Respirable Particulate and Ground-Level Ozone Sampling Study in the City of Greater Sudbury - Summer of 2009

Study Undertaken for the

Environmental Commissioner of Ontario

and Clean Air Sudbury

By

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Research & Project Management

And

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1.0 INTRODUCTION

There is increasing interest in knowing how current regional air quality forecasting and monitoring programs adequately represent the true air pollution exposure of urban populations. The majority of air quality monitoring stations in Ontario and Canada are in urban and rural locations removed from sources of air pollution such as major traffic corridors and significant point sources. Many of these are best described as urban background stations.

In order to gain a better understanding of these programs, in 2007 the Environmental Commissioner of Ontario (ECO) commissioned a review of current practices in Ontario and in the rest of Canada[1].

The review included a summary of initiatives used in other national and international jurisdictions, current state-of-the-science for systems designed to predict air quality at street level, and where the science is headed. The review indicated that the Ontario Ministry of the Environment (MOE) current air quality forecasting and monitoring system, which is similar to the systems used by Environment Canada, the USEPA and many North American cities, provides general information to the public on regional air quality. However this approach does not provide data needed to assess air quality at street level in the urban environment.

The review revealed that some advanced European systems provide near real-time air quality information on both urban background and roadside pollutant levels using data from comprehensive and state-of-the-science ambient air monitoring networks. For example, in some European cities real-time analyzers are positioned at key traffic intersections and have the ability to control traffic lights based on measured pollutant levels. These advanced systems more reliably approximate potential human exposures in urban settings.

[1] Predicting Air Quality at Street Level - A State-of-Science Review, Project Number: #W08-5129A, 25 March 2008

The August 2009 Air and Waste Management Association publication, *EM-The Magazine for Environmental Managers*[2], featured research articles on near-roadway health effects from air pollution and possible ways to mitigate air quality impacts from roadways. It was indicated that recent studies have confirmed the risk to human health for populations spending significant amounts of time near large roadways. Research studies also show elevated air pollutant concentrations of gaseous and particulate compounds near roads.

In order to obtain a better understanding of particulate concentrations near street level locations and in other locations not routinely monitored by agencies in North America, the ECO commissioned summer sampling programs in a number of communities and urban centres in the Province.

2.0 Sampling Program

2.1 Sampling Campaigns (2007 and 2008)

The initial study took place in 2007. It was aimed at estimating the concentrations of the very coarse (Total Suspended Particulate – TSP) and fine (respirable particulate matter as $PM_{2.5}$) that Ontario residents can be exposed to during short time periods in locations not monitored by the Provincial Air Quality Monitoring Network operated by the MOE. These locations included rural background, small/large urban areas, busily travelled downtown locations and public areas. High-volume (hi-vol) samplers, placed in the open cargo area of a half-ton pick-up truck and powered by a gasoline generator, were used to measure the TSP and $PM_{2.5}$ particle size fractions collected on quartz filters.

The study was repeated in the summer of 2008 and comprised simultaneous measurements of ground-level ozone (O_3) and $PM_{2.5}$, again using the hi-vol method.

$PM_{2.5}$ and ground-level ozone are both implicated in several current air quality issues in Ontario: they are the main constituents of smog and are

[2] EM – The Magazine for Environmental Managers, Air and Waste Management Association, August 2009

linked to climate change and acid deposition[3]. $PM_{2.5}$ is also responsible for reduced visibility and regional haze. Both pollutants are the focus of air quality management programs both in Canada and in the U. S.

The results of the 2007 and 2008 sampling programs revealed that the hi-vol method does not appear to be a reliable method for measuring $PM_{2.5}$ concentrations since it tends to frequently overestimate expected and true ambient values by significant amounts. It is suspected that the hi-vol sampler at times collects particulate matter greater in size than 2.5 microns. The study also revealed that for short time periods, the levels of TSP can be quite elevated due to emissions from natural and anthropogenic sources in a variety of urban and rural environments.

The 2008 study showed that the ozone concentrations obtained with a portable ozone analyzer were in the range measured at the closest MOE Air Quality Index (AQI) stations for the same time periods.

2.2 Sampling Campaign (2009) – City of Greater Sudbury

In the summer of 2009, the provincial study was undertaken in the same communities sampled in 2008. The City of Greater Sudbury had not been included in the earlier studies. Ground-level ozone concentrations were again measured with a portable analyzer. $PM_{2.5}$ measurements were taken with a portable GRIMM model 107 particulate analyzer. Both sampling methods are described below.

Clean Air Sudbury (CAS), a non-profit community group focused on air quality issues in Greater Sudbury, expressed an interest in this study and approached the ECO to include the City of Greater Sudbury in the 2009 sampling campaign. This in part stems from concerns by the CAS committee that exposure of the population to street level air pollution may not be adequately monitored by the MOE AQI station located on the southern shore of Ramsey Lake near Laurentian University. This station is considered to represent urban background air quality.

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[3] Air Quality in Ontario, 2007 Report, Ontario Ministry of the Environment, Publication PIBS 6930e © Queen's Printer of Ontario, 2008

This report presents the results of the sampling program undertaken in the City of Greater Sudbury at five locations in August. The air quality sampling results for the other communities are presented in a separate report.

It is important to note that ambient air quality concentrations were taken for very brief time periods and may not be representative of longer term averages over a range of meteorological conditions. Additional sampling over much longer time intervals would be required to obtain a better representation of air quality levels, especially at peak traffic times. However the results are deemed to provide an indication of the air quality at street level under the conditions when the sampling was conducted.

The study results were compared with hourly measurements taken at the MOE AQI station which continuously measures ground-level ozone and $PM_{2.5}$ concentrations. Ozone concentrations at that site are measured with a conventional analyzer using the ultraviolet (UV) absorption method, whereas $PM_{2.5}$ concentrations are measured with a Tapered Oscillating Microbalance (TEOM) analyzer operated at 30°C and with a Sample Equilibration System (SES). It is important to note that the data from the AQI station is preliminary from automatically polled data and is subject to change upon final verification by the MOE before it is published.

2.2.1 Particulate Analyzer

A portable battery-operated particulate analyzer (model 107), manufactured by GRIMM was used to simultaneously measure concentrations of TSP, PM_{10} and $PM_{2.5}$ in units of $\mu g/m^3$ for particles ranging in size from 0.25 to 34 microns (µm). The mass concentration range is 0.1 to 1500 $\mu g/m^3$. The measuring principle is laser light scattering at 90°. The unit's spectrometer is single particle detection and counting system. It is thus designed to measure every single particle and classify it by size. It continuously measures the particle concentration and the complete counts by size range are shown within 6 seconds. The data are reported in 1 minute intervals and stored on a removable data logger card. The analyzer

is factory calibrated by the manufacturer. The calibration cannot be adjusted in the field but is required to be checked every 18 to 24 months by the manufacturer or an authorized firm capable of providing this service.

The model 107 is listed as an acceptable dust monitor by the MOE[4]. It does not have USEPA or European approval. However it should be noted that the GRIMM model 180, which is the rack-mounted version and uses the same laser spectrometer system, has European approval for $PM_{2.5}$. This model has been submitted to the USEPA for approval which is expected in the spring of 2010 for $PM_{2.5}$. Preliminary EPA test results show very good comparison with a Federal Reference Method (FRM) sampler for $PM_{2.5}$.[5]

Brief inter-comparisons of $PM_{2.5}$ data collected with the portable Grimm analyzer near the MOE North Bay and Toronto Downtown (Bay Street and Wellesley Avenue) AQI stations during the study period revealed that, on an hourly basis, the concentrations obtained from the GRIMM analyzer were within about 1 to 1.5 $\mu g/m^3$ of the values reported by the TEOM analyzer at the AQI stations.

Using the 107 dust spectrometer as a handheld instrument outdoors without an automatic correction system for high Relative Humidity (RH) values (≥70% RH) can give results higher than expected since the high humidity may produce super-saturation and an artificial particle growth of the aerosols. At a high level of humidity (≥ 90% RH), some condensation will occur in the optics which will increase the instrument readings. Other than water vapor at RH >70%, no other compounds will affect the readings.[6]

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[4] Operations Manual for Air Quality Monitoring in Ontario, Ontario Ministry of the Environment, Operations Division, Technical Support Section, March 2008

[5] Personal communication with Gil Cossette, Representative of GRIMM Aerosol Canada Inc.

[6] Personal communication with Gil Cossette, Representative of GRIMM Aerosol Canada Inc

2.2.2 Ground-Level Ozone Analyzer

Ground-level O_3 measurements were simultaneously taken with a portable monitor (Model 202) supplied by 2B Technologies Inc. in Boulder Colorado. The monitor measures atmospheric O_3 in the concentration range 1.5 to 100 part per million of air by volume (ppmv) using the well-established technique of ultraviolet (UV) absorption at 254 nanometers (nm). This instrument features high precision, small size and weight (2.1 kg) and low power consumption (4.0 watts at 12 V DC). It can operate from an external battery or AC adapter. It is well-suited for remote and urban network applications.

The calibration of the monitor was independently audited by Rotek Inc. located in Hamilton, an environmental firm specializing in air quality monitoring instrumentation and monitoring programs. The audit report shows that the calibration of the Model 202 monitor was within 4% of the test gas value using an Environics Model 6103 ozone calibrator. This deviation is well within the ± 10% data acceptability criterion used by the MOE. The analyzer response to the audit test gas was linear. A copy of the audit report is provided in Appendix A. During the study, ambient O_3 concentrations were measured as 5 minute averages while the GRIMM analyzer was in operation. The 5 minute averages were then used to calculate 1 hour averages to compare against the Ontario Ministry of the Environment (MOE) Ambient Air Quality Criterion (AAQC) for 1 hour.

Most of the time, the analyzers were powered with an inverter. The GRIMM analyzer usually ran on its internal battery which was re-charged as required. A gasoline powered Honda generator was used as back-up in case of failure of the inverter. The generator had to be used only once for both analyzers. Figure B-1 in Appendix B is a photo of the analyzers used in this study.

Brief inter-comparisons of ozone data collected with the portable analyzer near the MOE North Bay and Toronto Downtown (Bay Street and Wellesley Avenue) AQI stations during the study period revealed that, on an hourly basis, the concentrations obtained from the portable analyzer were within

about 1 to 5 ppb of the values reported by the ozone analyzer at the AQI stations.

2.2.3 Locations Sampled in Greater Sudbury

The concentrations of ground-level ozone and $PM_{2.5}$ were measured at the five locations and the sampling periods shown in Table 1. These locations were proposed by Clean Air Sudbury since these street intersections have some of the highest traffic volumes in the city. They also provide a cross-section or mix of vehicular traffic (light duty gasoline vehicles, light and heavy duty diesel vehicles). It is important to note that the volume of heavy duty diesel vehicles in August 2009 was likely lower than normal at some intersections (Lasalle Blvd/Barrydowne Rd, Lasalle Blvd/Notre Dame Ave) due to the Vale Inco labour disruption. Lasalle Blvd is the major east/west artery travelled by heavy duty diesel trucks hauling ore and slurry concentrate for the mining sector. A map of the sampling locations and photos of the sites are shown in Appendix C.

Table 1: Sampling Locations and Periods

Date	Location	Sampling Period (EST)	
2009		$PM_{2.5}$	Ozone
August 11	Lasalle Blvd and Barrydowne Rd	08:00 to 11:37	08:45 to 11:48
August 11	Lasalle Blvd and Notre Dame	12:28 to 15:35	12:57 to 16:10
August 14	Notre Dame Ave and Elm St	0944: to 12:57	10:11 to 13:14
August 14	Regent St and Paris St	13:42 to 16:41	13:53 to 16:48
August 19	Notre Dame Ave and Main St	10:29 to 13:28	10:41 to 13:47

3.0 Reference Levels and AQI Determinations

3.1 Respirable Particulate

The Canada Wide Standard (CWS) reference level for respirable particulate matter (30 $\mu g/m^3$) is set on the basis of a 24-hour average. For practical reasons, the samples collected in this study were over a 3-hour interval. For such short-term exposures to respirable particulate, Ontario uses a value of 45 micrograms per cubic metre of air ($\mu g/m^3$) which is considered equivalent to the 24-hour CWS reference level of 30 $\mu g/m^3$. In other words, the CWS reference level would likely have been exceeded based on a 3-hour sample result of 45 $\mu g/m^3$. For this study, the equations used in Ontario to calculate the Air Quality Sub-index for $PM_{2.5}$ to categorize the air quality, as ranging from very good to very poor, were used to describe the air quality when and where sampling occurred. The equations used to calculate the sub-index for $PM_{2.5}$ in Ontario are shown in the following table:

Table 2: AQI Equations for $PM_{2.5}$ Sub-Index

AQI Category	$[PM_{2.5}]$ 3-hour average ($\mu g/m^3$)	AQI Equation
Very Good	<12	$1.364 \times [PM_{2.5}] + 0$
Good	12 to 22	$1.500 \times [PM_{2.5}] - 2.000$
Moderate	23 to 45	$0.7727 \times [PM_{2.5}] + 14.228$
Poor	46 to 90	$1.113 \times [PM_{2.5}] - 1.298$
Very Poor	>90	$1.100 \times [PM_{2.5}] + 0$

It is important to note that compliance with the CWS for $PM_{2.5}$ is based on the 98th percentile of the annual daily average, averaged over three

consecutive years. Compliance for designated cities (with population over 100,000) is set for 2010. Hence it was not possible or the intent in this study to assess compliance with the CWS.

3.2 Ground-Level Ozone

Ontario has an AAQC of 80 ppb for a 1 hour average. The Canada Wide Standard for O_3 is 65 ppb. It is based on an 8 hour running average and the 4th highest annual average value is averaged over three consecutive years. Again, designated cities meeting the population threshold of 100,000 are to comply with this standard by 2010. Ontario does not have a three hour O_3 average reference level equivalent to the CWS 8 hour running average. Hence the results of this study are compared with the Ontario AAQC of 80 ppb for a 1 hour average. In addition, the equations used in Ontario to calculate the Air Quality Sub-index for O_3 to categorize the air quality, as ranging from very good to very poor, were used to describe the air quality when and where sampling occurred. For this study, the maximum 1 hour average O_3 concentration measured during the 3 hour

Table 3: AQI Equations for O_3 Sub-Index

AQI Category	$[O_3]$ (ppb)	AQI Equation
Very Good	0 to 23	$0.6520 \times [O_3] + 0$
Good	24 to 50	$0.5800 \times [O_3] + 2.154$
Moderate	51 to 80	$0.5900 \times [O_3] + 2.1$
Poor	81 to 149	$0.7200 \times [O_3] - 8.37$
Very Poor	>149	$0.7200 \times [O_3] - 8.37$

sampling period for $PM_{2.5}$ was used to calculate the O_3 Sub-index. The equations used to calculate the AQI sub-index for O_3 in Ontario are shown in Table 3.

4.0 STUDY RESULTS

The sampling results are summarized in Table D-1 of Appendix D, and are discussed below for each location. Although simultaneous results of TSP and PM_{10} are available, only the $PM_{2.5}$ results are presented in this report. The traffic volume data was provided by Roads and Transportation, Infrastructure Services, City of Greater Sudbury and is the most recently available.

4.1 Results by Location

Lasalle Blvd and Barrydowne Rd –August 11:

This is one of the busiest intersections in Greater Sudbury with 2009 Average Annual Daily Traffic Volumes (AADTV) of 55,000. It is located near the largest shopping mall in the New Sudbury section of the city. It is bounded to the northeast and southeast corners by gasoline dispensing stations. A large parking lot servicing the shopping complex is on the southwest corner. During the sampling period on August 11, the traffic conditions were observed to be moderate to heavy, with a mix of cars and transports.

During the sampling period (08:00 am to 11:48 am EST), the temperature varied from 22°C to 31.6°C under mostly overcast skies and relative humidity varying from 40% to 59%. The winds were from the northeast and gusting from about 4 to 10 km/h. The mobile sampling unit was located on the southwest corner of the intersection, in the downwind quadrant of the intersection (see photo, Figure 2 in Appendix C).

The average $PM_{2.5}$ concentration for the sampling period was 14.9 $\mu g/m^3$, more than double the average of 6.3 $\mu g/m^3$ for measurements taken at the AQI station. The average ground-level ozone concentration at the study site was about 14 parts per billion (ppb) which compares well with an average of about 15 ppb for the AQI site.

For the sampling period, the MOE reported AQI values ranging from 7 to 10 (very good air quality) based on ozone measurements. At the sampling location, the AQI value at 10:00 EST would have been 21(good air quality) based on the 3 hour average $PM_{2.5}$ concentration.

Lasalle Blvd and Notre Dame Ave –August 11:

This is another busy intersection with 2005 Average Annual Daily Traffic Volumes (AADTV) of 53,000. It is located at the west end of Lasalle Blvd and consequently has a lot of the east-west traffic travelling on Lasalle Blvd. It is a major north-south artery for traffic from the "Valley" to the city downtown core. It also has a heavy traffic volume of heavy and light duty diesel vehicles. It is bounded to the northeast by a funeral home, to the southeast by the Revenue Canada Taxation Centre and to the northwest by a gasoline dispensing station and a Tim Horton's outlet. During the sampling period on August 11, the traffic conditions were observed to be moderate to heavy, with all forms of transportation.

During the sampling period (12:28 pm to 16:10 pm EST), the temperature varied from 29.7°C to 32.2°C under a mix of overcast and sunny skies and relative humidity levels varying from 20% to 40%. The winds were from the north and northeast and gusting from about 4 to 14 km/h. The mobile sampling unit was located on the northwest corner of the intersection, downwind of traffic to the north of the intersection (see photo, Figure 3 in Appendix C).

The average $PM_{2.5}$ concentration for the sampling period was 6.1 $\mu g/m^3$, double the average of 3.0 $\mu g/m^3$ for measurements taken at the AQI station over the same time period. The average ground-level ozone concentration at the study site was about 21 parts per billion (ppb) which is identical to the average obtained for the data at the AQI site. As is the case for most

days in the summer, the early to mid-afternoon ozone concentrations are higher than in the morning, following the well-known diurnal pattern.

For the sampling period, the MOE reported AQI values ranging from 13 to 18 (very good to good air quality) based on ozone measurements. At the sampling location, the AQI value at 15:00 EST would have been 15 (very good air quality) based on ozone and 8 (very good air quality) based on the 3 hour average $PM_{2.5}$ concentration. Hence the AQI values from the MOE station were representative of the air quality at the intersection of Lasalle Blvd and Notre Dame Ave at that time based on very similar ozone measurements.

Notre Dame and Elm St – August 14

This intersection has lighter traffic volumes with 2008 AADTV in the order of 45,000. It is the 'cross-roads' of the downtown city core. It has a larger fraction of light duty gasoline powered vehicles than on the Lasalle Blvd corridor due to commuters that work downtown and in the south end of the city where the hospitals and Laurentian University are located. Also, the Sudbury transit bus terminal is located on the southwest corner of the intersection and the downtown shopping mall is across the street on the northwest corner. A church occupies the northeast corner.

During the sampling period (09:44 pm to 13:44 pm EST), the temperature varied from 29.3°C to 31.9°C. The skies were sunny with periodic cloudy periods. The relative humidity was low ranging from 20% to 27%. The winds were initially light and from the south and southeast. Around 12 noon, the wind was from the south at 6 to 10 km/h. At about 1 pm, the wind had turned from the northeast and become gusty to 12 km/h. The mobile sampling unit was located on the southwest corner of the intersection (see photo, Figure 4 in Appendix C), such that it was downwind of the intersection with northeast winds.

The average $PM_{2.5}$ concentration for the sampling period was 15.0 $\mu g/m^3$, essentially the same as the average of 14.7 $\mu g/m^3$ for measurements taken at the AQI station over the same time period. The average ground-level ozone concentration at the study site was about 32 parts per billion (ppb)

which is somewhat higher than the average of 27 ppb obtained from the data at the AQI site.

For the sampling period, the MOE reported AQI values ranging from 21 to 23 which represent good air quality based on ozone measurements for the 12 noon hour and $PM_{2.5}$ for the two 3 hour periods before noon. At the sampling location, the AQI values would have been the same since the concentrations of both ozone and $PM_{2.5}$ were essentially the same. Hence the AQI values from the MOE station were representative of the air quality at the intersection of Notre Dame Ave and Elm St at that time.

Regent St and Paris St – August 14

This intersection is located in the south end of the city and commonly known as the 'four corners'. It is an area with a significant number of commercial and shopping establishments (shopping mall, strip mall, offices, bank, restaurants, and gasoline refueling station). Although there is some heavy duty truck traffic, a significant portion of the traffic is from light duty vehicles due to the nature of the businesses in the area. The AADTV from the 2006 survey is in the order of 62,000 which qualifies it as the busiest intersection of the ones in this study.

During the sampling period (13:53 pm to 16:48 pm EST), the temperature varied from 30.5°C to 32.6°C. The skies were sunny with periodic cloudy periods. The relative humidity remained steady at about 20%. The winds were from predominantly the south and sometime gusty from 6 to 14 km/h. The mobile sampling unit was located on the northeast corner of the intersection (see photo, Figure 5 in Appendix C), and consequently downwind of the east side of the intersection.

The average $PM_{2.5}$ concentration for the sampling period was 13.7 $\mu g/m^3$, which was higher than the average of 10.3 $\mu g/m^3$ for measurements taken at the AQI station over the same time period. The average ground-level ozone concentration at the site and at the AQI station was 39 parts per billion (ppb).

For the sampling period, the MOE reported good air quality with AQI values ranging from 24 to 26 based on ozone measurements. At the sampling location, the AQI value from $PM_{2.5}$ measurements at 16:00 would have

been 19 which also represent good air quality. Hence the AQI values from the MOE station were representative of the air quality at the intersection of Regent St and Paris St at that time, based on ozone concentrations.

Notre Dame Ave and Main St – August 19

This intersection is located approximately 10.3 km north of the Lasalle Blvd and Notre Dame Ave intersection, in the community of Blezard Valley. From the 2002 traffic count the estimated AADTV is in the order of 34,000. A substantial portion of the traffic is from commuters that work and shop in Sudbury. The population in that area has grown substantially in the past decade as well as commuter traffic into Sudbury. Hence, the current traffic volume is probably higher than estimated from the 2002 survey. The intersection is surrounded by commercial establishments and a gasoline refueling station.

During the sampling period (10:29 pm to 13:47 pm EST), the temperature rose from 21.0°C to 28.7°C. The skies were sunny with periodic cloudy periods. The relative humidity remained steady at about 20%. The winds were from predominantly the west and northwest and sometimes gusty from 4 to 18 km/h. The mobile sampling unit was located on the northeast corner of the intersection (see photo, Figure 6 in Appendix C), such that it was downwind of traffic-related emissions from the north side of the intersection.

The average $PM_{2.5}$ concentration for the sampling period was low at 2.9 $\mu g/m^3$. For the same time period, the average $PM_{2.5}$ concentration at the MOE AQI station in Sudbury was also low at about 1.5 $\mu g/m^3$. The average ground-level ozone concentration at the site was about 16 ppb, which is a bit lower than measured at the AQI station (18 ppb). Hence the air mass coming from the west and northwest during the sampling period was rather dry and had low concentrations of ozone and $PM_{2.5}$.

For the sampling period, the MOE reported very good air quality with AQI values ranging from 11 to 13 based on ozone measurements. At the sampling location, the AQI value from $PM_{2.5}$ measurements during the sampling period would have been 4 which also represent very good air quality. Hence the AQI values from the MOE station were representative of

the air quality at the intersection of Notre Dame Ave and Main St at that time, based on ozone concentrations.

5.0 OBSERVATIONS

- During the brief monitoring periods of this study, the air quality was determined to be very good to good, based on ground-level ozone and $PM_{2.5}$ measurements. In the majority of cases, the ground-level ozone sub-index was highest and determined the overall air quality in accordance with the reporting system used by the MOE. On a province-wide basis, the frequency of smog alerts and episodes was lower than normal in the summer of 2009, as was the case in 2008, due to cool and wet weather conditions.

- The maximum hourly ground-level ozone concentration measured in this study was 42 ppb, considerably less than the MOE criterion of 80 ppb.

- The maximum $PM_{2.5}$ concentration measured over a 3-hour period was 15.0 $\mu g/m^3$, which is considerably lower than the reference level of 45 $\mu g/m^3$ used by the MOE.

- The $PM_{2.5}$ concentrations measured at the study sites with a GRIMM model 107 analyzer were generally higher than those measured at the MOE AQI site, in several instances by as much as a factor of two. The largest differential, 6.9 $\mu g/m^3$, was obtained at the Lasalle Blvd and Barrydowne Road intersection in the morning of August 11th.

- There was good agreement in the ground-level ozone measurements taken at the study sites with measurements at the MOE AQI site. For the 3 hour sampling periods of this study, the differential was less than 5 ppb. Overall, the average concentrations were slightly lower

at the study sites presumably due to the scavenging of ozone by oxides of nitrogen from traffic-related emissions.

- The GRIMM model 107 particle analyzer and the 2B Technologies Inc. model 202 ozone analyzer were found to be very reliable and suitable for mobile studies of this nature.

- The results of this brief study suggest that the concentrations of $PM_{2.5}$ at street-level near busy intersections, at times can be substantially higher than measured at regional air quality monitoring stations.

- The results also suggest that the variability of ground-level ozone concentrations across an urban centre of the size of Greater Sudbury appears to be small.

6.0 Recommendations

- The results of this study are considered 'snapshots in time'. It is recommended that additional sampling should be done, preferably under a broader range of meteorological conditions, especially those conducive to air quality in the moderate to poor range, for a better understanding of the concentrations of $PM_{2.5}$ and ground-level ozone measured at street-level compared to those from urban background AQI monitoring stations.

- It is also recommended that, as much as possible, measurements of $PM_{2.5}$ and ozone be taken during some of the peak traffic times.

- From the experience gained, it is recommended that the portable $PM_{2.5}$ and ozone analyzers used in this study be strongly considered for similar future studies designed for sampling for brief periods and in the mobile mode, due to the quality of the data and the functionality of the analyzers.

APPENDIX A

Ozone Analyzer Calibration Audit Report

Pollutant Calibration / Audit Sheet

Pollutant	Page No.
OZONE	Page 1 of 1

Station No.	Station Location	Audit Date
Rotek	SHOP	July 21, 2009

Instrument Make / Model	Instrument Serial Number	Instrument Range
2B Technologies OZONE Model 202	s/n 287	0 - 500 ppb

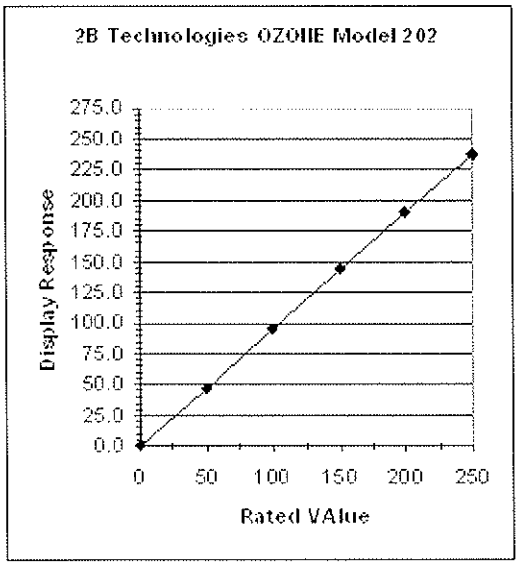
Calibrator Make / Model	Calibrator Serial Number
Environics 6103	3754

Client Company Name	Client Contact Name	Contact Number
Farrow Associates	Wayne Marshall	705 499 1418

Auditor Name	Auditor Contact Number	Auditor Signature
Ralph Frisina	905 573 9533	

Instrument Diagnostics and Response to Test Gases

Calibration Curve



Response to Audit / Calibration Gases. Values in PPB

Test Gas	Rated value	Display Response	% difference	Output Voltage	Instrument Reset
TG1	250.0	238.5	-4.6	-----	no
TG2	200.0	191.0	-4.5	-----	no
TG3	150.0	143.5	-4.3	-----	no
TG4	100.0	96.0	-4.0	-----	no
TG5	50.0	48.0	-4.0	-----	no

System Audit Results

Did data at the receiving terminal duplicate instrument displayed data?

n/a

Did data averages at receiving terminal duplicate generated averages?

Did not conduct data averaging test.

Audit Comments

Instrument reproduces test gas values at a consistent 4% deviation. RF

APPENDIX B

Photo of Ozone and $PM_{2.5}$ Analyzers

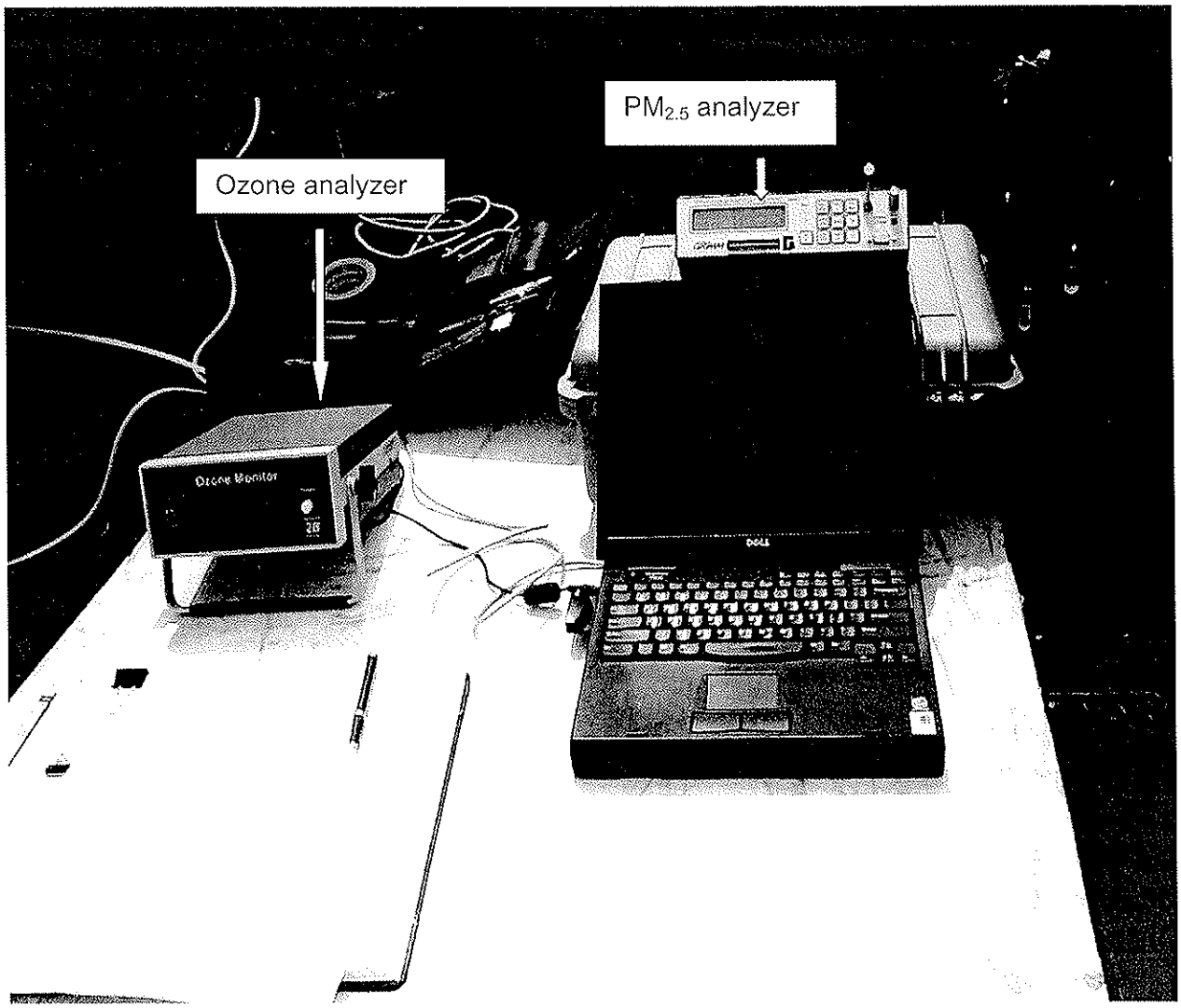


Figure B-1: Ozone and $PM_{2.5}$ Analyzers

APPENDIX C

Map and Photos of Sampling Locations

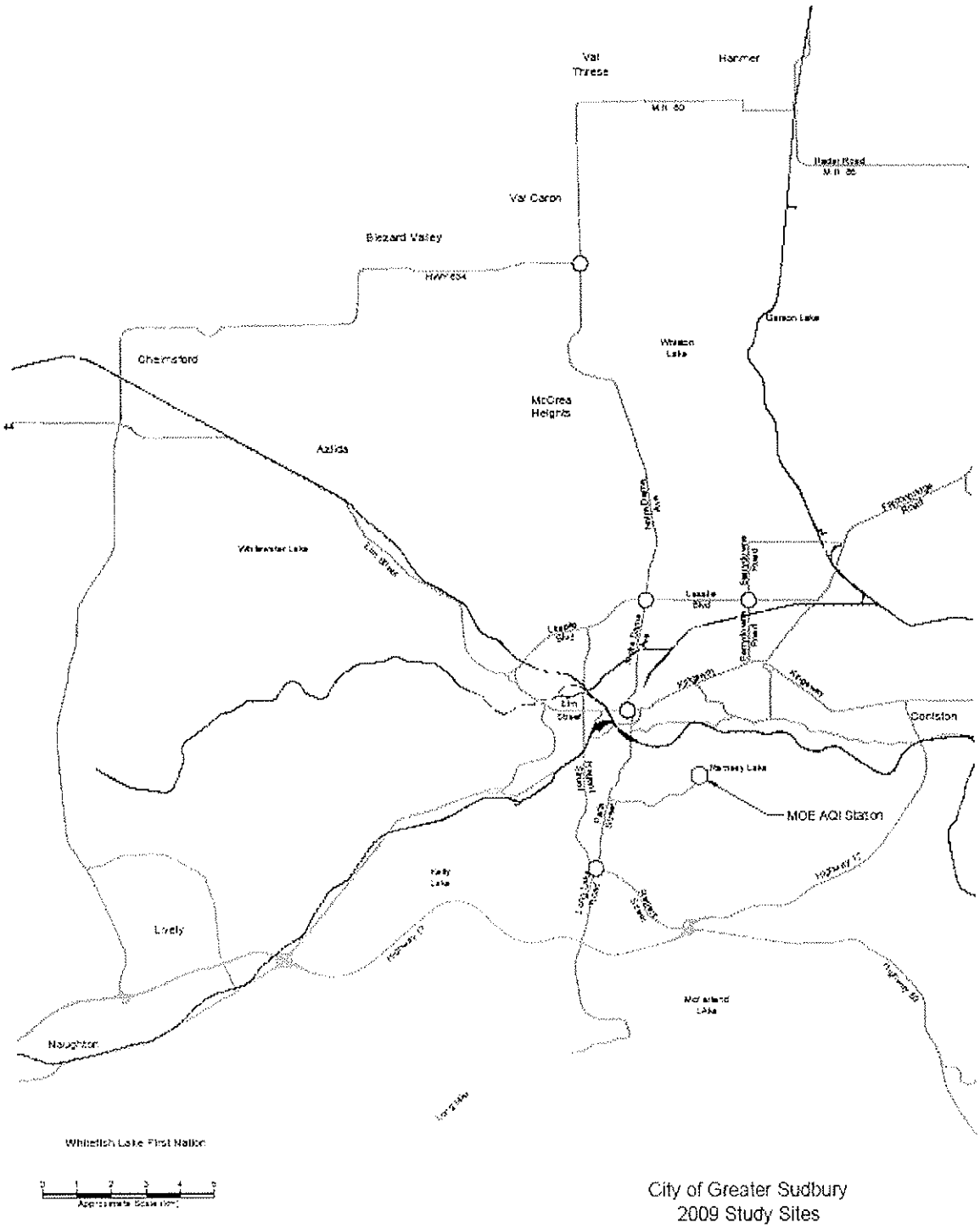


Figure C-1: Locations of Study Sites and MOE AQI Station

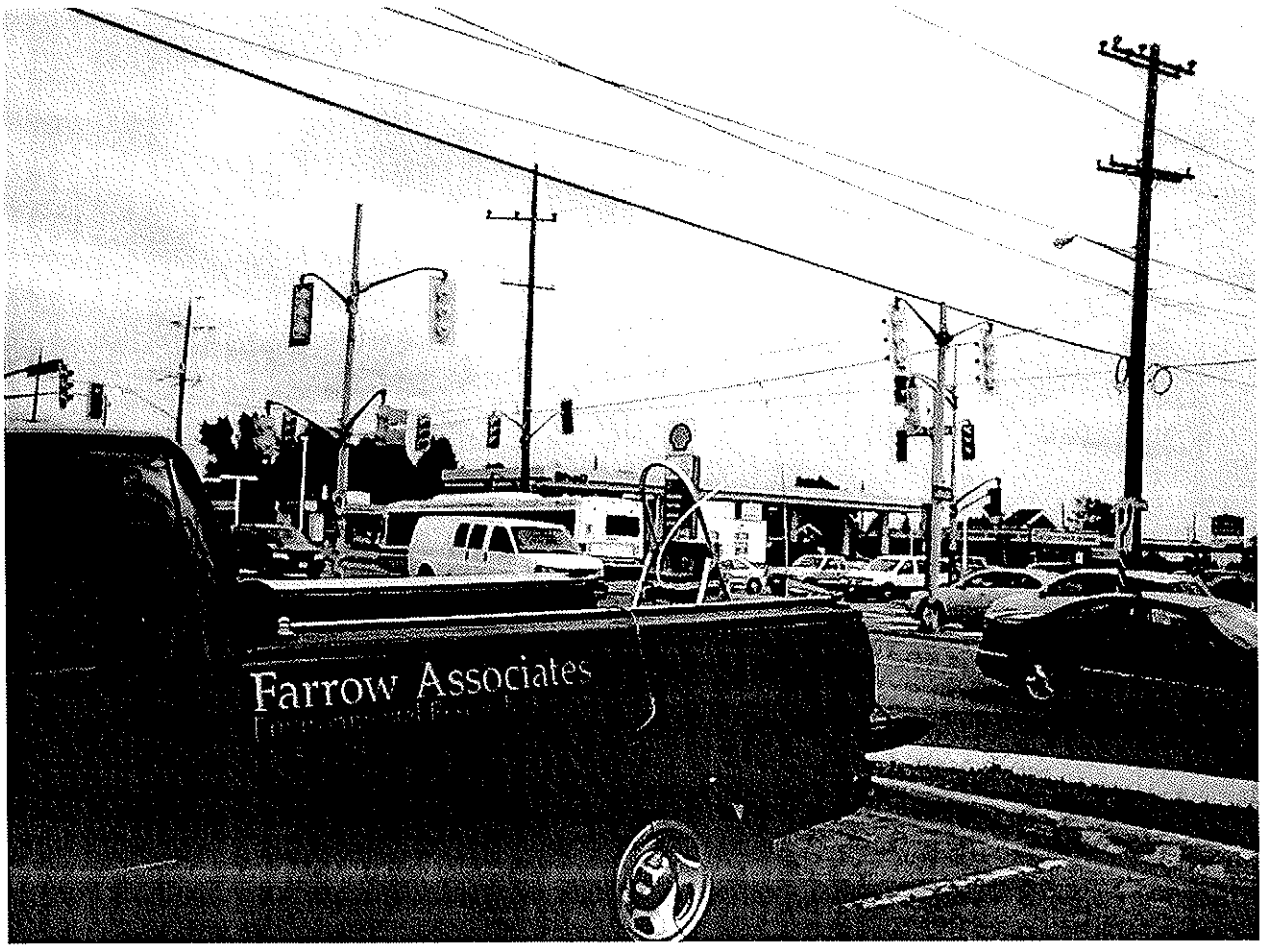


Figure C-2: Lasalle Blvd and Barrydowne Road (N 46°31'18.4", W 80°56'39.7") Looking to the northeast

Figure C-3: Lasalle Blvd and Notre Dame Ave (N 45°25'41.1", W 75°41'34.6") Looking to the southeast


Farrow Associates
F150

Figure C-4: Notre Dame Ave and Elm St (N 46°19'34.6", W 80°59'27.6")
Looking to the northeast

Figure C-5: Regent St and Paris St (N 46°27'07.2", W 81°00'12.0")

Looking to the southwest

Figure C-6: Notre Dame Ave and Main St (N 46°36'37.9", W 81°00'24.4")

Looking to the southwest

APPENDIX D

$PM_{2.5}$ and Ozone Study Results

Table D-1: $PM_{2.5}$ and Ground-Level Ozone Measurements in Greater Sudbury

Date	Location	Hour (EST)	$PM_{2.5}$ ($\mu g/m^3$)		Ozone (ppb)	
			ECO	MOE	ECO	MOE
August 11, 2009	Lasalle Blvd and Barrydowne Rd	8:00	12.6	7	13	13
		9:00	12.2	6	13	15
		10:00	14.9	6	16	17
		Average	13.2	6.3	14.0	15.0
August 11, 2009	Lasalle Blvd and Notre Dame Ave	13:00	7.8	3	18	20
		14:00	5.1	2	22	19
		15:00	5.3	4	23	25
		Average	6.1	3.0	21.0	21.3
August 14, 2009	Notre Dame and Elm St	10:00	17	17	29	23
		11:00	14	16	33	26
		12:00	14	11	33	32
		Average	15.0	14.7	31.7	27.0
August 14, 2009	Regent St and Paris St	14:00	14	10	36	37
		15:00	14	9	39	39
		16:00	13	12	42	41
		Average	13.7	10.3	39.0	39.0
August 19, 2009	Notre Dame Ave and Main St	10:00	3	3	11	17
		11:00	3.2	1	15	17
		12:00	2.6	1	17	18
		13:00	2.8	1	20	20
		Average	2.9	1.5	15.8	18.0

Sampling period: 30 min Sampling period:19 min