OZONE MANAGEMENT FRAMEWORK FOR THE REGIONAL MUNICIPALITY OF WOOD BUFFALO AREA

1 Introduction

The Issue:

Ozone is a naturally occurring constituent of the atmosphere. In the upper atmosphere it absorbs solar energy in the ultraviolet band and significantly reduces the amount of harmful radiation that reaches the earth's surface. In the lower atmosphere ozone can have a number of adverse effects on materials, vegetation and human and animal health.

Ozone concentrations in the lower atmosphere are affected by mixing rates between the upper and lower atmospheres and by ground-level ozone formation rates. Ground-level ozone formation involves complex interactions between nitrogen oxides, volatile organic compounds (VOCs) and sunlight.

Natural background concentrations of ground-level ozone are difficult to estimate but are likely in the 25-40 ppb range.[1] Higher ground-level ozone concentrations occur during summer periods in areas with elevated nitrogen oxide and VOC levels including urban regions and areas affected by industrial emissions. The management of nitrogen oxide and VOC emissions can significantly reduce ground-level ozone concentrations.

In recent years there has been a strong focus on developing national and provincial ozone standards and management frameworks. The Regional Municipality of Wood Buffalo Area ("the Region") is largely basing its ozone management plan on this recent body of work. The application of the national and provincial frameworks to the region is considered the focus required at the present time.

The Region's ozone management plan establishes a framework for addressing issues and priorities related to ozone and its precursors in the Region.

1.1 Background

Alberta Environment, in consultation with regional stakeholders, drafted a Regional Sustainable Development Strategy (RSDS) for oilsands development in the Region in 1999. The RSDS attempts to balance development in the Region with environmental protection through implementation of adaptive management approaches that address regional cumulative environmental effects, environmental thresholds, appropriate monitoring techniques, resource management approaches, knowledge gaps and research to fill gaps. The Cumulative Environmental Management Association (CEMA), a multi-stakeholder group, was formed to address the issues raised in the RSDS. The RSDS identified a number of air issues related to ozone and ozone precursors.

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[1] National Ambient Air Quality Objectives for Ground-level Ozone: Summary Science Assessment Document (August 1999). A Report by the Federal-Provincial Working Group on Air Quality Objectives and Guidelines. ISBN:0-662-64394-1

In 1998, the oil sands industry funded a study to model the formation of ozone in the Region. Several scenarios were examined using emissions for 1998. The study concluded that exceedances of the Alberta Environment ozone guideline would be infrequent. An Ozone Experts Forum was held in 1999 to examine the ozone formation issue in the area. The forum recommended the development of an ozone management plan for the Region. It was recommended that this plan include additional measurement studies and a further evaluation of ozone modeling tools.

The NO_x-SO_x Management Working Group (NSMWG) is mandated by CEMA to develop management strategies to address the acid deposition, nitrogen eutrophication, and ozone issues associated with SO_x and/or NO_x emissions.[2] In 2001, the NSMWG finalized an "Ozone Action Plan" with three components:

1. Establish environmental capacity guidelines;
2. Establish environmental management objectives; and
3. Establish a management system and plan.

The plan was to develop an ozone management plan by 2003. Under the Ozone Action Plan, a field program was conducted in 2001 and 2002 to measure the formation of ozone in the Region. The contribution of both industrial and natural emission precursors to ozone formation was examined. The Action Plan also recommended that a new modelling program be undertaken to examine ozone formation using the results of new research and modelling tools. This work is presently being conducted by Environment Canada.

In 2001, a multi-stakeholder team under the Alberta Clean Air Strategic Alliance (CASA) was formed to develop an Alberta implementation plan for the Canada-wide Standard (CWS) for $PM_{2.5}$ and Ozone. The NSMWG subsequently delayed some of its ozone-related activities as it was thought that the CASA work would provide context for, and possible constraints on, any regional ozone management plan. In 2003, CASA produced a consensus Particulate and Ozone Management Framework for Alberta (refer to Appendix 1). This framework addressed the issue of regional ozone management and provided "planning" and "exceedance" ozone triggers that apply across the province. The regional management framework outlined in this document supports the Alberta provincial approach (Section 1.2). Material from the CASA Particulate Matter and Ozone Management Framework is presented as background information in Appendix 1.

Because of the significant efforts undertaken nationally and provincially on ozone criteria and management, the Region is largely basing its Ozone Management Framework on that body of work. The customized application and implementation of the national and provincial frameworks to the region is the focus of this management framework.

[2] See CEMA Five Year Strategic Plan Summary of Working Group Activities (December 2004)

1.2 Context

Emissions of ozone precursors are expected to grow in the Region, as a result of the operation of projects that have received regulatory approvals as well as additional planned oil sands growth. This growth is forecast to result in increased ambient concentrations of NO_x and VOCs, the precursor gases for ozone formation. A comparison of the ozone precursor emissions from the Region and the Edmonton and Calgary regions is given in Table 1.

Projected NO_x emissions do not take into account the expected reductions in emissions that should occur as a result of reduced emissions from mobile equipment built to US-EPA Tier IV standards starting in 2011.[3] However, the projected emissions raise questions about the potential for elevated ozone concentrations at areas downwind of the sources in a manner similar to that observed downwind of Alberta's urban centres.

Table 1 – Forecast of ozone precursor emissions (kilotonnes per year) for selected regions of Alberta.

	NOx [4]					VOC [5]
Region	**2000**	**2005**	**2010**	**2015**	**2020**	**2010**
Wood Buffalo	69	97	168	204	208	345
Edmonton	92	82	81	80	81	133
Calgary	181	174	167	166	169	226

Ozone formation in the Region was demonstrated during a sampling program undertaken in July 2002. There was indication that ozone levels within the industrial plume increased to concentrations above background after 5 to 7 hours of plume parcel travel. This was most clearly demonstrated during a series of three flights on July 16, 2002 where the elevated plumes were tracked to a distance of 80 km downstream. The ozone peak concentrations of 73 ppbv were noted at a distance of approximately 70 km downstream of the emission sources. This ozone production occurred in a manner that is consistent with expectations from photochemistry model predictions and rates of ozone production observed in the 2001 study. The prediction of in-plume concentrations would be 72 to 74 ppbv as compared to background levels of approximately 50 ppbv. The plume level measurements were approximately 5 ppbv higher than concurrent ground-level concentrations at monitoring sites under the conditions of this study. Ground level concentrations could however range from background levels to plume levels depending

[3] Typical industrial heavy equipment in the Region that falls into the United States Tier II and Tier IV non-road diesel engine emission control categories includes: excavators, off-highway trucks, dozers, loaders and scrapers

[4] From: "Emissions Trading For Alberta: Major Feasibility Study Part A: Profile of Criteria Air Contaminants, Mercury and Greenhouse Gases Emissions in Alberta (Current and Forecast Emissions, Ambient Air Quality Stress Analysis)", Submitted to Alberta Environment by Cheminfo, October 2002.

[5] 2010 forecast from CASA report "Forecast of Common Air Contaminants in Alberta (1995to 2020)".

on the proximity of the plume and atmospheric mixing conditions. Ambient levels at the monitoring sites did not rise to levels above the Alberta/CWS objectives during the monitoring study.

Monitoring data for ground-level ozone and its precursors in the province of Alberta and the Region are compared in Appendix 2. When calculated according to the Canada-Wide Standard metric, ozone concentrations at the regional monitoring stations do not exceed either the CASA Planning (58 ppb) or Exceedance (65 ppb) levels. However, the focus of the current air quality monitoring program is on compliance with Alberta Air Quality Objectives, attribution of air quality exceedances to emission sources, and community exposure. Consequently the continuous monitoring stations in the Region are located near industrial emission sources and in communities. These are not the locations where highest regional ozone concentrations are likely to occur; only passive monitoring devices are located in areas 70 km and further downwind of ozone precursor emission sources. One exception is a continuous monitoring station located in Anzac, which is approximately 70 km south of Fort McMurray.

The Canada-Wide Standards, which form the basis for this management framework, were set for the protection of human health and state: **"***Since the current CWSs are related primarily to protection of human health, their adequacy for the protection of vegetation, visibility impairment, material damage or other adverse effects may need to be assessed.*" It is therefore not clear whether they are also fully protective of vegetation. This is a national as well as a regional issue. There has been tremendous effort by other research groups throughout the world to define the effects of ozone on vegetation and on health, to establish the environmental capacity of the ecosystem to ozone concentrations, and to develop ozone guidelines for Canada and for Alberta. These efforts should not be duplicated, but rather the learnings from these efforts should be applied to assist in addressing these issues in the Region.

The predicted increased emissions of ozone precursors in the Region due to continued oil sands development, the potential for increased ambient concentrations of those precursor gases, the limitations in the current ozone monitoring programs, and the significant role meteorology plays in oxidant chemistry, are all factors that need to be considered when interpreting the existing monitoring data or making extrapolations regarding future ozone concentrations. For these reasons an initial management approach that focuses on monitoring and modeling, with an emphasis on continuous improvement in emissions management, is considered appropriate. The results of this monitoring and modeling should provide the information necessary to determine if ozone will become a concern to health or the ecosystems in the region and, if it could, what effective management actions might consist of.

2 A Regional Approach for Ozone Management

The regional ozone management system includes the following elements:

- clear and measurable ***management objectives*** that the system will be designed to achieve;
- ***management tools*** to attain the objectives;
- ***review of information gaps***, new research and monitoring results related to the indicators (ambient ozone and precursor concentrations); and
- a ***system evaluation*** of the tools and monitoring/research to assess the success in achieving the goals and objectives.

2.1 Management Objectives:

It is the goal of CEMA to recommend an environmental management system that will protect human health and vegetation from human-caused ground-level ozone. Based on the current and projected ozone precursor emissions in the Region, the NSMWG recommends that the Region be considered at this time as falling in the Surveillance Level of the provincial Ozone Management Plan (Appendix 1) and that management actions consistent with that level should be implemented. This categorization would be reviewed in 2011 as per Section 2.4 of this framework. The NSMWG recommends that regional management actions consistent with the surveillance level be adopted at this time.

If at any time Alberta Environment, as part of its annual action level criteria reviews under the Alberta Particulate and Ozone Management Framework, designates the Region as falling within the Management or Exceedance level, the management actions consistent with that designation would apply. A regional stakeholder body, such as WBEA or CEMA, would work with Alberta Environment in the development of action plans associated with a Management or Exceedance Level designation.

2.2 Management Tools:

The need for, and type of, management actions will be guided by those suggested by the action levels from the Alberta Particulate and Ozone Management Framework. Specific implementation of these actions will be regionally relevant and appropriate. The Region will implement management actions consistent with the provincial Baseline and Surveillance Levels.

Monitoring:

- Ongoing monitoring of ambient air quality levels will continue to be conducted by a regional stakeholder body, such as the Wood Buffalo Environmental Association (WBEA), reporting annually on the observed ozone and precursor concentrations.

- Regional ozone and ozone precursor ambient air monitoring programs will continue to provide data to determine attainment of the CWS for ozone and to assess human exposure to ozone in the populated areas of the region.
- As per the provincial framework, attainment of the CWS is the responsibility of Alberta Environment (AENV). Therefore, AENV, in conjunction with WBEA, will review the adequacy of ambient air quality monitoring in the Region. Ozone and precursor monitoring data should be analyzed in a scientific manner to identify possible improvements to the regional monitoring network, with the overall goal of addressing uncertainties about current and future ground-level ozone concentrations. Specifically, follow-up studies should be carried out to evaluate existing and possible additional regional continuous and passive ozone monitoring locations in 2006.
- The regional programs will be directed at long term environmental monitoring for ambient air ozone and ozone precursor concentrations to provide data for trend analysis. In addition to the regular AENV annual report of concentration averages, long-term trends in regional ozone levels will be analyzed annually. It is recommended that a regional stakeholder body such as WBEA, which also collects and archives the data, conduct this analysis. The results of this analysis would be made available to all regional stakeholders.

Modelling:

- Environment Canada (EC) has initiated a scientific modelling activity using state-of-the-art regional scale models to facilitate appropriate placement of ozone monitoring stations (for example, identification of where highest ozone concentrations are likely to occur) and to assess the potential for future exceedances of Alberta/Canada Wide standards based on the increased emissions scenarios. This is expected to be completed by the end of 2006.
- EC, working together with Alberta Environment and in consultation with stakeholders, will periodically model current and future ground level ozone concentrations. It is recommended that initially modelling be done every 3 years and include both an “approved development” (including existing and approved projects) and a “full development” (including all existing and approved, plus all planned projects) emissions scenario.
- The sources of elevated concentrations of emission gases and secondary pollutants will be assessed (e.g. industrial, urban, biogenic, transport of precursors or ozone into the region). It is recommended that AENV, working through the body identified in Section 2.4, champion this type of assessment in 2007 following the completion of the monitoring trends analysis and the initial modelling assessment.

Emissions Management:

- It is recommended that the Energy and Utilities Board (EUB) and AENV, through their respective regulatory approval processes, continue to
- establish continuous improvement assessment and implementation requirements for regional emitters.[6] Reporting on continuous improvement actions should be included as part of a company's reporting requirements and be made available to regional stakeholders.
- AENV should work with a regional stakeholder body to identify and encourage opportunities for Keeping Clean Areas Clean (KCAC) and Continuous Improvement (CI).
- Tools to manage precursor emissions should include:
  - Industry actions to look for opportunities to reduce current NO_x emission from stationary sources and include steps to improve mobile fleet emissions such as adoption of US EPA Tier II standards (which come into effect in 2006) and Phase 1 US EPA Tier IV emission standards for diesel engines greater than 560 kW (750 hp) (which take effect in 2011).
  - Industry actions to continue to apply VOC emissions controls and work to improve current technology (e.g. Solvent Recovery Units, Vapour Recovery Units, Leak Detection and Repair Programs for plant-site fugitive emissions).
  - AENV maintenance of a regional inventory of air emissions, including ozone-forming compounds from industrial, urban and biogenic sources in the Region.
  - Approval conditions that regulate emissions of oxides of nitrogen and non-methane hydrocarbons with the intent to minimize regional increases.
- In order to provide consistency and industry-wide comparability in this time of rapid development, it is recommended that best available technology economically achievable (BATEA[7]) based standards be established for the Region by a multi-stakeholder process led by AENV.

[6] Continuous improvement with respect to ozone precursor emissions will usually require significant capital investment and will generally be achieved during normal stock turnover, as for example, with the replacement of large trucks and shovels.

[7] BATEA refers to technology that can achieve superior emissions performance and that has been demonstrated to be economically feasible through successful commercial application across a range of regions and fuel types. BATEA is used to establish emission control expectations or limits. Generally it is the emission limit that is specified and not the specific BATEA. Facilities can opt for other technologies or emission strategies as long as the emission limit is met. (From the "An Emissions Management Framework for the Alberta Electricity Sector Report to Stakeholders" Prepared by the Clean Air Strategic Alliance Electricity Project Team Nov. 2003)

2.3 Review of Information Gaps:

It is recommended that guidelines for the protection of vegetation from ozone effects for the region be established through scientific processes. Some specific considerations at the present time include:

- A review of existing standards and/or criteria for ground level ozone related to vegetation protection;
- Comparison of those criteria with existing and projected ozone levels to determine if vegetation impacts may be an issue in the Region;
- If potential issues are identified, then AENV and/or EC will be requested to develop a provincial/ federal ambient ozone standard for vegetation protection that could be applied in the Region; and
- If AENV and/or EC identify the need, CEMA will assist with studies on ozone effects on vegetation in the Region to develop a vegetation effects ozone standard relevant to the Region.

2.4 System Evaluation

The NSMWG recommends that in 2011 as part of a Five-Year Review, AENV work with a regional body (perhaps WBEA or CEMA) to conduct a review of the regional Ozone Management Framework. It is recommended that this review include:

- identification of data gaps and research needs;
- re-evaluation of the linkage between the environmental monitoring results for indicator compounds (ozone, NO_x, CO and NMHC) and oil sands air emissions; and
- comparison of the monitoring results with the latest national or provincial ambient objectives with consideration of both health and ecosystem impacts.

If this review indicates ozone levels are higher than, approaching, or are predicted to exceed the Management Action Level objective (or another agreed to environmental and human health benchmark), then:

- a multi-stakeholder group should be formed to review the Ozone Management Framework for the Region.

If this review indicates ozone levels are stable or decreasing then:

- the ozone management actions should be reviewed and possibly reduced, with consideration being given to classifying the region as at a “baseline” action level.

The NSMWG recommends that the Ozone Management Framework evaluation process should be repeated at a future date to be set during the 2011 review process.

Appendix 1:

Guidance Document for the Management of Fine Particulate Matter and Ozone in Alberta

The Regional Municipality of Wood Buffalo area ("the Region") is an area of the province that meets Canada Wide Standards (CWS) for ozone. For areas of Alberta that meet the CWS, the guidance document provides the following statements:

Principles that apply below the Numeric CWS[8]

Recognizing that the focus of the management framework below the numeric CWS is Keeping Clean Areas Clean and Continuous Improvement, the following guiding principles and concepts apply:

1) The action trigger concentrations are neither "pollute up to" levels, nor "not to exceed" levels.

2) Activities should be prioritized according to available resources, contextual factors (see 5), and air quality needs.

3) More stringent management tools are to be used as ambient concentrations approach the CWS; more flexible management tools are to be used when ambient concentrations are at baseline or surveillance levels.

4) Action triggers will be used for airshed planning. They will not be applied as "point of impingement"[9] concentrations in relation to approval limits and conditions.

5) Contextual factors, including but not limited to:
   a) population growth and density;
   b) trends in ambient levels;
   c) the predicted impact of existing activities and initiatives;
   d) economic growth forecasts;
   e) age of facilities; and
   f) any factors related to the overall practicality of actions will be considered in the development of mandatory plans, management plans and other activities in areas with ambient concentrations below the CWS.

6) The management framework will work towards the long-term goal of minimizing risks to human health and the environment, balancing the desire to achieve the best health and environmental protection possible in the relative near term and the

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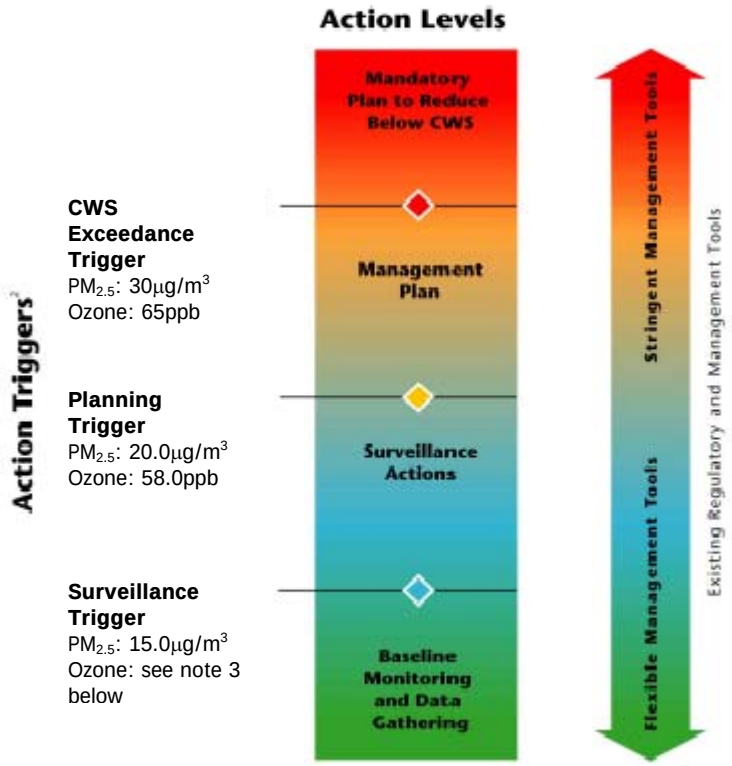
8 From the "Guidance Document for the Management of Fine Particulate Matter and Ozone in Alberta" Prepared by the Clean Air Strategic Alliance Particulate Matter and Ozone Project Team (p. 16-17)

9 Point of impingement concentrations are the ambient concentrations of individual pollutants as measured at the boundary/property line of an emitting facility.

feasibility and costs of reducing the pollutant emissions that contribute to elevated concentrations of PM and ozone in ambient air.



1. The framework must be applied in the context of its key elements, including guiding principles, existing initiatives and mechanisms that support management of PM and ozone, and the goals and objectives for each action level.
2. Action triggers for PM2.5 are based on a 24-hour average, and achievement is based on the 98th percentile ambient measurement annually, averaged over 3 consecutive years. Action trigger levels for ozone are based on an 8-hour average, and achievement is based on the 4th highest measurement annually, averaged over 3 consecutive years.
3. For ozone, Alberta Environment will determine on an annual basis which areas of the province are in baseline and which are in surveillance.

Figure A-1: Provincial PM and Ozone Management Framework[1]

The CASA Particulate Matter (PM) and Ozone Project Team submitted a report entitled "Particulate Matter and Ozone Management Framework". This report was approved by the CASA Board of Directors on September 18, 2003, and has subsequently been accepted by Alberta Environment. The report can be downloaded from the CASA web site. The framework is Alberta's plan for implementing the Canada-Wide Standards (CWS) for PM and Ozone, agreed to in June 2000, by the federal, provincial (except Quebec), and territorial governments. The following information is extracted from that report.

Canada-Wide Standards for Ozone

The CWS sets ambient levels of ground-level ozone to be achieved by 2010. The standard is focused on human health protection. It also includes provisions of Keeping Clean Areas Clean and Continuous Improvement (KCAC/CI) in areas where ambient levels are already below the CWS:

- *Numeric Target*: 65 parts per billion (ppb), 8-hour averaging time, by 2010. Achievement to be based on the 4th highest measurement annually averaged over 3 consecutive years. There are specific provisions for transboundary flow, high background or natural events. The standard applies to population centers over 100,000.
- *KCAC/CI*: Take remedial and preventative actions to reduce emissions from anthropogenic sources to the extent practicable rather than simply "polluting up to the limit".

The Alberta Framework

The Alberta framework applies the CWS to all parts of Alberta, not only population centers over 100,000. With respect to ozone, it defines four action levels based on the following criteria:

- Exceedance: 65 ppb, CWS metrics as described above
- Management: 58 ppb, CWS metrics as described above
- Surveillance: at the discretion of AENV, based on considerations as described below
- Baseline: at the discretion of AENV, based on the considerations as described below

Alberta Environment will determine on an annual basis which areas of the province are in baseline and which areas are in surveillance based on:

- Location of existing monitoring
- Ambient ozone data (prepared using the 3 year CWS metric)
- Available resources for baseline and surveillance activities

- Priorities for improving understanding of ozone sources, formation, concentration and movement.
- Consultation with regional stakeholders

An annual analysis will be performed by AENV, with the assistance of Environment Canada, of ambient monitoring data from the Alberta monitoring network. The analysis applies the CWS three-year metric to the monitoring data to determine the appropriate action level for an area (i.e. exceedance, management, surveillance, baseline). Episodes that are primarily caused by natural events, high background or transboundary transport are removed from the calculation of the three- year metric as described in the "Guidance Document for the Management of Fine Particulate Matter and Ozone in Alberta". This document can be downloaded from the CASA web site. Demonstration of background or natural influence is the responsibility of AENV, while demonstration of transboundary flow, including high background levels originating from sources outside of Alberta, will be a shared responsibility of the federal government and AENV. Technical details on monitoring and analysis are contained in the guidance document.

Management actions associated with each level are:

*Exceedance***:** AENV will develop and implement a management plan containing measures to reduce ambient concentrations to below the numeric CWS, striving to develop the plan within two years and working with stakeholders to the greatest extent possible. Key stakeholders from both emission sources and receptor communities, including airshed zones, will be identified and consulted. AENV will ensure that monitoring is adequate.

Management: The goal is to avoid exceedance of the CWS. Stakeholders from source and receptor areas will develop a management plan. Actions will be appropriate to the ambient concentrations, trends, and contextual factors. AENV or the affected airshed zone(s), as appropriate, may coordinate development of the plan. If this is not done within two years, AENV may impose a plan.

Surveillance: AENV, with the support of the affected airshed zone(s) as appropriate, will ensure that the source(s) of elevated ambient concentrations are determined and that trends in ambient concentrations are analyzed and monitored. The focus is on ensuring that ambient air quality monitoring and information required to assess the region's air quality is in place, and that, where possible, steps are taken to maintain or improve air quality. AENV will review ambient air quality monitoring data annually and assess, in consultation with the Operations Steering Committee (OSC), the adequacy of existing ambient air quality monitoring in the area and other available information relating to air quality. If an airshed zone exists AENV will work with them. Opportunities for KCAC and CI will be identified and encouraged.

Baseline: The primary goal is ongoing monitoring of ambient air quality levels.

Appendix 2:

Presentation of Air Monitoring Data for Ozone and Precursor Gases in the Regional Municipality of Wood Buffalo Area ("the Region")

Data from the CASA Warehouse, over several years, have been collected for comparison of ozone and ozone precursor levels in the Regional sites to levels at other sites across Alberta. This is not intended to be a scientifically rigorous evaluation of the existing data, but is rather a simple comparative display of archived information. There has been no effort to undertake any quality control of the data and it has been accepted as provided by the responsible airshed zone and stored in the CASA Warehouse.

The first comparison (Table 1) presents ozone levels from across the provincial network of ozone monitoring stations in relation to the Canada-Wide Standard and Alberta provincial framework ozone levels. The data presented are the 4th highest 8-hour average measurements annually for 3 consecutive years (2001 to 2003) plus a 3-year average of these 4th highest 8-hour average values. These data have not been adjusted to account for trans-boundary or natural sources of ozone. The Table list the stations in a general geographic order from north to south.

This data indicates that the greater risk of exceeding the national standard for concentration of ozone is in the West Central and Edmonton regions where several stations show ozone levels possibly exceeding the Canada-Wide Standard metric. In the Region, monitoring for 2001-2003 indicates that annual and 3 year average 4th highest 8-hour average ozone measurements are not exceeding the provincial Exceedance Level. Stations at Fort McKay and Syncrude indicate annual 4th highest 8-hour average ozone measurements have approached or exceeded the 58 ppb Management Level but are below this level based on a 3 year average which is the basis of the metric.

Figure 1 compares annual average ozone measurements taken throughout the province of Alberta. Values for this metric are between 15 and 30 ppb in Alberta. Individual stations show little variability from year to year. The lower average annual ozone levels occurring in the Calgary and Edmonton regions, are likely the result of ozone scavenging by NO and the data indicate that some scavenging may be occurring in the Athabasca Valley locale.

Figure 2 shows annual average passive ozone measurements at Wood Buffalo Environmental Association stations. These values are consistent with the annual averages from continuous monitoring in the region, with levels ranging from 22 to 30 ppb. The stations are ordered by distance away from the industrial corridor (left to right). Annual averages smooth variability in data, but the data would seem to show possible small increases in the ozone at distances of about 20-30 km and 40-70 km from the existing industrial sources. At the distance of site PL8 greater than 100 km away, the annual ozone is lower. The directionality of the sites is indicated on the axis after the distance.

Figure 3 presents annual average ozone precursor gas measurements of NO_2 and hydrocarbons in a general south to north direction within the province. There is substantially more variability from station to station in the NO_2 values than in the hydrocarbon values. Stations show little variability in levels from year-to-year and the stations in the Region show little variability between sites. This likely indicates that hydrocarbons are ubiquitous and consistent across the Region. The NO_2 concentrations vary quite substantially between stations which is likely reflective of variations in automobile usage in the areas. The Calgary and Edmonton urban centres show high annual average NO_2 values. This is consistent with the observation of ozone scavenging in those locales. Similarly, though certainly on a smaller magnitude, the slight scavenging observed at the Athabasca Valley site would be consistent with the enhanced local NO_2 concentrations seen here.

Figure 4 show the maximum hourly and annual averages for ambient NO_2 measured during each year from 1989 through 2003 at sites in the Region. The NO_2 values are compared to the Alberta Ambient Air Quality Objectives (AAAQO) and clearly indicate that measured levels are currently well below Objective levels. To date, annual variability has been small at the stations and it is difficult to identify any trends in the data. As more approved and planned projects commence operation, an upward trend would be expected.

In the plume field studies during 2001 and 2002, the AMEC report showed that NO scavenging was observed in-plume close to the sources with ozone production (an additional 6 to 8 ppb) observed further downwind. The diurnal patterns in ozone observations at ground level on the study days showed that highest concentrations near the facilities occurred on days with warm temperatures and light winds.

Table 1: CASA Warehouse ozone concentrations (ppb) of 4th highest 8-hour average measurements for 2001-2003 with a 3-year average of those values. Values in blue exceed the provincial Management Level of 58 ppb O_3 and values in red exceed the Exceedance Level of 65 ppb O_3.

Monitoring Site	2001	2002	2003	3 yr Avg
Fort Chipewyan[1]	49.4	54.6	54.8	52.9
Fort McKay[1]	50.4	50.9	61.7	54.3
Syncrude	na	na	57.5	57.5
FtMc-Athabasca Valley[1]	49.3	54	56	53
FtMc-Patricia McInnes[1]	54	55.6	53.3	54.2
Beaverlodge	62	49.5	54.6	55.3
Lamont[2]	na	na	61.9	61.8
Fort Saskatchewan[2]	62.5	69.8	55.8	62.6
Elk Island[2]	na	na	59.1	59.1
Edmonton Central	49.5	62.5	52	54.6
Edmonton East	64.3	69.5	63.9	65.9
Edmonton Northwest	58.6	69.3	65.4	64.4
Edmonton CMA	64.3	69.8	65.4	66.5

Hightower Ridge[3]	73.4	64.1	61.4	66.3
Steeper[3]	65.9	60.1	66.9	64.2
Tomahawk[3]	60.1	74	67.6	67.2
Carrot Creek[3]	68.3	65.5	66.1	66.7
Violet Grove[3]	61.3	67.1	65.3	64.5
Red Deer	57.9	67	63.9	62.9
Caroline[3]	66.3	68	70.5	68.3
Esther [4]	59.9	na	na	59.8
Calgary Central	51.5	52	52.5	52
Calgary East	53.5	53.8	53	53.4
Calgary Northwest	58.8	69.1	63.3	63.7
Calgary CMA	58.8	69.1	63.3	63.7

Stations are operated by Alberta Environment except as indicated.
[1] Wood Buffalo Environmental Association
[2] Fort Air Partnership
[3] Parkland Airshed Management Zone
[4] Environment Canada

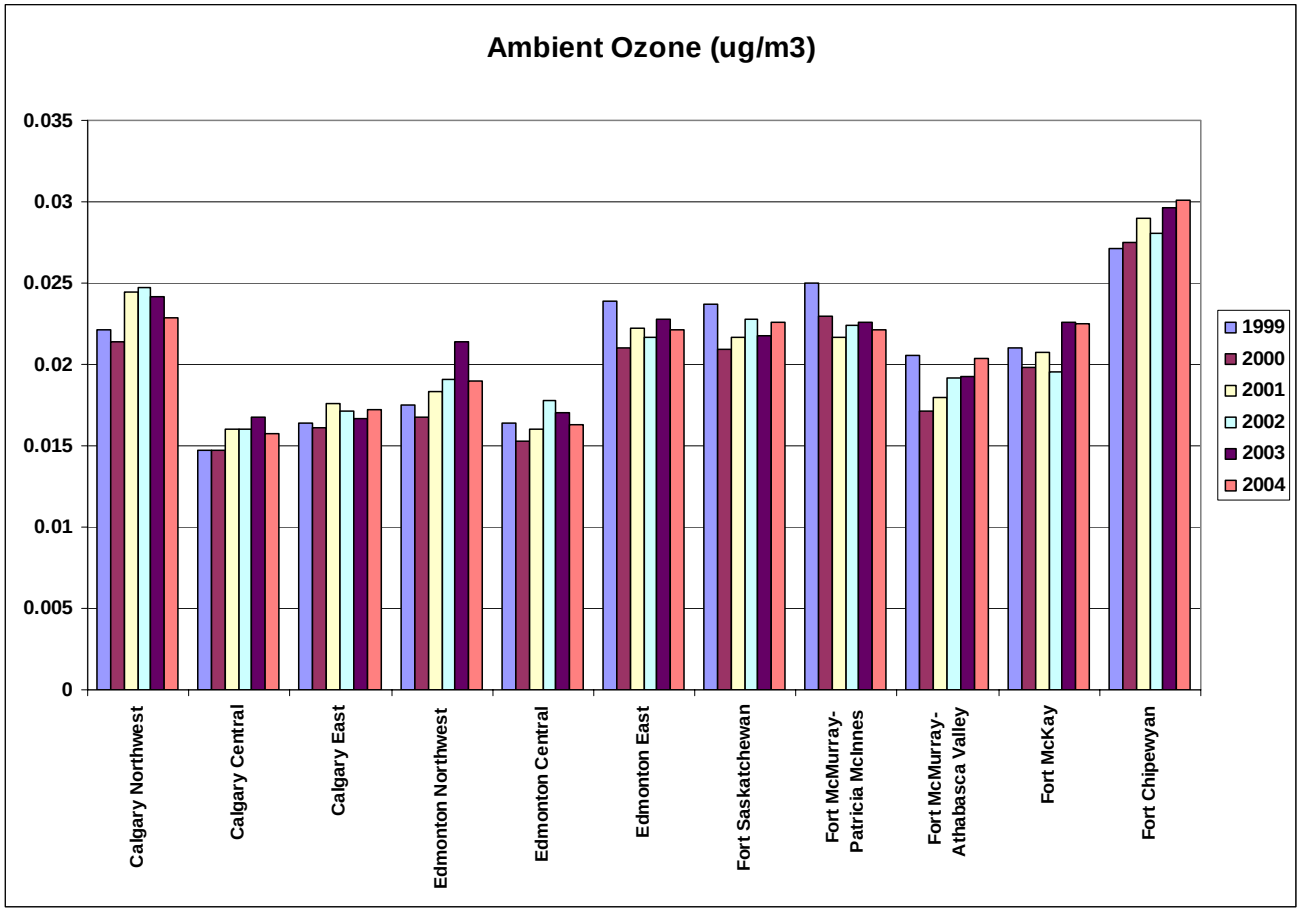


Figure 1: Annual average continuous monitoring ozone (ppb) concentrations at Alberta stations presented from south to north through the province.

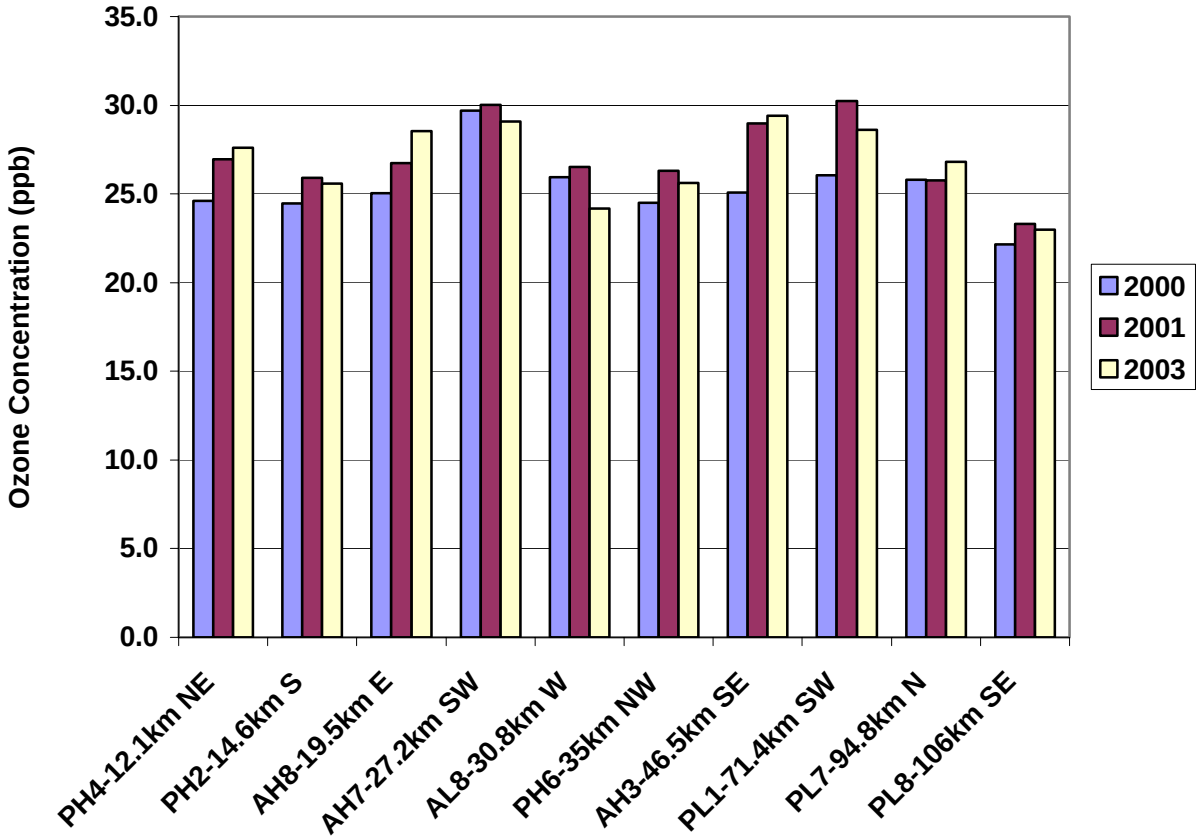
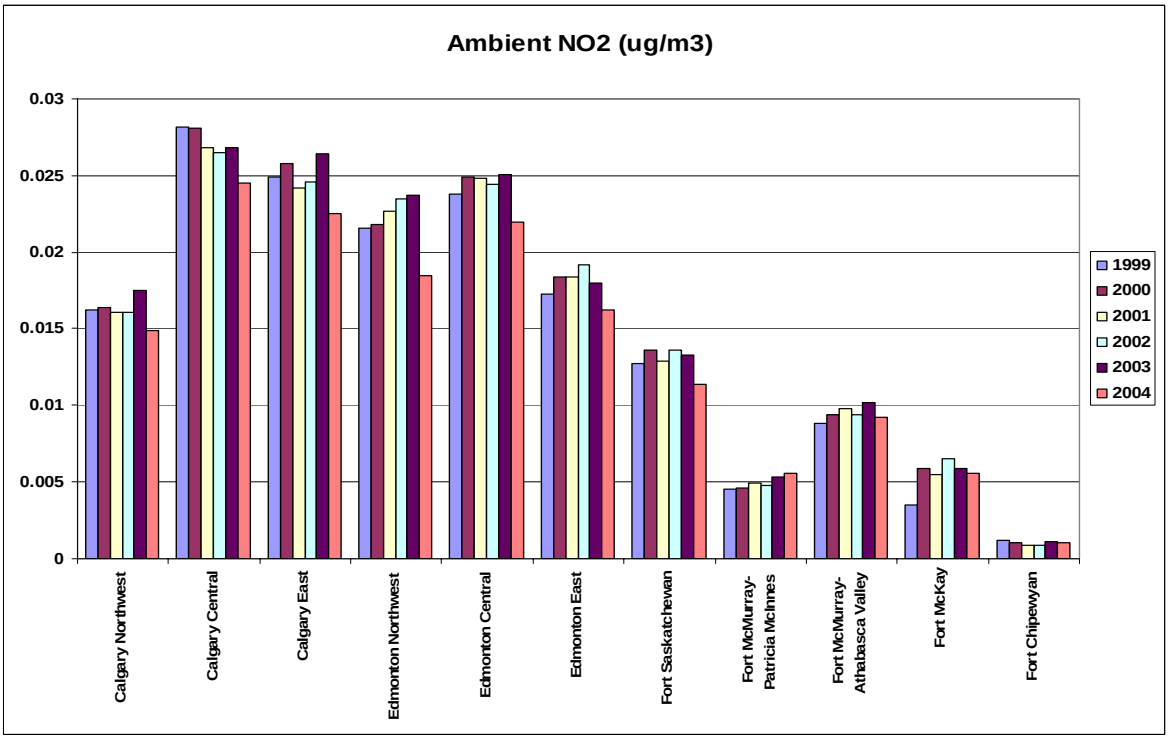


Figure 2: Annual average passive monitoring ozone (ppb) concentrations at WBEA stations presented from closest to furthest from the main industrial corridor. The directionality of the site follows the distance.

(a)



(b)

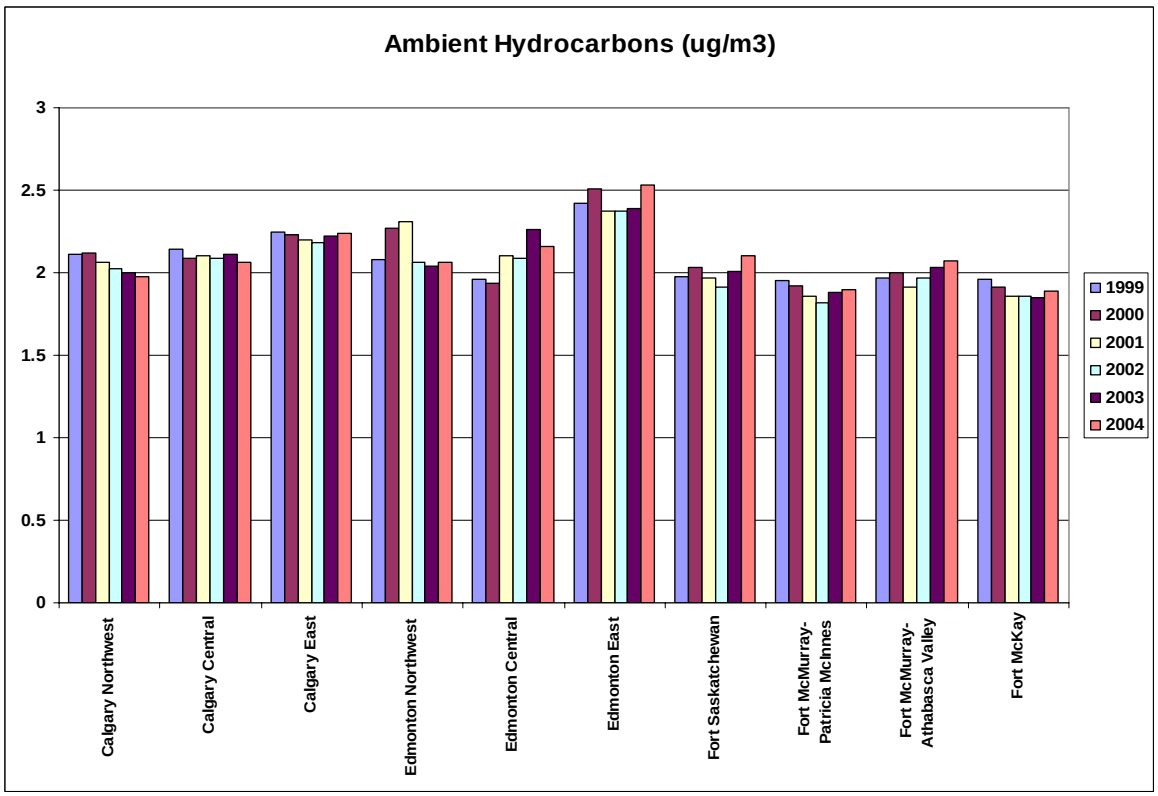
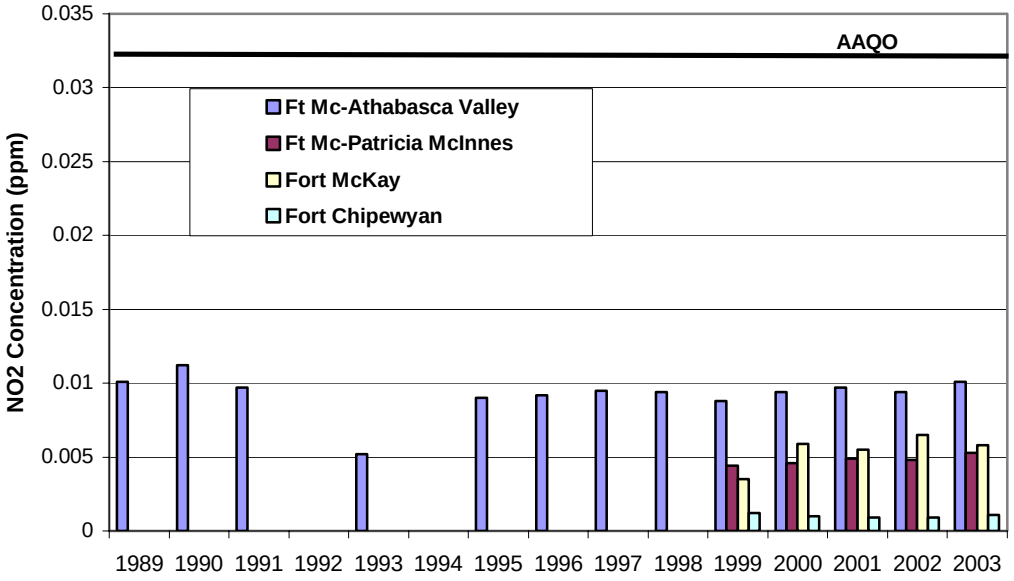


Figure 3: Annual average ambient (a) NO_2 and (b) hydrocarbon ozone precursor concentrations in Alberta.

(a)



(b)

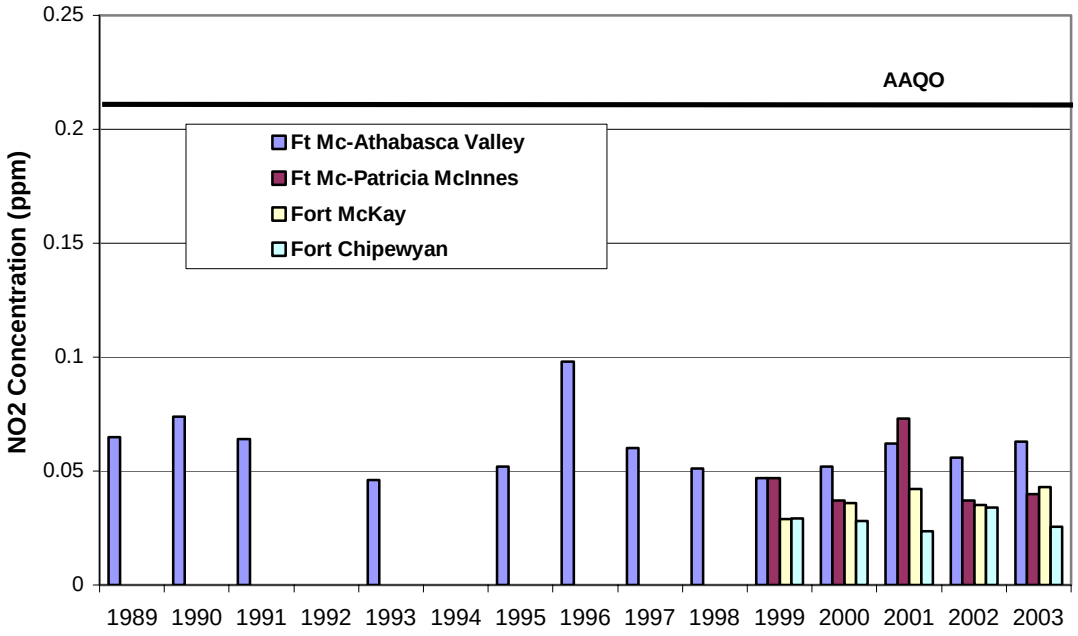


Figure 4: Annual (a) average and (b) maximum hourly averages of ambient NO_2 concentrations (ppm) in the Region.