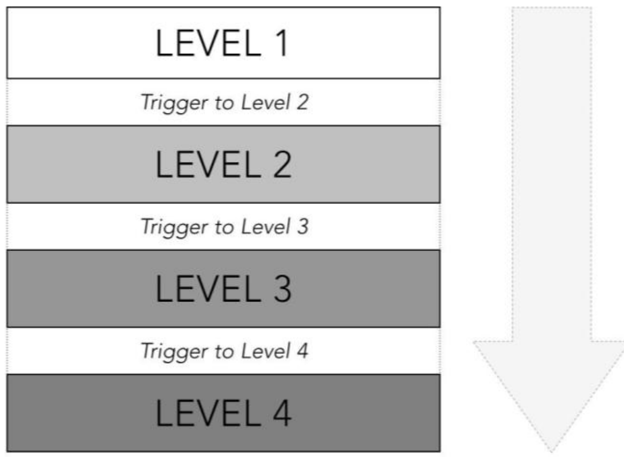


Figure 9: The Four-level and Trigger Management Approach

3.3 Determining Annual Assessment Triggers and Limit

Annual assessment triggers were developed to assess annual average concentrations of NO_2 and SO_2 for each station. The assessment identifies any systematic or recurring issues evident in the annual average concentrations.

3.3.1 Method for Determining Triggers and Limit

The trigger development methodology for *The Framework* is identical to that used to determine the annual trigger in the *Draft Lower Athabasca Region Air Quality Management Framework*. Equation 6 is used to determine triggers and limit for the annual assessment.

$$Trigger_n = AAAQO \times \frac{n}{3} \qquad \text{Equation 6}$$

Where:
$Trigger_n$ is the n^{th} trigger
AAAQO is the annual *Alberta Ambient Air Quality Objective* for NO_2 or SO_2
n ranges from 1 to 3
the number 3 in the equation is the number of triggers in the framework.

Note that $Trigger_1$ is the trigger into Level 2 and $Trigger_3$ is a limit for the annual assessment. The annual *Alberta Ambient Air Quality Objective* is interpreted as a limit because regulatory action can be taken when that value is exceeded. The current values (April 2011) are:

NO_2 Annual *AAAQO* = 45 µg/m^3 (24 ppb)

SO_2 Annual *AAAQO* = 20 µg/m^3 (8 ppb)

The resulting trigger values are presented in Table 2. The results of the annual assessment are presented in Table 3 and Table 4. The monitoring stations within the City of Edmonton were identified as being in Level 2 or Level 3 for NO_2. All other monitoring stations were in Level 2 or Level 1. For SO_2, with the exception of a single fenceline station, all monitoring stations were in Level 1.

Table 2. Annual Assessment Limit and Triggers Values

Substance	Triggers and Limit Values to Levels			
NO_2	Trigger to:	Level 2	Level 3	Level 4
		8 ppb	16 ppb	24 ppb
SO_2	Trigger to:	Level 2	Level 3	Level 4
		3 ppb	5 ppb	8 ppb

Note: Trigger values to Level 4 are limits.

Table 3. Results of the Annual NO_2 Assessment for the Capital Region

Year	Edmonton Central	Edmonton East	Edmonton South	Elk Island	Fort Saskatchewan	Genesee	Lamont	Meadows	Range Road 220	Redwater	Ross Creek	Tomahawk	Wagner	Sherwood Park	Gold Bar
2004	3	3			2		1		1	1	2	1			
2005	3	3			2	1	1	1	2	2	2	1			
2006	3	2	2		2	1	1	1	1	2	2	1			
2007	3	2	2	1	2	1	1	1	1	2	2	1			
2008	3	2	2	1	2	1	1	1	2	2	2	1			
2009	3	2	2	1	2	1	1	2	1	2	2	1		2	2
2010	3	2	2	1	2	1	1	2	2	2	2	1	1	2	2

Table 4. Results of the Annual SO_2 Assessment for the Capital Region

Year	Edmonton East	Edmonton South	Elk Island	Fort Saskatchewan	Genesee	Lamont	Meadows	Range Road 220	Redwater	Ross Creek	Scotford	Tomahawk	Wagner	Sherwood Park	Elmjay	Gold Bar	Beverly
2004	1			1		1		1	2	1		1					
2005	1			1	1	1	1	1	2	1		1					
2006	1			1	1	1	1	1	1	1		1					
2007	1		1	1	1	1	1	1	2	1	1	1					
2008	1	1	1	1	1	1	1	1	2	1	1	1					
2009	1	1	1	1	1	1	1	1	2	1	1	1		1	1	1	1
2010	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1

The annual assessment methodology for NO_2 and SO_2 in the Capital Region includes two triggers and a limit derived from annual *AAAQOs* using the same methodology as that used for the *Draft Lower Athabasca Region Air Quality Management Framework*. Assessment of the data using this method indicated that the method is appropriate for the Capital Region, as the levels highlight problem areas and allow sufficient time for action. There were no scientific reasons identified that justified a move away from what was done in Lower Athabasca Region.

Recommendation: That *The Framework* follow the *Draft Lower Athabasca Region Air Quality Management Framework* and have two triggers and a limit derived from annual *AAAQOs*.

Decision of the Steering Committee: The Steering Committee accepted this recommendation.

3.4 Determining Hourly Assessment Triggers

Assessing the upper range of hourly data allows for the examination of episodic events. The assessment methodology involved determining 99^{th} percentile hourly ambient concentrations for each calendar year and assessing the determined value against the various triggers. To evaluate the best hourly assessment of triggers for the Capital Region, four methods were examined, which are outlined in Sections 3.4.1 to 3.4.4. For each respective set of triggers, a regional assessment was conducted using data that met the completeness criteria. The four methods are:

1 The *Draft Lower Athabasca Region Air Quality Management Framework (Draft Lower Athabasca Regional Plan)* Method
2 The Capital Region Method
3 The *AAAQO*-I Method
4 The *AAAQO*-II Method

3.4.1 The *Draft Lower Athabasca Regional Plan* Method

The *Draft Lower Athabasca Regional Plan* trigger development methodology uses the relationship between historical 99th percentile and maximum hourly concentrations from ambient data. Triggers are determined using Equation 7.

$$Trigger_n = \left(\frac{1}{J} \sum_{i=1}^{J} \left(\frac{1}{k_j} \sum_{i=1}^{k_j} \left(\frac{p}{Max} \right)_{i\,j} \right) \right) \times AAAQO \times \frac{n}{3} \qquad \text{Equation 7}$$

Where:
$Trigger_n$ is the n^{th} trigger,
p is the 99^{th} percentile of the one-hour concentration at the k^{th} station and j^{th} year
Max is the maximum one-hour concentration at the k^{th} station and j^{th} year
k_j is number of stations for each year
J is the number of years being considered
AAAQO is the one-hour average *Ambient Air Quality Objective* for NO_2 or SO_2
n ranges from 1 to 3
the number 3 in the equation denotes the number of triggers.

In the *Draft Lower Athabasca Regional Plan* Method, all continuous monitoring stations are used in developing the NO_2 triggers. The SO_2 triggers were developed using only community stations (i.e., non-industrial). The Technical Work Group saw a need to refine this methodology to better suit the data collected within the Capital Region. Sections 3.4.2.1 – 3.4.2.4 outline the modifications applied.

3.4.1.1 Replicating the *Draft Lower Athabasca Regional Plan* Method

As a preliminary exercise, the Technical Work Group applied the *Draft Lower Athabasca Regional Plan* Method to data collected within the Capital Region, and determined triggers. Table 5 presents the triggers determined using the *Draft Lower Athabasca Regional Plan* Method applied to data collected within the Capital Region.

Table 5. Trigger Values Determined by the *Draft Lower Athabasca Regional Plan* Method for the Upper Range of Hourly Data Assessment

Substance	Trigger Values to Levels			
		Level 2	Level 3	Level 4
NO_2	Trigger to:	32 ppb	64 ppb	96 ppb
		Level 2	Level 3	Level 4
SO_2	Trigger to:	13 ppb	27 ppb	40 ppb

3.4.2 Capital Region Method

The following sub-sections outline the refinements considered and the actual modifications to the *Draft Lower Athabasca Regional Plan* trigger development methodology. The method of using the ratio of the 99th percentile to the maximum hourly concentration is still maintained in this section.

3.4.2.1 Averaging Methodology

There were three averaging methods considered:

1. Average of all stations for each year (used by *Draft Lower Athabasca Regional Plan* and shown in Equations 6 to 8): for every calendar year, all the stations averaged together and then the regional average for each calendar year was averaged.
2. Average of all years for each station: for each station, all the years were averaged together. The station averages were then averaged over the number of years of study. This method helps avoid potential bias when one station has been operating for many years and another station has only been operating for a few years.
3. Overall average (temporal and spatial): involves taking an overall average of the data. This method does not perform an average of averages, it weights every data point equally. This is the simplest approach.

The Technical Work Group chose to use the third averaging method because of its simplicity and because the method is less likely to introduce temporal or station bias. Using this averaging methodology, triggers for the upper range of hourly data assessment will be determined using a simplified Equation 8.

$$Trigger_n = \left(\left(\frac{1}{m} \sum_{i=1}^{m} \left(\frac{p}{Max} \right)_i \right) \times AAAQO \right) \times \frac{n}{3} \qquad \text{Equation 8}$$

Where:
Trigger$_n$ is the nth trigger
n ranges from 1 to 3
p is the 99th percentile
Max is the maximum one-hour concentration
m equals the number of years multiplied by the number of stations for a complete data set
AAAQO is the one-hour average *Ambient Air Quality Objective* for the contaminant being assessed.

3.4.2.2 Years of Assessment

The *Draft Lower Athabasca Regional Plan* Method used the most recent seven years of available air monitoring data (2003 to 2009). For *Draft Lower Athabasca Regional Plan*, the bulk of air monitoring data spanned over those last seven years. There was no sound reasoning for the Technical Work Group to use seven years of data for *The Framework*, so a sensitivity test was performed. *The Framework* triggers were calculated with the most recently available seven years, five years and three years of air monitoring data. There were no substantial differences noted between these three different year-spans of assessment.

The Technical Work Group chose to use the five most recent years (2006 – 2010) of air monitoring data to develop the Capital Region trigger. A five-year period provides a good representation of the various possible meteorological conditions which might occur at a site. Further, regulatory air dispersion modelling assessments performed in Alberta use five years of data to ensure a representative meteorological dataset is used.

3.4.2.3 Utilization of Data with Lower Significant Digits

Three stations operated by the Fort Air Partnership historically reported data to the nearest 0.01 ppm (lower significant digits) whereas other stations report to 0.001 ppm. The stations that reported the rounded off concentrations were:

NO_2

- Range Road 220: 2004 to 2009
- Redwater Industrial: 2004 to 2009
- Ross Creek: 2004 to 2009

SO_2

- Redwater Industrial: 2004
- Ross Creek: 2004 to 2009

Even though these data have been rounded to two significant digits, Fort Air Partnership data reporting was in full compliance with the *Alberta Air Monitoring Directive*. Since 2009, the Fort Air Partnership stations are reporting to 0.001 ppm. If all data (including the lower precision data) are used to calculate *The Framework* trigger, the trigger values would have to be rounded to the lowest significant digits used.

A sensitivity test was performed to examine the differences between including and removing the data with lower significant digits. The comparison showed minor differences. The Technical Work Group agreed that excluding the rounded off data was the preferred approach as it prevents excessive rounding of determined trigger values. In addition, removal of the lower significant digit data is more compatible with data that will be collected in the future.

3.4.2.4 Stations Used to Determine Triggers

Available data suggested that NO_2 in the Capital Region is driven largely by transportation influences. A sensitivity analysis was performed to determine the effects of using only data collected at selected stations to develop the trigger values. The methodology outlined in Section 2.2 was used to identify monitoring stations highly influenced by commuter vehicle emissions. The following stations were selected by the Technical Work Group:

- Edmonton Central
- Edmonton East
- Edmonton South
- Fort Saskatchewan
- Sherwood Park
- Gold Bar.

As NO_2 is predominantly elevated in urban settings, the Technical Work Group agreed that using only urban stations would be a fair representation of the sources and would allow for proper trend analysis. The urban stations were therefore used in the calculation of the hourly trigger values.

The Redwater Industrial station is primarily affected by one specific source, and this station was excluded from SO_2 trigger calculations. Inclusion of this monitoring station would markedly skew the trigger value determination. The issue with this point source is well known and is being addressed. Table 6 lists the years of data for each station used to develop the triggers for NO_2 and SO_2.

Table 6. Data Used in Trigger Development for the Capital Region Method

Station	Years of Data Used	
	NO_2	SO_2
Beverly	Excluded	2009 - 2010
Edmonton Central	2006 - 2010	Not monitored
Edmonton East	2006 – 2010	2006 - 2010
Edmonton South	2006 – 2010	2008 - 2010
Elk Island	Excluded	2007 - 2010
Elmjay	Not monitored	2009 - 2010
Ft. Saskatchewan	2006 – 2010	2006 - 2010
Genesee	Excluded	2006 - 2010
Gold Bar	2009 - 2010	2009 - 2010
Lamont	Excluded	2006, 2008 - 2010
Meadows	Excluded	2006 - 2010
Range Road 220	Excluded	2006 - 2010
Redwater Industrial	Excluded	Excluded
Ross Creek	Excluded	2010
Scotford 2	Not monitored	2007 - 2010
Sherwood Park	2009 – 2010	2009 - 2010
Tomahawk	Excluded	2006 - 2010
Wagner 2	Excluded	2010

3.4.2.5 Method for Developing Triggers for Capital Region

Based on the modifications to the *Draft Lower Athabasca Regional Plan* Method outlined in Sections 3.4.2.1 —3.4.2.4, a set of triggers was developed for the hourly assessment. The values for these triggers are outlined in Table 7. Results of the assessment using this method are presented in Table 8 and Table 9.

Table 7. Trigger Values Determined by Capital Region Method for the Upper Range of Hourly Data Assessment

Substance	Trigger Values to Levels			
NO_2	Trigger to:	Level 2	Level 3	Level 4
		34 ppb	67 ppb	101 ppb
SO_2	Trigger to:	Level 2	Level 3	Level 4
		14 ppb	29 ppb	43 ppb

Table 8: Results of NO_2 Hourly Assessment Using the Capital Region Method

Year	Edmonton Central	Edmonton East	Edmonton South	Elk Island	Fort Saskatchewan	Genesee	Lamont	Meadows	RR 220	Redwater	Ross Creek	Tomahawk	Wagner	Sherwood Park	Gold Bar
2004	2	2			2		1		1	2	2	1			
2005	2	2			2	1	1	1	2	2	2	1			
2006	2	2	2		2	1	1	1	2	2	2	1			
2007	2	2	2	1	2	1	1	1	2	2	2	1			
2008	2	2	2	1	2	1	1	1	3	2	2	1			
2009	2	2	2	1	2	1	1	1	2	2	2	1		2	2
2010	2	2	2	1	2	1	1	1	2	2	2	1	1	2	2

Table 9: Results of SO_2 Hourly Assessment Using the Capital Region Method

Year	Edmonton East	Edmonton South	Elk Island	Fort Saskatchewan	Genesee	Lamont	Meadows	Range Road 220	Redwater	Ross Creek	Scotford	Tomahawk	Wagner	Sherwood Park	Elmjay	Gold Bar	Beverly
2004	1			1		1		1	4	1		1					
2005	1			1	2	1	1	1	4	1		1					
2006	1			1	2	1	2	1	4	1		1					
2007	1		1	1	1	1	1	1	4	1	1	1					
2008	1	1	1	1	1	1	1	1	4	1	1	1					
2009	1	1	1	1	1	1	1	1	4	1	1	1		2	1	1	2
2010	1	1	1	1	1	1	1	1	4	1	1	1	1	2	1	1	1

3.4.3 *AAAQO* Method-I

A simpler method of developing hourly assessment triggers was considered, as the Capital Region Method has many complexities. A method utilizing the one-hour *AAAQO* as the upper limit was explored and is essentially the same method that is outlined in Section 3.2 for annual assessments. This method uses the one-hour *AAAQO* as $Trigger_3$, as *AAAQOs* are often developed using a strong scientific basis.

At the time of trigger development one-hour *AAAQOs* were:

- NO_2 hourly AAAQO = 159 ppb
- SO_2 hourly AAAQO = 174 ppb

The trigger values developed using the *AAAQO* Method-I are presented in Table 10. Results of the assessment using this method are presented in Table 11 and Table 12.

Table 10: Trigger Values Determined by the *AAAQO* Method-I for the Upper Range of Hourly Data Assessment

Substance	Trigger Values to Levels			
		Level 2	Level 3	Level 4
NO_2	Trigger to:	53 ppb	106 ppb	159 ppb
		Level 2	Level 3	Level 4
SO_2	Trigger to:	57 ppb	115 ppb	172 ppb

Table 11: Results of NO_2 Hourly Assessment Using *AAAQO* Method-I

Year	Edmonton Central	Edmonton East	Edmonton South	Elk Island	Fort Saskatchewan	Genesee	Lamont	Meadows	RR 220	Redwater	Ross Creek	Tomahawk	Wagner	Sherwood Park	Gold Bar
2004	1	1			1		1		1	1	1	1			
2005	2	1			1	1	1	1	1	1	2	1			
2006	1	1	1		1	1	1	1	1	1	1	1			
2007	1	1	1	1	1	1	1	1	1	1	1	1			
2008	1	1	1	1	1	1	1	1	2	1	1	1			
2009	1	1	1	1	1	1	1	1	1	1	1	1		1	1
2010	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 12: Results of SO_2 Hourly Assessment Using *AAAQO* Method-I

Year	Edmonton East	Edmonton South	Elk Island	Fort Saskatchewan	Genesee	Lamont	Meadows	Range Road 220	Redwater	Ross Creek	Scotford	Tomahawk	Wagner	Sherwood Park	Elmjay	Gold Bar	Beverly
2004	1			1		1		1	2	1		1					
2005	1			1	1	1	1	1	2	1		1					
2006	1			1	1	1	1	1	1	1		1					
2007	1		1	1	1	1	1	1	2	1	1	1					
2008	1	1	1	1	1	1	1	1	2	1	1	1					
2009	1	1	1	1	1	1	1	1	2	1	1	1		1	1	1	1
2010	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1

3.4.4 *AAAQO* Method-II

A method believed to be more sensitive than that outlined in Section 3.4.3 was also examined. This method uses 75 per cent of one-hour *AAAQO* as $Trigger_3$. The trigger values developed using the *AAAQO* Method-II are presented in Table 13. Results of the assessment using this method are presented in Table 14 and Table 15.

Table 13: Trigger Values Determined by the *AAAQO* Method-II for the Upper Range of Hourly Data Assessment

Substance	Trigger Values to Levels	Level 2	Level 3	Level 4
NO_2	Trigger to:	40 ppb	80 ppb	119 ppb
SO_2	Trigger to:	43 ppb	86 ppb	129 ppb

Table 14: Results of NO_2 Hourly Assessment Using *AAAQO* Method-II

Year	Edmonton Central	Edmonton East	Edmonton South	Elk Island	Fort Saskatchewan	Genesee	Lamont	Meadows	RR 220	Redwater	Ross Creek	Tomahawk	Wagner	Sherwood Park	Gold Bar
2004	2	2			2		1		1	1	2	1			
2005	2	2			2	1	1	1	2	1	2	1			
2006	2	2	2		2	1	1	1	1	1	2	1			
2007	2	2	2	1	2	1	1	1	2	1	2	1			
2008	2	2	2	1	2	1	1	1	2	2	2	1			
2009	2	2	2	1	2	1	1	1	1	1	1	1		2	2
2010	2	2	2	1	2	1	1	1	1	2	2	1	1	2	2

Table 15: Results of SO_2 Hourly Assessment Using *AAAQO* Method-II

Year	Edmonton East	Edmonton South	Elk Island	Fort Saskatchewan	Genesee	Lamont	Meadows	Range Road 220	Redwater	Ross Creek	Scotford	Tomahawk	Wagner	Sherwood Park	Elmjay	Gold Bar	Beverly
2004	1			1		1		1	3	1		1					
2005	1			1	1	1	1	1	2	1		1					
2006	1			1	1	1	1	1	2	1		1					
2007	1		1	1	1	1	1	1	2	1	1	1					
2008	1	1	1	1	1	1	1	1	2	1	1	1					
2009	1	1	1	1	1	1	1	1	2	1	1	1		1	1	1	1
2010	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1

3.4.5 Choice of Hourly Assessment Method for the Capital Region

The Technical Work Group presented the methodologies, benefits and drawbacks of the modified methods (Capital Region Method, *AAAQO* Method-I and *AAAQO* Method-II) to the Steering Committee. Each method was reviewed for its:

- trigger development options
- derived numerical values
- assessment.

The hourly assessment using the Capital Region Method provides enhanced sensitivity to ambient NO_2 and SO_2 concentrations. It also provides strong alignment with the *Draft Lower Athabasca Region Air Quality Management Framework*. However, the Capital Region Method is more complex than the *AAAQO* methods. It uses the measured data and thus triggers may change with change in measured data. Actions associated with Level 1 and 2 may be "trivial" due to low trigger levels.

AAAQO Method-I has an advantage of being simple, consistent with the annual assessment and independent of the Capital Region's performance. However, triggers developed using this method may not be sufficiently sensitive to allow proactive action.

AAAQO Method II was presented as an alternate that combined the merits of the Capital Region Method and *AAAQO* Method-I. It is less complex, but sensitive enough to allow proactive action.

Further to their review, the Capital Region Method was chosen by the Steering Committee to conduct the hourly assessments.

4 Examining the Importance of Transboundary and Naturally Occurring NO_2

The Steering Committee tasked the Technical Work Group to explore the influence of transboundary and naturally occurring NO_2 in the Capital Region. The purpose of this exercise was to determine if it was necessary to remove data collected during periods of notable influence from sources that are not controlled by management actions. Such NO_2 sources can include background, transboundary or natural episodic influences. The Technical Work Group determined that the most pronounced natural sources of NO_2 (an air contaminant primarily associated with combustion) are forest fires. Forest fires produce a number of pollutants, including fine particulate matter and NO_2, which can be transported into the Capital Region.

A methodology for sample days within the Capital Region that were markedly influenced by forest fires has already been identified as part of the Canada-Wide Standard Achievement Determination for particulate matter exercise described in Alberta Environment and Sustainable Resource Development 2007. This methodology was applied to data for the years 2004 – 2009. For each day identified as impacted by forest fires, a full day (24 hours) of NO_2 data was removed from the impacted station. For data collected in 2010, analysis for achievement determination was not complete at the time the Technical Work Group conducted its activities. Between August 18 and 22, 2010 the Capital Region was heavily impacted by smoke from forest fires. An assumption was made that these days would be identified for removal by the Achievement Determination exercise. Therefore, this data was removed from the Capital Region data set. Sample days impacted by multiple sources (which make it difficult to determine event origin) and those impacted by local anthropogenic sources were not removed. Table 16 illustrates the sample days identified for removal for each monitoring station within the Capital Region.

The NO_2 data set, with data removed for those days impacted by forest fires, was then used in the trigger calculations using the Capital Region Method (Section 3.4.5.2). A 1 ppb threshold was identified to indicate changes to calculated values. Only two changes within the trigger calculations were observed as a result of the data removal: an increase in the 99^{th} percentile at Tomahawk in 2004 and Genesee in 2010 (Table 17). These increases in 99^{th} percentile values may indicate that lower NO_2 values were removed from the data set. Changes in concentration greater than the threshold of 1 ppb were observed for the maximum one-hour concentrations. The observed changes in the 99^{th} percentile values were small (1 ppb) and did not to affect the overall trigger calculations. The calculated annual and upper range of hourly data levels assessments remained unchanged. The results imply that the emissions from forest fires impacting the Capital Region are not major contributors to peak ambient NO_2 concentrations.

Table 16: Sample Days Identified as Impacted by Forest Fire Smoke

Year	Edm C	Edm E	Edm S	Elk Island	Ft Sask	Genesee	Lamont	Redwater	Tomahawk	Bruderheim
2004									17-Jul-04	
	22-Jul-04	22-Jul-04			22-Jul-04		22-Jul-04			
	23-Jul-04	23-Jul-04			23-Jul-04					
	24-Jul-04									
	11-Aug-04	11-Aug-04			11-Aug-04				11-Aug-04	
	12-Aug-04				12-Aug-04				12-Aug-04	
	13-Aug-04									
	14-Aug-04	14-Aug-04			14-Aug-04		14-Aug-04		14-Aug-04	
	15-Aug-04	15-Aug-04			15-Aug-04		15-Aug-04		15-Aug-04	
	16-Aug-04	16-Aug-04			16-Aug-04		16-Aug-04		16-Aug-04	
	17-Aug-04	17-Aug-04			17-Aug-04		17-Aug-04		17-Aug-04	
	19-Aug-04	19-Aug-04			19-Aug-04				19-Aug-04	
2005							9-Jun-05			
							10-Jun-05			
							11-Jun-05			
		25-Aug-05					25-Aug-05	25-Aug-05		
		27-Aug-05								
2006	5-Jul-06	5-Jul-06	5-Jul-06		5-Jul-06					
	6-Jul-06	6-Jul-06	6-Jul-06		6-Jul-06		6-Jul-06			
								7-Aug-06		
								8-Aug-06		
								3-Sep-06		
	4-Sep-06		4-Sep-06					4-Sep-06		
2007				1-Jun-07						
				2-Jun-07						
				3-Jun-07						
				4-Jun-07				4-Jun-07		
				5-Jun-07				5-Jun-07		
				7-Jun-07						
				8-Jun-07						
2008										
2009								5-May-09		
							15-Sep-09			
							16-Sep-09			
							23-Sep-09			
	24-Sep-09		24-Sep-09		24-Sep-09		24-Sep-09	24-Sep-09		
							25-Sep-09			
2010	18-Aug-10	18-Aug-10	18-Aug-10	18-Aug-10	18-Aug-10	18-Aug-10	18-Aug-10	18-Aug-10	18-Aug-10	18-Aug-10
	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10
	20-Aug-10	20-Aug-10	20-Aug-10	20-Aug-10	20-Aug-10	20-Aug-10	20-Aug-10	20-Aug-10	20-Aug-10	20-Aug-10
	21-Aug-10	21-Aug-10	21-Aug-10	21-Aug-10	21-Aug-10	21-Aug-10	21-Aug-10	21-Aug-10	21-Aug-10	21-Aug-10
	22-Aug-10	22-Aug-10	22-Aug-10	22-Aug-10	22-Aug-10	22-Aug-10	22-Aug-10	22-Aug-10	22-Aug-10	22-Aug-10

Note: Edm C, Edm E and Edm S represent the Edmonton Central, East and South monitoring stations respectively. Edmonton South was not operational until 2006. Ft Sask represents the Fort Saskatchewan monitoring station.

Table 17: Change in 99th Percentile Concentrations

Monitoring Station	2004	2005	2006	2007	2008	2009	2010
Edmonton Central	No Change	No Change	No Change	No Change	No Change	No Change	No Change
Edmonton East	No Change	No Change	No Change	No Change	No Change	No Change	No Change
Edmonton South	ND	ND	No Change	No Change	No Change	No Change	No Change
Elk Island	ND	ND	ND	No Change	No Change	No Change	No Change
Ft Saskatchewan	No Change	No Change	No Change	No Change	No Change	No Change	No Change
Genesee	ND	No Change	No Change	No Change	No Change	No Change	Increase
Lamont	No Change	No Change	No Change		No Change	No Change	No Change
Meadows	ND	No Change	No Change	No Change	No Change	No Change	No Change
RR 220	No Change	No Change	No Change	No Change	No Change	No Change	No Change
Redwater Industrial	No Change	No Change	No Change	No Change	No Change	No Change	No Change
Ross Creek	No Change	No Change	No Change	No Change	No Change	No Change	No Change
Tomahawk	Increase	No Change	No Change	No Change	No Change	No Change	No Change
Wagner2	ND	ND	ND	ND	ND	ND	No Change
Bruderheim	ND	ND	ND	ND	ND	ND	ND
Sherwood Park	ND	ND	ND	ND	ND	No Change	No Change
Gold Bar	ND	ND	ND	ND	ND	No Change	No Change

Note: Increase = 1 ppb change in calculated concentration.
ND: No data or insufficient data

5 Air Quality Modelling

The Technical Work Group reviewed the results of a modelling exercise conducted in preparation for the North Saskatchewan regional plan. This air quality modelling exercise used the Community Multiscale Air Quality (CMAQ), 2006 emissions and meteorology to predict ambient concentration for three spatial scales: 36,12 and 4 km. The focus of the study was on predicted ambient concentrations of ozone, NO_2, SO_2, carbon monoxide, particulate matter ($PM_{2.5}$ and PM_{10}) and the deposition of sulphur and nitrogen for Central Alberta (4 km domain). Predicted concentrations were compared to monitoring data to test model performance. The Technical Work Group identified that $PM_{2.5}$ modelling on the timescale of diurnal variations is not as good as for some other pollutants and that more work is needed in the area of $PM_{2.5}$ modelling. The Technical Work Group also recognized that further exploration of sulphur and nitrogen depositions may be warranted for the Capital Region.

In addition, the contribution of various sectors was examined through sensitivity testing scenarios, where emissions for identified sectors were removed. Six scenarios were designed by eliminating emissions from the following sources:

- small upstream oil and gas sources
- agriculture and other area sources
- on- and off-road mobile sources
- coal-fired power plants (electrical generating units)
- other stationary point sources
- all anthropogenic sources.

Recommendation: Conduct additional sensitivity scenarios to assess the suitability of using the model in evaluating the impact of change at a single facility. This work should be done as part of the implementation phase of *The Framework*, and a summary report of this work should be issued.

5.1 Identification of Additional Work

The Technical Work Group identified two additional areas of work to complement the modelling exercise conducted in preparation for the North Saskatchewan regional plan. The first task was to prepare a focused summary report including three analysis components as described below, while the second task was to determine whether the model was robust enough to show the effectiveness of management action plans for anthropogenic sources. This work will be done as part of the implementation phase of *The Framework*. Both tasks are further explained below.

5.1.1 Capital Region Focused Summary Report – Task One of Two

1(A) Substances for discussion: predicted concentration of NO_2, SO_2 and O_3 for 2006.

- Using the results obtained from modelling runs conducted in preparation for the North Saskatchewan regional plan, discuss the spatial variation of the predicted ambient distribution for the following.
    - Ozone
        - Maximum one-hour concentrations (discussion should include episodic "tracks" which were illustrated on the isopleths)
        - Annual average

        - 8-hour average
    - SO_2/NO_2
        - Discuss maximum one-hour and annual concentrations

- Identify concentration hot spots and discuss findings with placement of current monitoring highlighting gaps (if any).

1(B) Using the results from zero out runs, discuss the results of predicted concentrations of:

- 1 hour maximum ozone concentrations
- Annual average NO_2/SO_2 concentrations

1(C) For each grid cell containing an air monitoring station, indicate change in predicted concentration as a result of a zero out scenario for each substance listed above.

5.1.2 Sensitivity Runs – Task Two of Two

2(A) Evaluate predicted change in ambient concentrations of NO_x, SO_2 and O_3 with changes in transportation emissions.

2(B) Evaluate predicted change in ambient concentrations of NO_x, SO_2 and O_3 with change in mass emission rate change at a single point source.

6 References

Alberta Environment and Sustainable Resource Development. 1989. *Alberta Air Monitoring Directive.*

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