

**Health-Impacting Air Pollutants:
A Mobile Monitoring Study to
Identify and Rank Sources in Hamilton, Ontario**

Performed by

Rotek Environmental Inc.

For

Clean Air Hamilton / City of Hamilton
Ministry of the Environment / Environment Canada / Green Venture

ROTEK

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Acknowledgements:

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1. Executive Summary

A mobile air quality monitoring study was undertaken to identify the transient levels of air pollutants in Hamilton, Ontario.

Historical fixed-site air monitoring data and National Pollutant Release Inventory data for Hamilton were used to develop a target list of sources of health impacting air pollutants to be monitored in this study. Five separate industrial areas were identified in the city. A mobile command vehicle was fitted with a GPS detector and modified to support a data acquisition and storage system, along with instruments to measure NO_x (Oxides of Nitrogen), SO₂ (Sulphur Dioxide), PM (Airborne Particulate Matter) and CO (Carbon Monoxide).

Mobile scans for the above pollutants were performed in traverses across the city, at selected industrial areas, at traffic intersections and at a school during student pickup and drop-off times.

Although it might be expected that industrial sources would be responsible for the highest concentrations of pollutants, overall, the highest concentrations were observed near major road intersections and along heavily used roads affected by dirt track-out in the industrial sectors of the city. These high levels are attributed to the impacts of city traffic emissions and the industrial transportation sector, respectively. Industrial point sources still made significant contributions, particularly for SO₂.

This study clearly showed a cumulative effect of city emissions, high ambient levels of combustion emissions from vehicles idling at intersections and from large diesel trucks, as well as very high levels of particulate from dirt track-out onto roads and re-suspension of road dust by large trucks.

Fourteen track-out locations were identified in need of cleanup and an additional fifteen point sources were ranked in order of peak ambient impacts.

Point source impacts did not in all cases agree with NPRI emissions data.

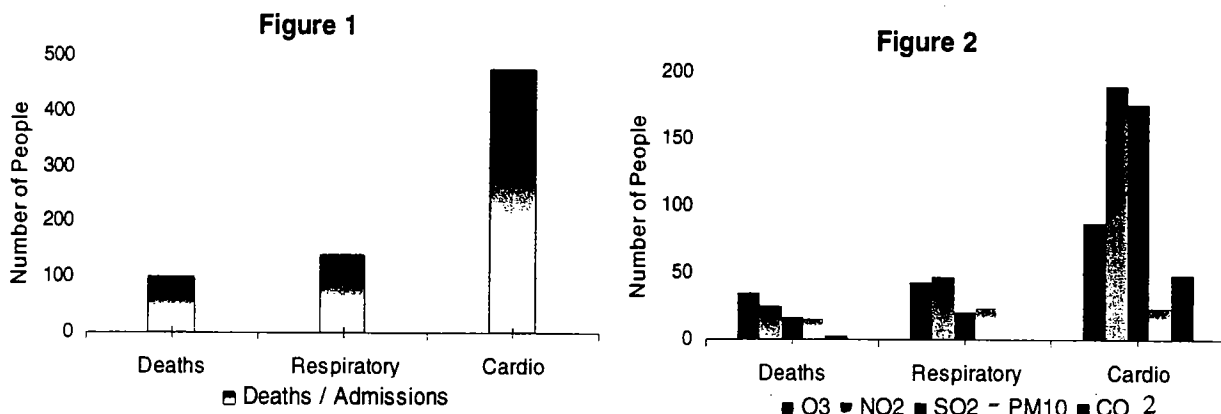
Relatively simple GIS techniques proved very useful and a more sophisticated GIS analysis of the data would be worthwhile.

The data led to a number of specific recommendations.

2. Introduction and Background

Clean Air Hamilton (CAH) has determined that air pollution causes significant morbidity and mortality in the City of Hamilton. In particular, a 2003 report by the McMaster Institute of Environment and Health (Tara Sahsuvaroglu and Michael Jerrett) identified NO₂, SO₂, O₃, PM₁₀ and CO as the pollutants causing most health effects. Except for O₃, all these pollutants have local sources, including the transportation sector.

Air Pollution Health Impacts in Hamilton (Sahsuvaroglu & Jerrett 2003)



Hamilton has been a leader in the development of fixed network air monitoring, building a strong groundwork for long-term evaluation of sources and impacts. However, emission inventories and stationary air monitoring devices may not give complete coverage. Mobile air monitoring can be used to provide air quality data for areas not covered by the fixed monitoring sites.

Previously, a pilot study to identify PM₁₀ sources had been commissioned in 2004 by Clean Air Hamilton and was performed by Rotek Environmental Inc. This study evaluated the feasibility of using the mobile monitoring technique to identify and isolate the impact of previously unexamined sources.

The pilot project focused on the highly industrialized and densely populated section of northeast Hamilton. This area has always posed a difficult challenge for air monitoring, as it is home to more than 400 industries, including steel manufacturing, chemical production, recycling, machining, waste and scrap operations and materials handling. It is uniquely complex in the number and types of emission sources.

In addition to direct emissions, a specific problem in this area was the presence of large quantities of particulate on local roads in the industrialized area. This particulate material was then re-suspended by high volumes of truck and passenger vehicle traffic.

The pilot study was successful in identifying one facility that was a major source of PM₁₀, as well as specific roads and intersections that would require intensive street cleaning in order to reduce road dust levels.

The current study extends these monitoring techniques to a wider area across the city and to other pollutants originating in the city with direct health impacts, i.e., NO_x, SO₂, PM, and CO. Since O₃ does not originate in the city, it was not monitored in this current survey.

3. Study Objective

The objective of this study was to identify and rank sources of NO_x, SO₂, PM and CO in Hamilton, using mobile monitoring techniques.

Sampling was to be performed along city roads, near major traffic intersections, along roads in industrial areas and near industrial point sources. One sampling day was also to be spent at a designated school to investigate the effect of idling vehicles during student drop off and pickup times.

4. Study Outline

- Phase 1:** Review previous data, including MOE (Ontario Ministry of the Environment), HAMN (Hamilton Industrial Air Monitoring Network) and NPRI (Environment Canada National Pollutant Release Inventory) data. Collate NPRI information, including source locations, in Excel tables for each contaminant and rank in order of emission quantity for that contaminant. Discuss data with MOE and Rotek staff to develop target sampling areas.
- Phase 2:** Modify mobile command vehicle to hold rack mounted instruments to measure NO_x, SO₂, PM and CO together with a data acquisition and storage system and a GPS detector.
- Phase 3:** Perform mobile monitoring of target areas, including the designated school.
- Phase 4:** Review preliminary data and prepare an interim report.
- Phase 5:** Refine target areas for second part of monitoring study.
- Phase 6:** Perform second part of monitoring, including different wind regimes and climatic conditions.
- Phase 7:** Evaluate data and prepare final report.

5. Evaluation of Previous Data

NPRI data for the contaminants of concern were downloaded into Excel files. Matching source locations were also downloaded. The information was then sorted in descending order of emissions; see Tables 1 – 5.

Table 1 – PM₁₀ Emission Sources

NPRI ID	Facility Name	Address	PM ₁₀ Tonnes
2984	Stelco	386 Wilcox Street L8N 3T1	964
3713	Dofasco	1330 Burlington Street East L8N 3J5	688
10139	Carmeuse Lime, Dundas	600 Highway 5 West, Gate 1 L9H 3S9	87
2660	Columbian Chemicals	755 Parkdale Avenue North L8H 7M2	73
10059	Lafarge Nebo HMA	669 Nebo Road L0R 1P0	57
161	Bunge Canada	515 Victoria Avenue North L8L 8G7	32
2161	Hamilton Specialty Bar	319 Sherman Ave. N. L8N 3R5	23
1388	Multiserv Stelco	Stelco Wilcox Street Gate L8L 7T5	15
10632	Alcarb Resources	190 Lanark Street L8E 4B3	9
10610	Dufferin Aggregates Flamboro	685 Brock Road L9H 5E4	7.6
1391	Multiserv Dofasco	Gate 10, Burlington St. L8R 3M2	6.7
7134	North American Tillage Tools NATTCO	460 Sherman Avenue North L8L 8J6	6.3
2496	Amcan Castings	10 Hillyard Street L8L 6B1	5.6
5657	PSC Taro Landfill	65 Green Mtn Road West L8J 1X5	4
10017	Lafarge Hamilton Slag	139 Windermere Road L8H 3Y2	4
5685	Regional Die casting	695 Arvin Avenue L8E 5R2	3
10005	Oldcastle Decor-Stoney Creek	682 Arvin Avenue L8E 5R4	2.6
7402	Canadian Liquids Processors	15 Biggar Avenue, L8L 3Z3	2.5
7135	Opta Minerals Waterdown	407 Parkside Drive L0R 2H0	2.4
2057	Rheem	128 Barton Street West L8N 3P3	2.3
10600	McMaster University	1280 Main Street West L8S 4M3	2.2
6750	Transcanada Pipelines Stn 1301	Pt Lot 25 Con 7, Plan 62R-8308 Pts 1-8	1.6
4550	Siemens Westinghouse	30 Milton Avenue L8L 6E6	1.4
7422	Imperial Precast.	294 Fifty Road L8E 5L1	1.3
5904	Orlick 411 Parkdale	411 Parkdale Ave North L8H 5Y4	1.1
4045	Stelwire – Parkdale	690 Strathearne Ave N L8H 7N8	1
7588	Lafarge Hamilton Quality RMC	583 Nebo Road L0R 1P0	1
7015	Dufferin Concrete	886 Nebo Road L0R 1P0	1
7587	Lafarge Hamilton Dock RMC	525 Victoria Ave N L8L 8G7	0.8
10057	Lafarge Ham East HMA	C81 Brockley Road L8P 1K8	0.8
7234	Century Brick	Lawrence Road L8M 3N1	0.6
5906	Orlick Industries- 20 Teal	20 Teal Avenue L8E 3Y5	0.6
7243	Lafarge Stoney Creek Plant	360 Jones Road L8E 5N2	0.4
10042	Lafarge - Ham West HMA	501 Main Street West L8P 1K8	0.4
7001	Robertson Building Systems	61 Burford Road L8N 3B6	0.4
5768	Nelson Steel- Glover Road	400 Glover Road L8E 5X1	0.3
3859	Nelson Steel. – Arvin Avenue	199 Arvin Avenue L8E 2L9	0.1
5954	Greif Bros.	370 Millen Road L8E 2H5	0.04
		Total	2010

Table 2 – NO_x Emission Sources

NPRI ID	Facility Name	NO_x Tonnes
3713	Dofasco	3114
2984	Stelco	2703
2660	Columbian Chemicals	1070
10139	Carmeuse Lime Dundas	649
10672	Hamilton Community Energy – Energy Centre	260
6750	Transcanada Pipelines- Station 1301	198
2161	Hamilton Specialty Bar	76
10600	McMaster University	53
161	Bunge	40
2070	VFT	20
7243	Lafarge – Stoney Creek	2.6
7001	Robertson Building Systems	1.7
10005	Oldcastle Decor-Stoney Creek	0.98
Total		8188

Table 3 – SO_x Emission Sources

NPRI ID	Facility Name	SO_x Tonnes
3713	Dofasco	5035
2984	Stelco	3399
2660	Columbian Chemicals	3130
10139	Carmeuse Lime Dundas	281
7243	Lafarge Stoney Creek	16
2161	Hamilton Specialty Bar	14
2070	VFT	0.12
7001	Robertson Building Systems	0.005
5954	Greif Bros. Canada	0.003
Total		11875

Table 4 – CO Emission Sources

NPRI ID	Facility Name	CO Tonnes
2984	Stelco	23016
3713	Dofasco	6360
2161	Hamilton Specialty Bar	451
10139	Carmeuse Lime Dundas	382
2660	Columbian Chemicals	236
2496	Amcan	58
6750	Transcanada Pipelines Station 1301	49
161	Bunge	34
10600	McMaster University	25
2070	VFT	17
7243	Lafarge Stoney Creek	2.2
10005	Oldcastle Decor-Stoney Creek	1.1
5954	Greif Bros. Canada	0.44
7001	Robertson Building Systems	0.2
Total		30632

Table 5 – Point Source Emissions by Contaminant

	CO	SOx	NOx	PM ₁₀
Tonnes	30,632	11,875	8,188	2,010

Table 6 – NPRI Total Emissions by Source Category for Hamilton

Source Category	CO	SOx	NOx	PM ₁₀
Industrial	15,987	10,903	8,414	5,430
Fuel Combustion	7,236	308	1,659	1,707
Transportation	47,389	635	12,766	1037
Incineration	365	36	173	2
Miscellaneous	143	0	0	118
Open Sources	0	0	0	21,669
Total Tonnes	71,120	11,882	23,012	29,963

Note: Quantities in Table 6, (source category emissions) do not agree with the other tables due to differences in NPRI search areas for different types of searches as well as data years. Open sources include road dust, construction and agriculture. Transportation sources include air transportation, marine transportation and heavy duty diesel vehicles.

Pollutant concentrations at ground level due to these emissions will vary widely according to a large number of factors, including release height, flow rate, pollutant release temperature, ambient temperature, wind speed and direction. See Fig. 3 below, a diagrammatic representation of emission concentrations being modified by environmental factors.

Modifiers of Point of Impact Concentrations

Emission - Dispersion - Accumulation - Removal

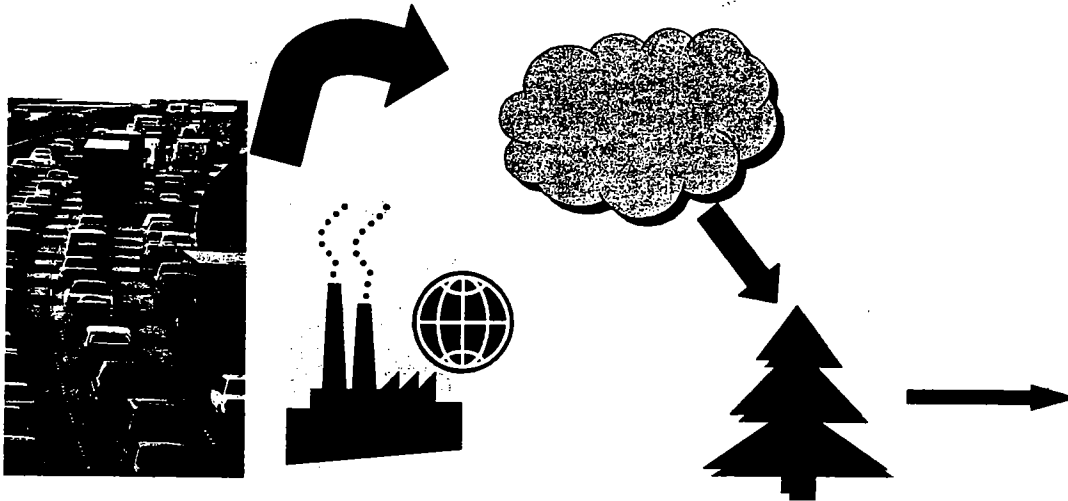


Figure 3

Nevertheless, the raw emissions data suggest that CO is the major contaminant from point sources, at 30,632 tonnes, followed by SO_x at 11,875 tonnes, NO_x at 8,188 tonnes and PM₁₀ at 2,010 tonnes, with the two major steel companies being the largest single contributors.

NPRI Point Source Emissions

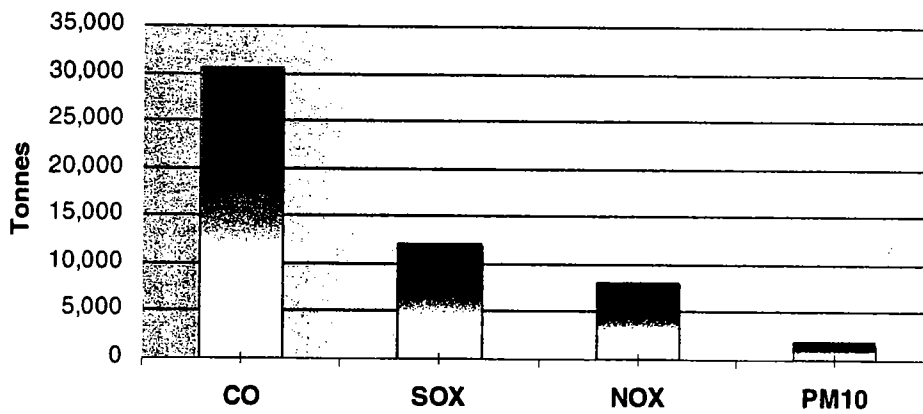


Figure 4

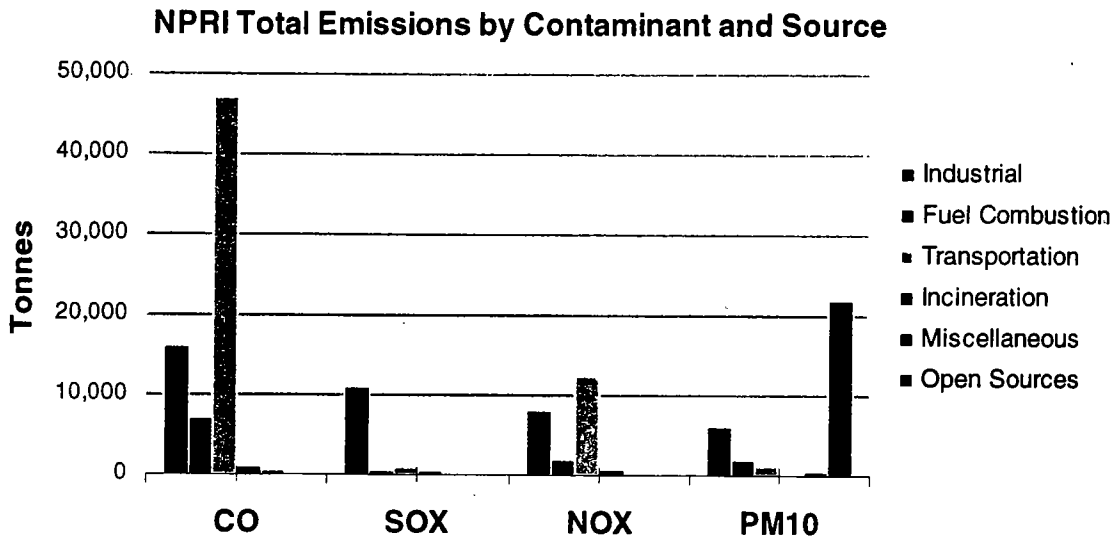


Figure 5

Total (compared to point source) emissions by source category also show CO as the pollutant with the largest tonnage of emissions. Transportation is the largest CO source with three times the emission rate of point source industrial emissions. Open sources (including road dust) are the largest generator of PM₁₀.

Transportation is also the largest source of NO_x (12,766 tonnes), although industrial sources are of similar magnitude (8,414 tonnes). The top three industrial sources, Stelco, Dofasco and Columbian Chemicals account for 6,887 tonnes or 82% of this total.

The top three transportation sources for NO_x are Air Transportation (1,219 tonnes), Marine Transportation (558 tonnes) and Heavy Duty Diesel Vehicles (440 tonnes). Thus, the NPRI data show that industrial NO_x sources exceed heavy duty diesel emissions by a factor of 20.

Overall the NPRI data show 56 point sources of PM₁₀, 14 sources of CO, 13 sources of NO_x and 9 sources of SO₂.

In light of these data, we would expect to measure the following contaminants and attribute their sources as follows:

- **Carbon Monoxide** – 66% Transportation, 23% Industry
- **Sulphur Dioxide** – 92% Industry, 5% Transportation
- **Nitrogen Oxides** – 57% Transportation, 37% Industry
- **PM₁₀** – 73% Open Sources/Road Dust, 18% Industry

The NPRI point sources fell into 5 well defined geographic areas, Flamborough/Waterdown (aggregates), East Mountain (aggregates), West Hamilton/Frid (mixed industrial and university), Northeast Industrial Area (heavy and mixed industrial) and Stoney Creek (mixed industrial and aggregates).

Emission Sources by Regions in Hamilton Area

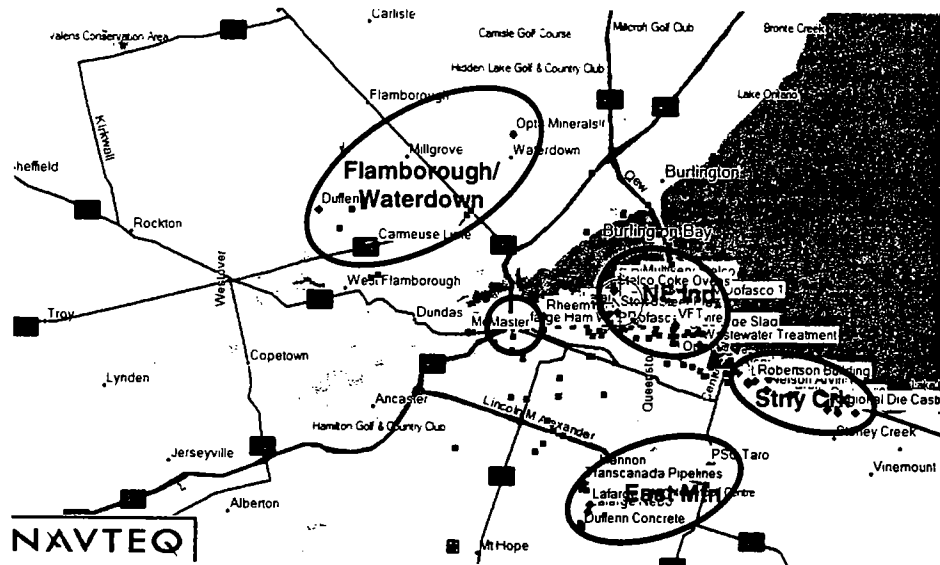


Figure 6

In addition to reviewing the NPRI data, a meeting was held with MOE to discuss previous monitoring as well as abatement and STAC experience in the Hamilton area. The MOE STAC program, Selected Targets for Air Compliance, requires industries to submit detailed emission and modeling data to MOE for evaluation.

MOE staff provided the results of a number of special studies of the industrial area of Hamilton as well as the 2004 Data Summary for the Hamilton area. A list of areas and industries which should be sampled was developed and compared with the NPRI lists, see Table 7.

Table 7 – Sources and Areas Identified for Investigation

Source/Area MOE Sampling Recommendation	Identified Source, NPRI
Stelco	x
Dofasco	x
Multiserv Stelco	x
Multiserv Dofasco	x
FMT	
Lafarge, Victoria N	x
Plaza Environmental	
Triple M	
Waxman	
Poscor 1 and 2	
Hotz	
Lafarge, Eastport Drive	
Bitumar	
City Works Yard, Eastport	
Lafarge Hamilton Slag	x
VFT	x
Hamilton Specialty Bar	x
Lafarge Stoney Creek	x
Alcarb	x
Shell Victoria N	
Beach Strip	
Eastport Drive	

Table 7 includes a number of areas and sources not identified in the NPRI database. Industries, scrap yards and metal recycling operations that have been identified in the past as possible sources of pollutants were included in this table. The previous pilot survey found some of the sources in the table to be generators of PM₁₀, both from direct emissions and re-suspended track out dust.

MOE West Central Region's Air Quality Data Analyst, Mr. Frank Dobroff, provided suggestions for roads to be traversed by the mobile monitoring unit as part of this study.

6. Mobile Sampling Unit

The mobile sampling unit had originally been designed as an MOE command centre and thus required modifications to use as a monitoring facility.



Figure 7 – Mobile Command Centre

Rack mounts were installed to accept continuous monitoring instruments to measure NO_x , SO_2 , PM and CO. Instruments used were a TECO Model 42C NO_x analyzer, a Monitor Labs 8850 SO_2 analyzer, a TECO Model 48 CO analyzer and a Grimm Model 1.107 Dust Monitor. The Dust Monitor is capable of simultaneous measurement of PM_{10} , $\text{PM}_{2.5}$ and PM_{1} . A sampling pump was also installed to provide appropriate air flow for the gas analyzers.

The Grimm Dust Monitor was mounted separately, since a straight sampling path to ambient air is required to avoid unwanted particle size selection artifacts during sampling.



Figure 8 – Rack Mounting



Figure 9 – Particle Analyzer

Outputs from the instruments were fed to an analog-to-digital converter connected to an EMC Station Manager data logger. The Station Manager allowed viewing of instantaneous or averaged data for NO_x , SO_2 , CO, PM_{10} , $\text{PM}_{2.5}$ and PM_{10} , while storing one-minute averages of each data stream, identified by pollutant and data collection time (Eastern Standard).



Figure 10 – Analog/Digital Converter, Data Logger, GIS Software

Ambient air for the gaseous analyzers was sampled through a specially constructed gooseneck sampling head which passed through the roof of the vehicle, see Fig.11. A rain shield attachment was added to prevent precipitation entering the system. Sampling intake height was approximately 3 metres above ground level. This sampling height is important to mitigate instantaneous fluctuations in pollutant concentrations due to tailpipe emissions, however, some higher level diesel emissions could still impact the intake. $\frac{1}{4}$ in. diameter Teflon tubing with particle pre-filters was used to distribute the incoming air to the gas analyzers. The sampling system was challenged with NO_x , SO_2 and CO test gases to establish response time of the system. Response time was 1 to 2 minutes. The Grimm Dust Monitor was modified with a 2 metre long sampling intake to reach through the vehicle roof.

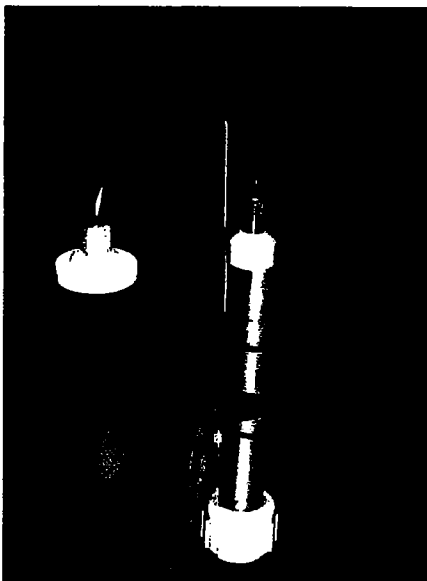


Figure 11 – Sampling Intakes on Roof of Vehicle

GPS (Global Positioning System) data was collected with a Garmin 18 laptop-enabled GPS head attached to the vehicle windshield and connected to a Hewlett Packard Pavilion zv5000 laptop computer through a USB connection. Garmin nRoute GIS software was loaded on the laptop. The software automatically displays location and records GIS waypoints with time for each traverse. Waypoints with comments can also be recorded, as well as the bearing from selected locations. This proved very useful for back trajectories / plume tracking.

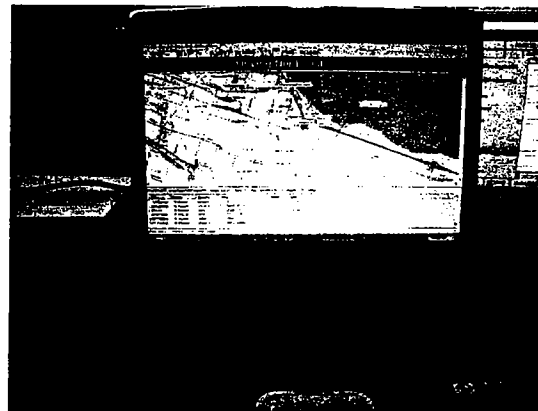
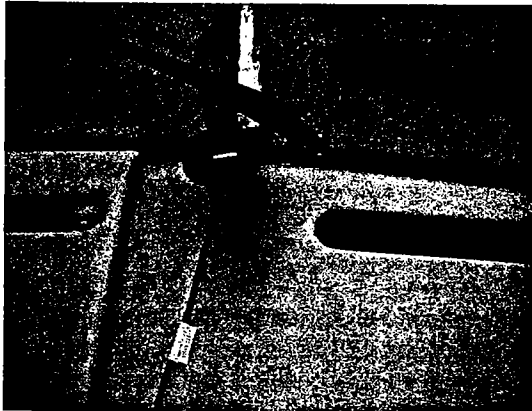


Figure 12 – Dashboard-mounted GPS head, Figure 13 – Display on Laptop Computer of Geographic Information System (GIS)

Pollution Source Identification

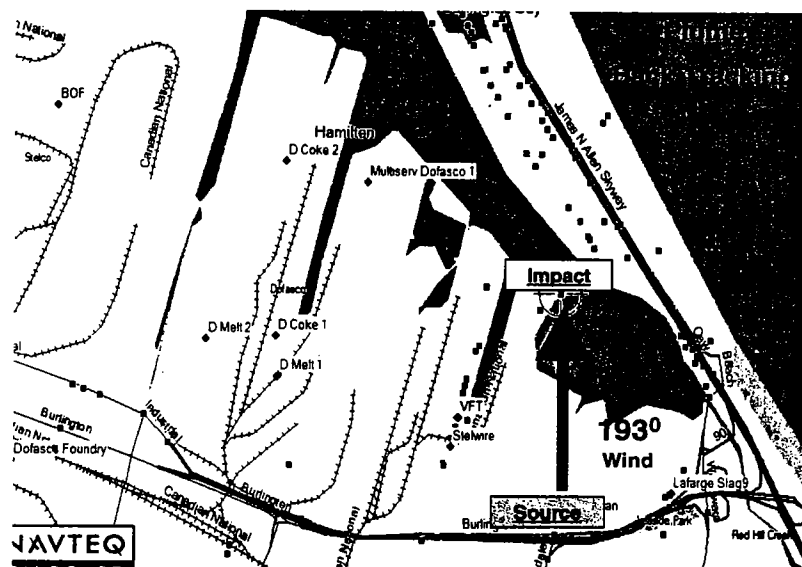


Figure 14 – Plume Back Tracking (black squares are GPS waypoints)

When a pollution impact was recorded by the monitoring / data collection system, wind direction was downloaded from a local wind monitor in the fixed air monitoring network. The measurement tool in the GIS software then allowed backtracking using the wind direction information to identify the emission source and determine the distance from the source.

Electrical supply in the vehicle was through shore power while parked in a garage, converting to generator power while mobile, during the majority of the study. This necessitated a careful power down / power up sequence for the instruments, since they are designed to operate continuously and cannot be subjected to power surges or voltage spikes while switching power sources. An Uninterruptible Power Supply (UPS) was purchased to avoid this power down/power up sequence but the power supply quality from the generator was outside acceptable tolerances for the UPS to operate. Towards the end of the survey, an integrated battery pack/charger/inverter 120V power supply was installed in the vehicle allowing four hours of continuous sampling, including pump operation, without generator use.

7. Data Collection Procedures

Following standardized data collection procedures were developed for the survey:

1. Install laptop in vehicle; connect laptop to GPS head using USB extension connector.
2. Open nRoute software on laptop to initiate recording of vehicle position with time (track), nRoute will automatically save vehicle track with associated times.
3. Check logger is displaying instantaneous air pollutant data on computer.
4. Review sampling plan for the day and objectives with both driver and data collector.
5. As sampling route is being followed, notify vehicle driver of instantaneous data excursions, making way points in the GIS software and recording in data log with comments, e.g. "large truck passing by", "downwind company A".
6. When pollutant excursion is detected, retrace route as slowly as possible. Instantaneous data are not stored in the logger, only one minute averages.
7. Stop in "hot spots" for more accurate data capture.
8. Where possible, monitor both upwind and downwind of suspected source.
9. While stopped, attach exhaust extension tubing to generator exhaust pipe and extend downwind.
10. Note that the vehicle and generator exhaust can interfere with monitoring if the wind is blowing from the exhausts towards the sampling intake. Both exhausts are on the driver side of the vehicle. For best sampling, the vehicle should be facing as closely into wind direction as possible – or else the wind should be blowing from the passenger side to the driver side of the vehicle (both generator and vehicle exhaust are on the driver side of the vehicle). Note that there is very a strong downdraft from the generator cooling fan which can generate a large PM10 peak when first stopped.
11. After battery pack installed; operate instruments in battery mode while point source sampling, recharge battery pack from generator while not source sampling.
12. While driving, valid point source sampling will occur while driving on the upwind side of the road, otherwise instruments will be sampling traffic on the other side of the road.
13. Update sampling log continuously with incidents/events.

8. QA/QC

1. Calibrate instruments monthly to MOE standards.
2. Check SO₂ and NO_x instruments with zero air on a regular basis.
3. Record events/potential interferences in sampling log.

9. Sampling Plan

The sampling plan required several different approaches in order to cover all aspects of the sampling objectives.

To determine city impacts, including cumulative effects across the city, sampling was conducted on a day when the wind blew steadily from the southwest so that the city was always upwind of most industrial impacts. Two traverses of the city were conducted: one from the near rural area southwest of the city towards and through the industrial sector and another from the industrial northeast end to a rural area southwest of the city. Sampling points were established in the centre of city blocks, away from the direct influence of traffic emissions on major roads.

Transportation related effects were investigated by monitoring downwind of some major intersections and of idling vehicles stopped at traffic lights as well as upwind/downwind of an arterial road. Measurements were also taken while traveling on major arterial roads, such as Burlington Street. School related effects of vehicle student drop off and pick up were measured at George R. Allen School in Westdale, as directed by Green Venture and with the agreement of the school authorities.

Trackout/road dust re-suspension target areas were identified from Ministry of Environment experience and by visual observation and monitoring conducted near sites of known visible dust generation.

Industrial sources were investigated after reviewing wind direction conditions while sampling, then focusing additional sampling on areas identified by MOE and NPRI data. Low speed vehicle scans were used initially to identify pollutant plumes. In these cases the vehicle was then deployed carefully to investigate the plume.

10. Sampling Results

Sampling data streams results were one of four types:

- Sampling logs – handwritten records of instantaneous data, events, locations and associated waypoints.
- One minute averages for concentrations of NO_x, SO₂, CO, PM₁, PM_{2.5} and PM₁₀.
- GIS tracks (times, locations) and waypoints.
- Wind and temperature data from fixed network meteorological stations.

All four types of data had to be combined in data interpretation.

Sampling took place in November and December, 2005 and January and March, 2006.

Inclement winter weather restricted sampling on a number of days.

City Sampling

Two sampling transect sequences were taken across the city. The first test began on Nov 30, 2005 in a rural area southwest of the city and progressed through residential areas to the Lincoln Alexander Expressway. The other began in the Northeast industrial sector and traversed to the rural south west.

Conditions on November 30, 2005 were, ambient temperature of 2/3° C, wind direction from 240 – 256°, wind speeds of 10 – 30 km/hr.

Conditions on December 8, 2005 were ambient temperature of -3/-5° C, wind direction from 130 – 300°, wind speeds of 4 – 11 km/hr.

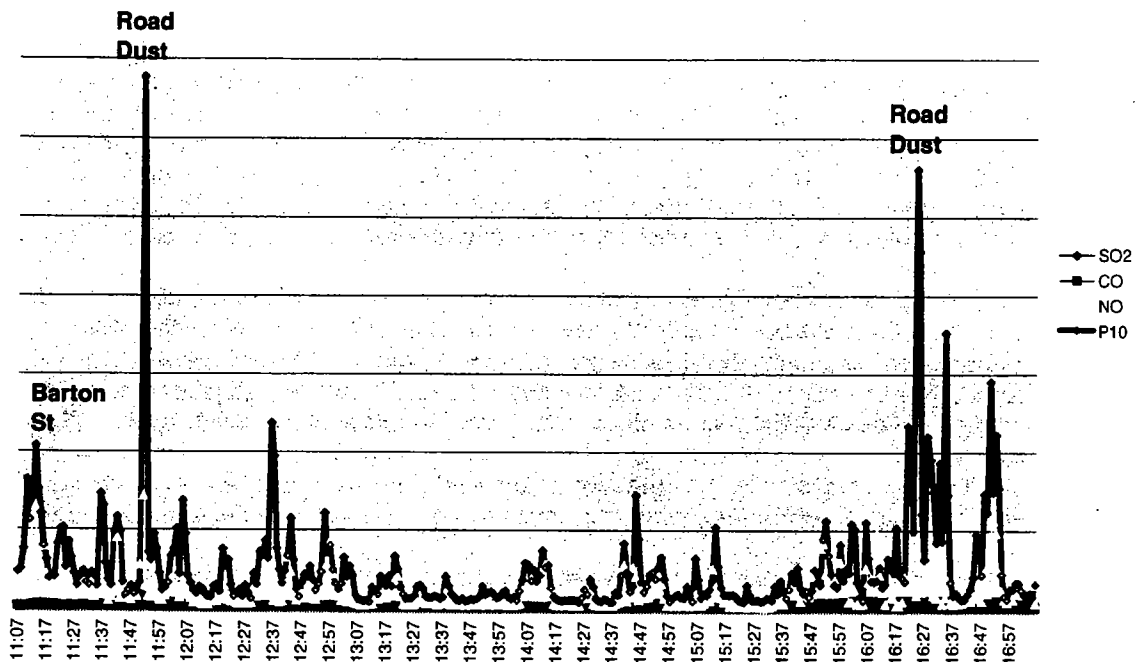
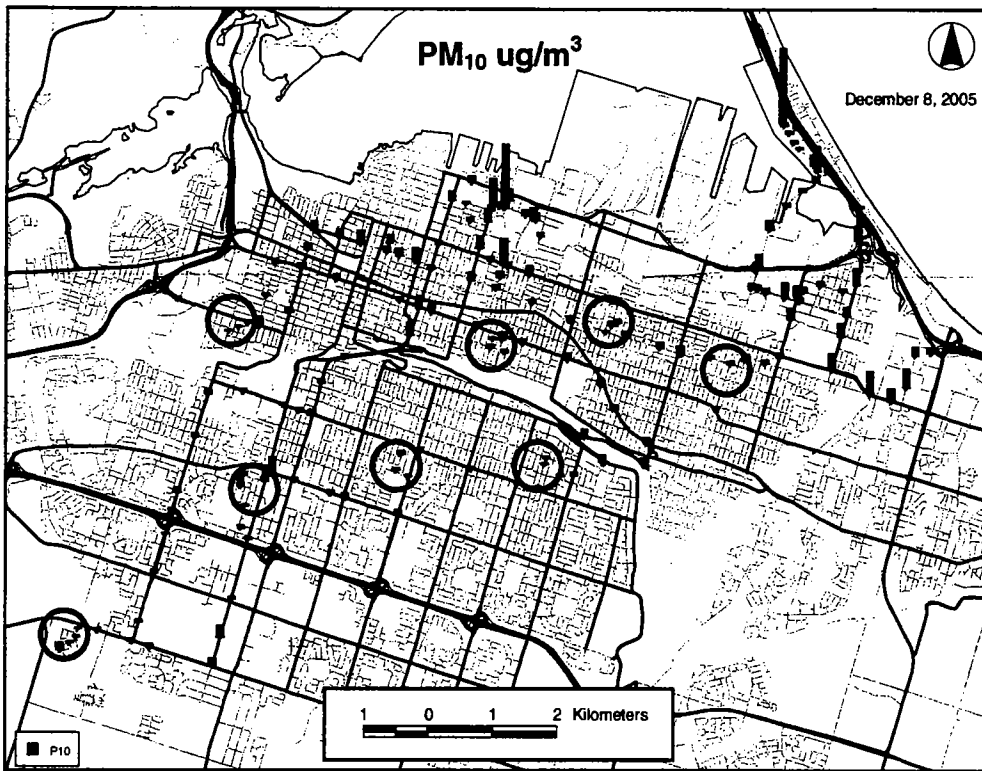
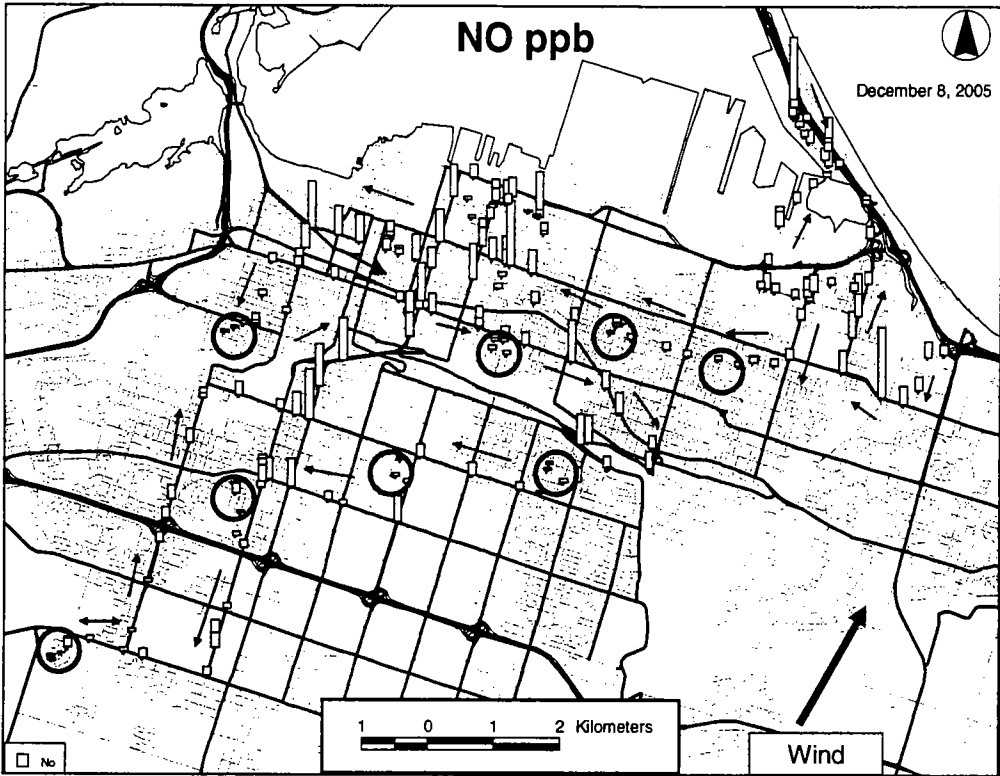


Figure 15 – Concentrations of PM₁₀, NO, CO, and SO₂ across Hamilton, December 8, 2005

The most obvious features of the city wide scan are the very high PM₁₀ values and NO peaks related to transportation, i.e. impacts of dusty roads and diesel trucks. This chart shows that on a southwest wind day (prevailing wind), when all data are displayed concurrently, traffic effects predominate across the city. PM₁₀ values are in ug/m³, NO and SO₂ in ppb and CO in ppm. (Note, CO data displayed in ppm, as measured by instrument and 1 ppm = 1000ppb).

Another way of displaying these data is to superimpose concentrations of the pollutants separately on a city map using GIS software. In these figures, note that the pollutants are not to the same scale. Separating the pollutant data allows some variation in the SO₂ and CO data to emerge. Residential levels of SO₂ are very low at several ppb, however, and some of the variation may be zero drift in the instrument due to the motion of the vehicle.



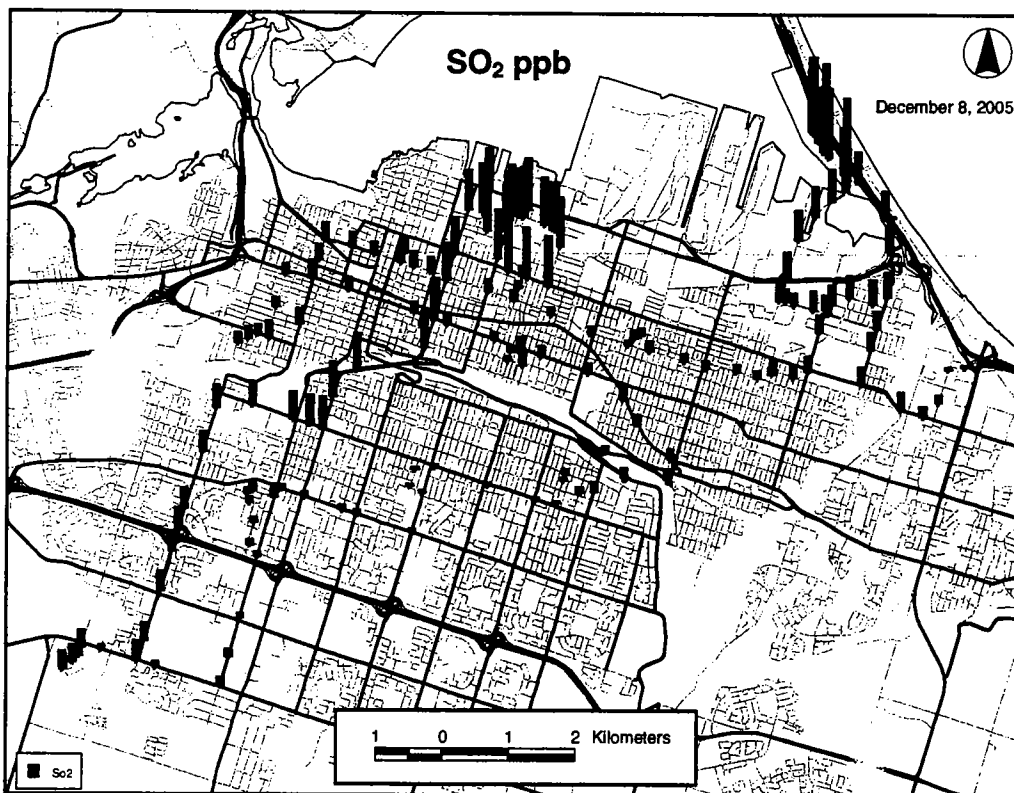
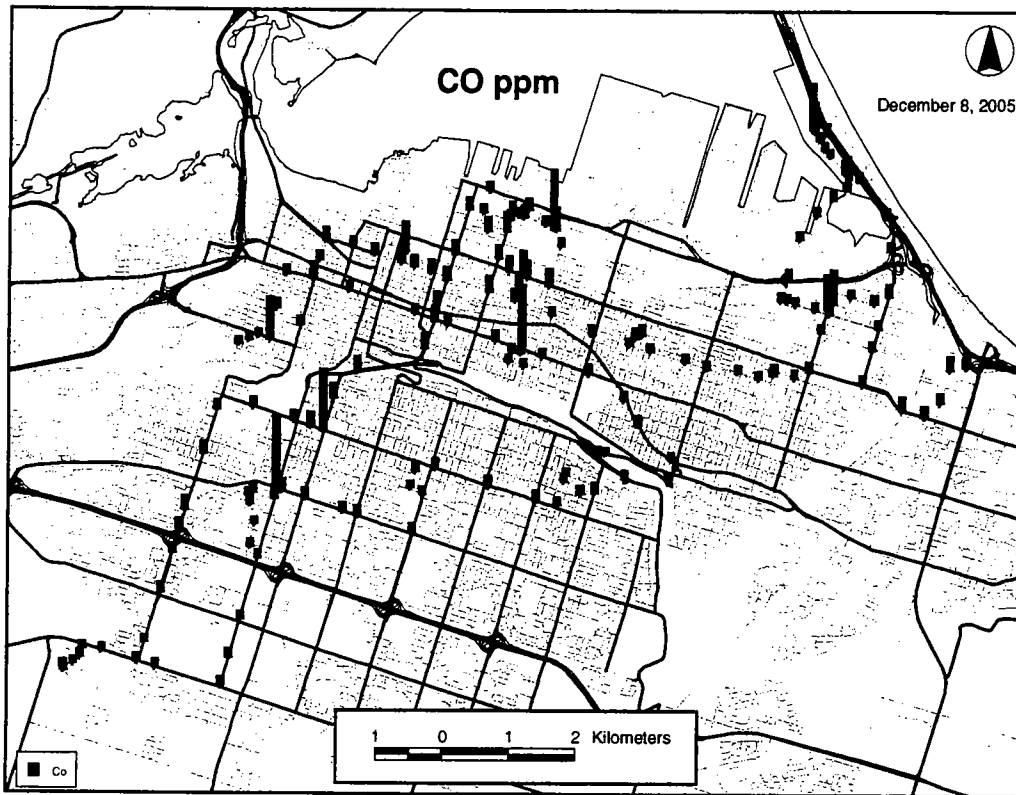


Figure 16 – Concentrations of PM₁₀, NO, CO and SO₂ Superimposed on City Map (Red circles on PM₁₀ and NO maps are residential sampling locations, arrows show travel)

In order to determine the city wide effects it was necessary to go into residential areas and make measurements with the mobile unit parked facing into the wind and upwind and away from the closest major road. Areas sampled were Tolton / Melvin, Rosslyn / Campbell, Fairleigh / Main, Beulah / Aberdeen, E44 / Queensdale, E18/Vickers, Marlowe / Westmount and Eaglegen.

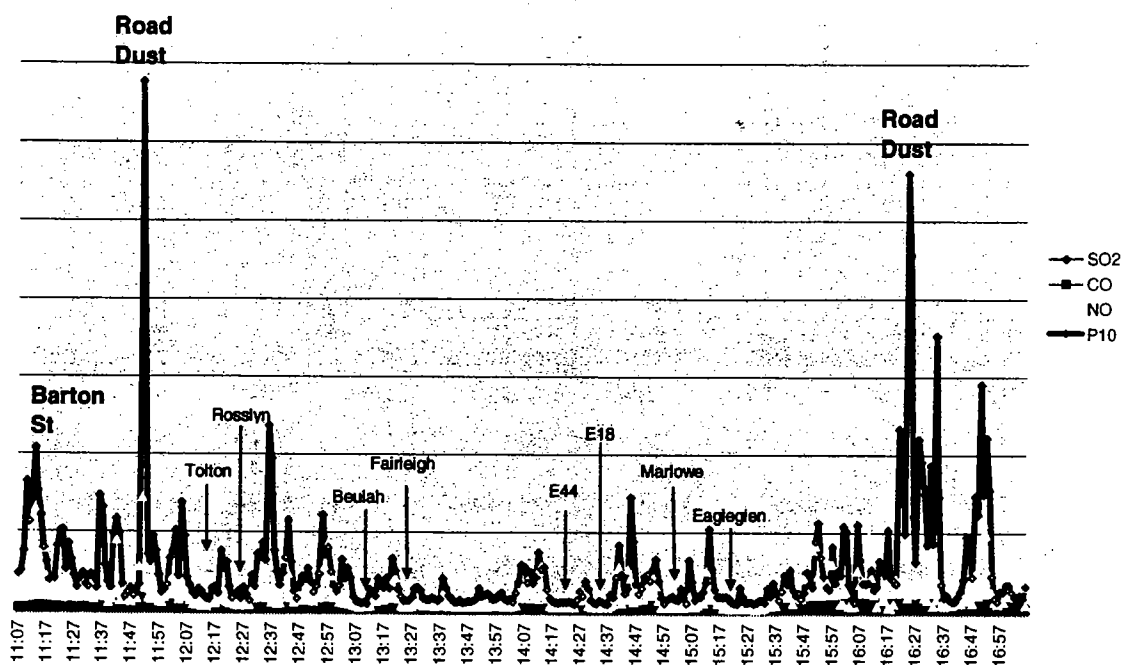


Figure 17 – Concentrations of PM₁₀, NO, CO, and SO₂, Dec 8 Scan

Table 8 – Average Concentrations at City Residential Locations

Location	SO ₂ ppb	CO ppm	NO ppb	PM ₁₀ ug/m ³
Tolton/Melvin, T/M	3	1	12	39
Rosslyn/Campbell, R/C	3	1	20	45
Fairleigh/Main, F/M	2	1	9	32
Beulah/Aberdeen, B/A	4	1	10	27
E44/Queensdale, E44/Q	0.9	1	7	19
E18/Vickers, E18/V	1	1	7	22
Marlowe/Westmount, M/W	2	1	8	31
Eaglegen, E	3	1	4	29

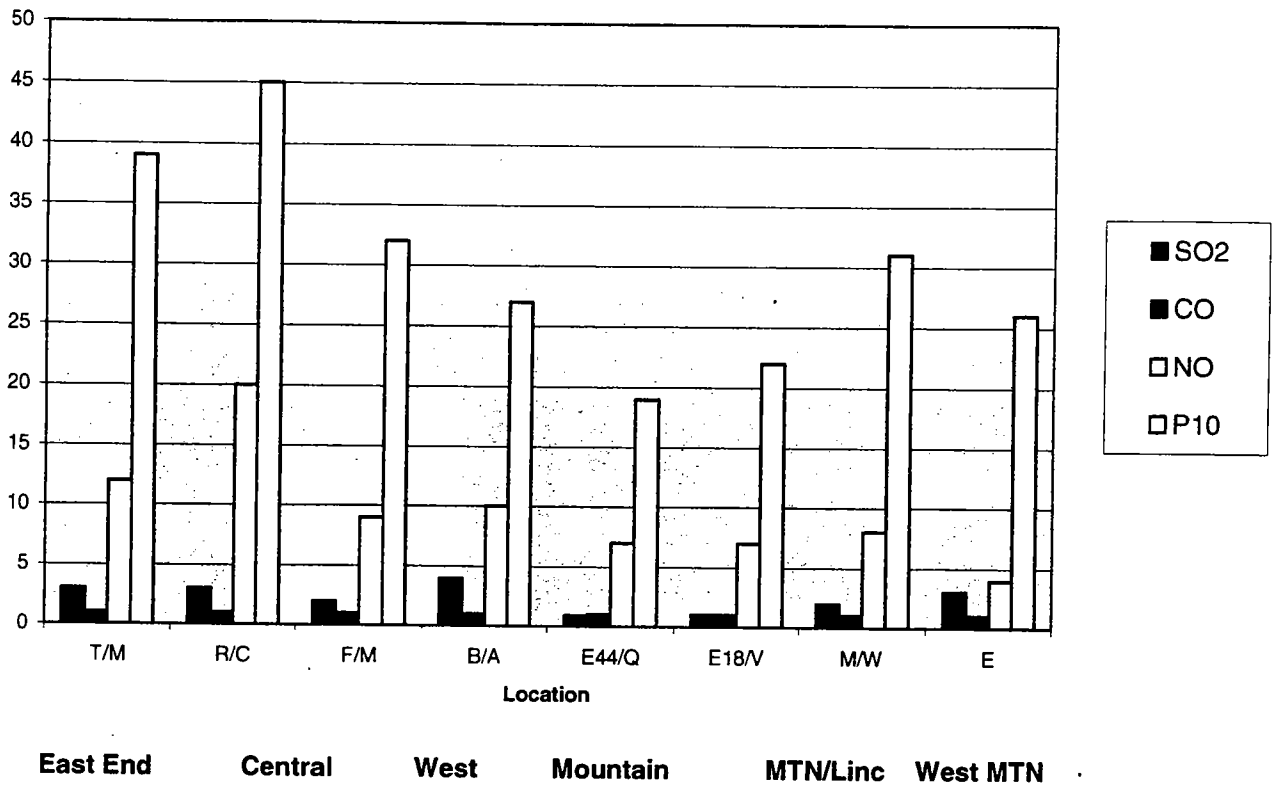


Figure 18 – Concentrations of SO₂, CO, NO and PM₁₀ in residential areas across city.

December 8, 2005 was a day with very little long range transport of air pollution and thus a good day to investigate city effects on air quality. CO remained steady in residential areas across the city at 1 ppm, although it would be expected from the NPRI data to have significant variations. The NPRI data also suggested that CO should be the dominant contaminant, as it was. Note, CO is measured in ppm = 1000ppb, while NO and SO₂ are measured in ppb. NO and PM₁₀, as expected, decreased across the city downtown from east to west (industrial to residential) and further decreased towards the Central Mountain. It would have been expected that the levels of these pollutants would have continued to decrease while moving towards the southwestern edge of the city, however somewhat higher levels of NO and PM₁₀ occurred at Marlowe/Westmount at the West Mountain. These higher levels may be due to transportation impacts from the Lincoln Alexander Expressway, approximately one km upwind. Eagle Glen, at the southwest edge of the city, is a subdivision surrounded by a rural area and would have been expected to show very low levels of contaminants. NO and PM₁₀ were higher than on the Central Mountain. Again, this may be due to transportation impacts, in this case from the 403 Highway, 2 km upwind.

These results show that on days with moderate west southwest winds and low levels of long range pollution from the U.S., nearly all of the pollutant impacts for the residential areas of the city are due to local transportation and home heating, since the city is upwind of the major industrial areas for this wind regime. With the prevailing winds blowing from the southwest, this is the most frequent meteorological condition for Hamilton, with varying degrees of long range pollution added, depending on the season and U.S. emissions.

In contrast, pollutant exposures while driving can be very high, in one case, 1200 ug/m³ of PM₁₀ and 350 ppb of NO. Routinely on busy roads, 300 ug/m³ of PM₁₀ and 150 ppb of NO are experienced, compared to residential area levels of 20 – 40 ug/m³ PM₁₀ and 4 – 20 ppb NO.

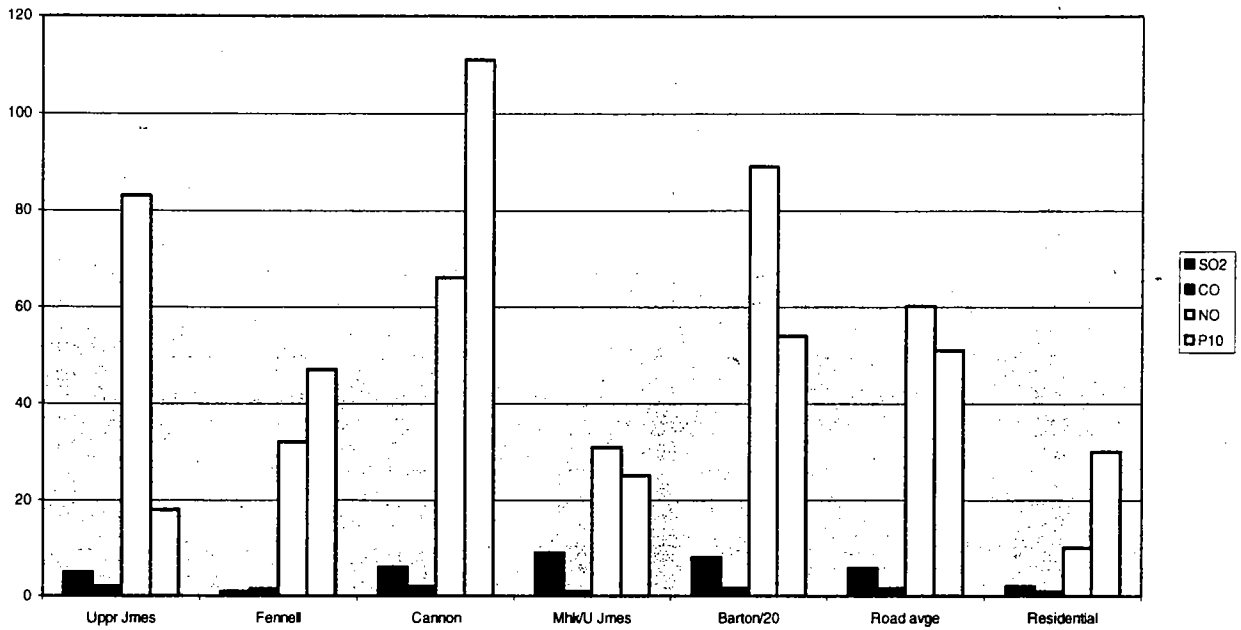


Figure 19 – Comparison of Average Road and Intersection Levels to Residential

Fig. 19 shows that average values of pollutants on main roads are significantly higher than the overall residential road average.

Arterial roads and highways contribute substantial amounts of air contaminants to areas directly downwind. Burlington St. was monitored upwind and downwind to determine its contribution. Sampling took place during non rush hour morning traffic from 10:55 am to 11:40 am on Jan 13, 2006. Large truck traffic was frequent, on average 10 vehicles per minute.

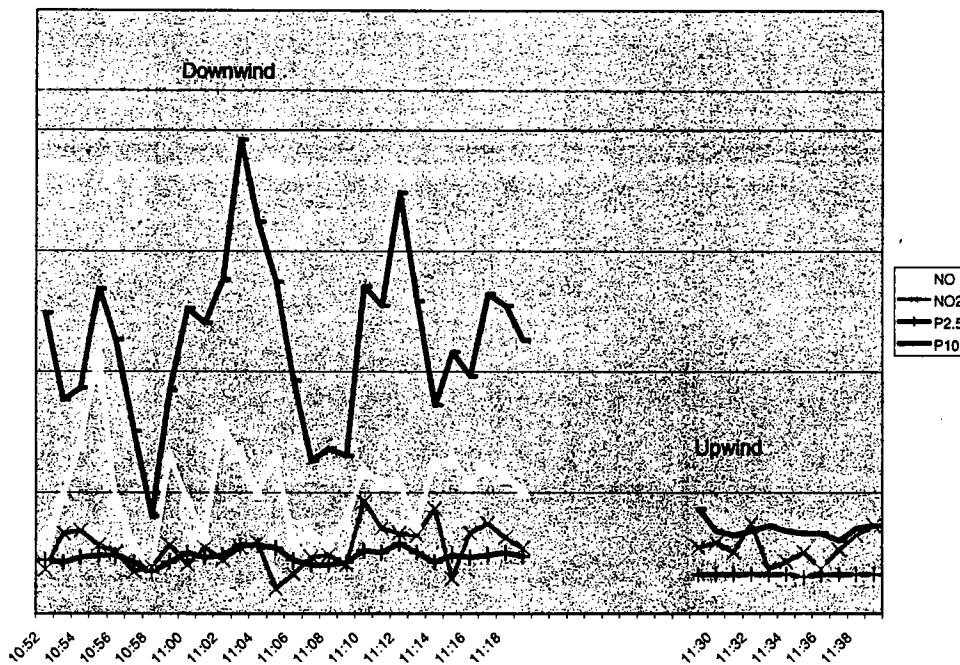


Figure 20 – Burlington St. Downwind – Upwind

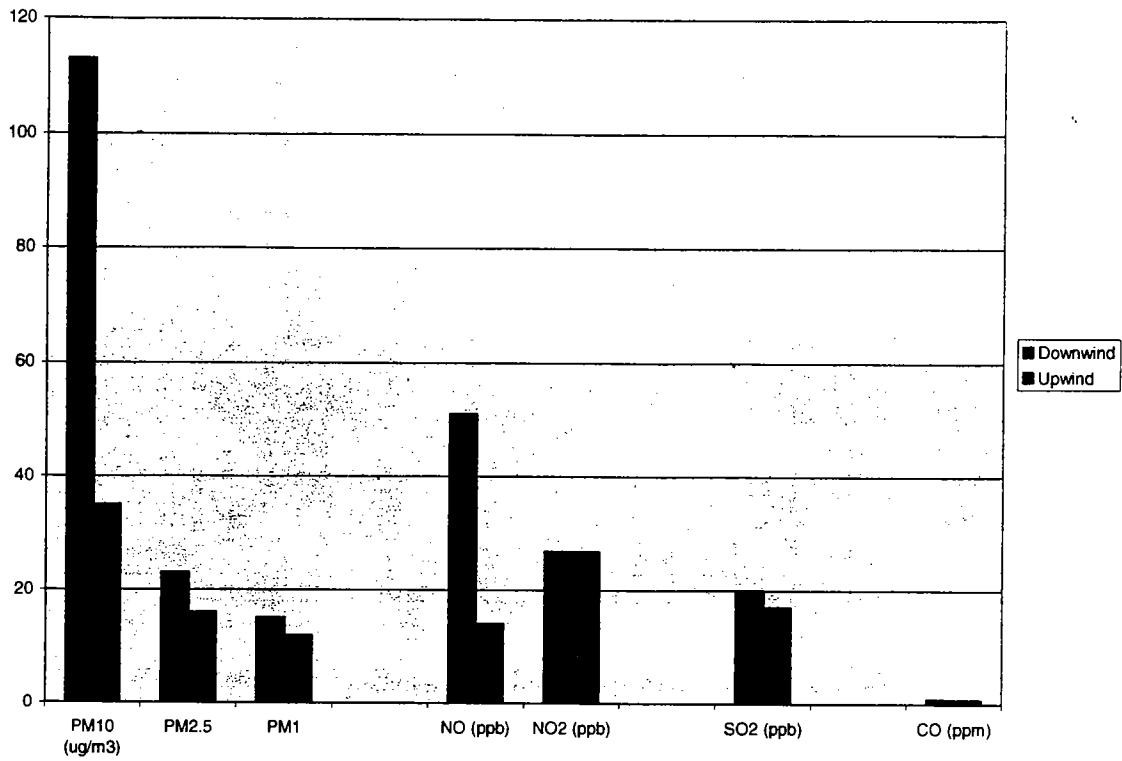


Figure 21 – Burlington St. Downwind – Upwind Bar Chart

Measured at a location approximately 45 m downwind, Burlington St. added 78 ug/m³ of PM₁₀, 37 ppb of NO, 3 ppb of SO₂ and 60 ppb (0.06 ppm) of CO to upwind air concentrations.

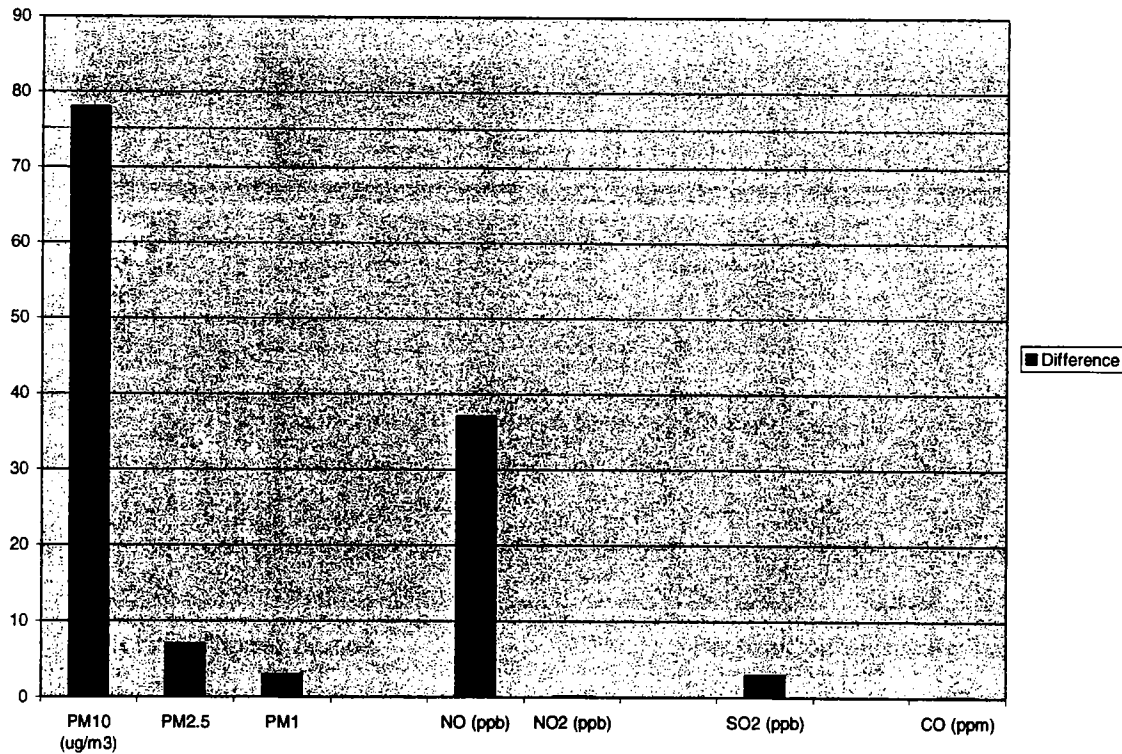


Figure 22 – Burlington St. Net Contribution

Traffic Intersections

High levels of contaminants were frequently detected at traffic intersections in the current and previous studies. On December 6 measurements were taken downwind of idling traffic but upwind of the intersection at Mohawk Rd and Upper James and downwind of the intersection/idling traffic at Barton St. and Centennial Pkwy, see diagram, Fig. 23.

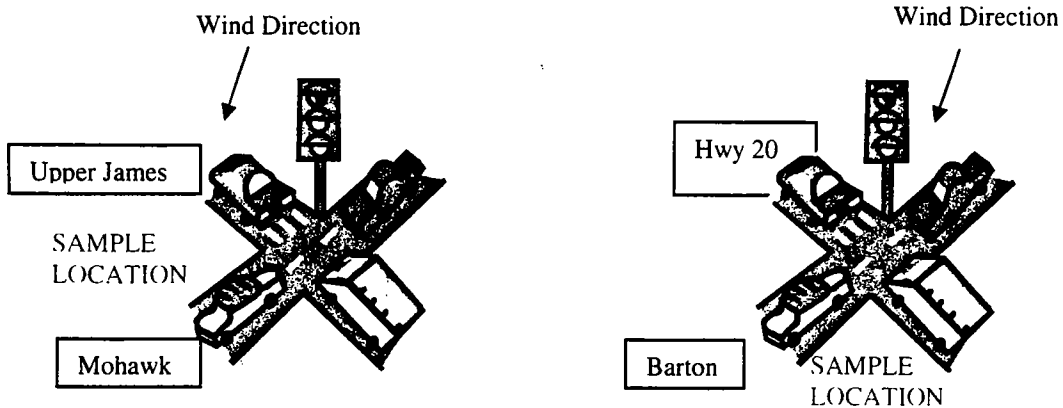


Fig 23. Diagram of Intersection Sampling Locations.

Wind direction was $250-260^{\circ}$, WSW, wind speed was 20 km/hr and temperature was -5° C.

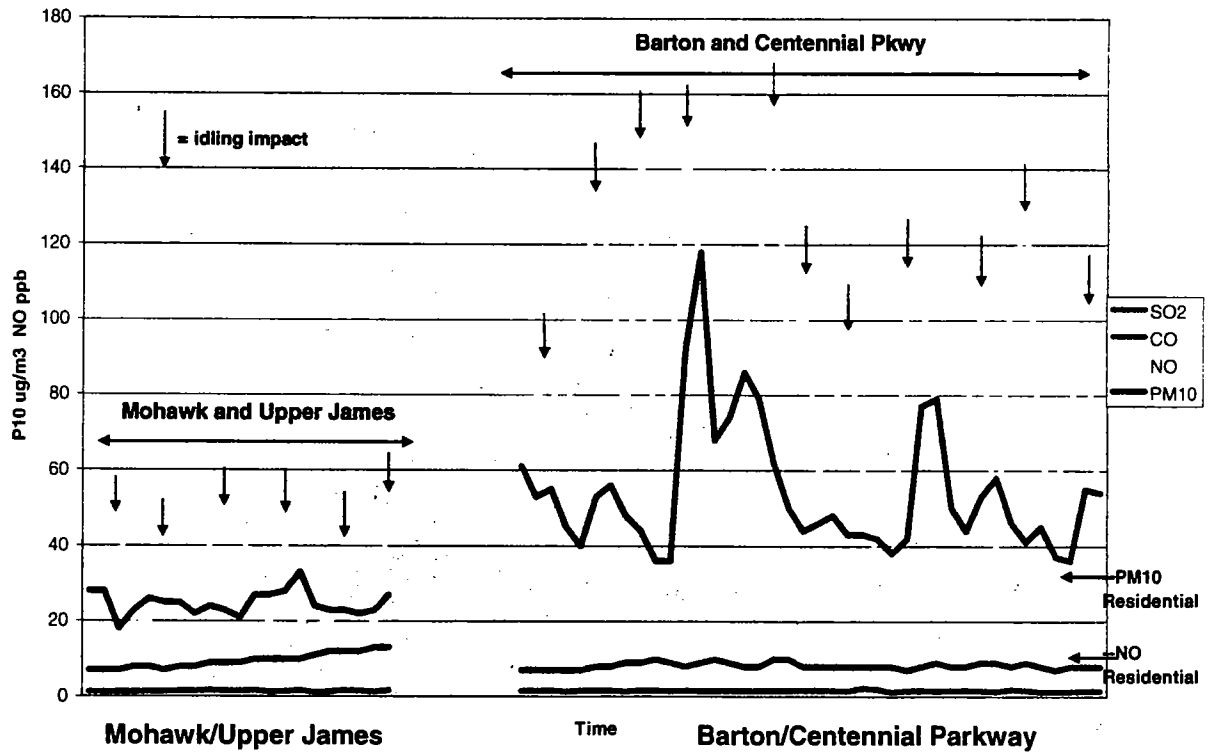


Figure 24 – Stoplight Idling, Concentrations of PM_{10} , NO, CO, and SO_2 downwind of intersections (Graph lines offset for visibility).

There is a very clear idling / driving pattern of NO and PM₁₀ impacts directly linked to idling of vehicles at stop lights. At Mohawk and Upper James the sampling location was approximately 30 metres downwind from the road but upwind of the intersection itself so that only idling and not intersection effects would be measured.

NO varied from 19 to 46 ppb for idling v free traffic flow and PM₁₀ from 18 to 28 ug/m³ for idling v. free traffic flow.

At Barton and Centennial Parkway, the sampling location was approximately 10 metres downwind of the east/west road and 30 metres downwind of the intersection. As a result, baseline levels were higher but there is still quite a dramatic effect of idling vs. stop light changes. NO varied from a low of 35 ppb to a high of 154, i.e., by a factor of five. PM₁₀ varied from 36 to 118 ug/m³, i.e., by a factor of three.

Some newer diesel engines have the potential to install automatic idle off controls and hybrid passenger vehicles have these controls also. Installation of such controls on the current passenger fleet may well lead to greatly improved fuel economy and reductions in transportation related emissions.

School Sampling

There are concerns about the impacts of idling emissions on schoolchildren while being dropped off or picked up at school. It was requested that sampling be performed during student exposure times for one sampling day at a designated school, George R. Allen in Westdale. School authorities agreed to the sampling and were notified in advance of the specific times.

It was planned to arrive early before school opened, monitor background levels with no idling vehicles present, then monitor idling emissions, then background again and leave, return before school closed, monitor background levels, monitor idling emissions, monitor background, complete sampling.

Due to difficulties with the uninterruptible power supply for the instruments, the sampling vehicle did not arrive at the school site until student drop off was at its maximum intensity at 8:53 a.m. Afternoon sampling commenced at 2 p.m., well before school finished for the day at 3:30 p.m. Sampling continued through student pickup time and continued until 3:54 p.m.

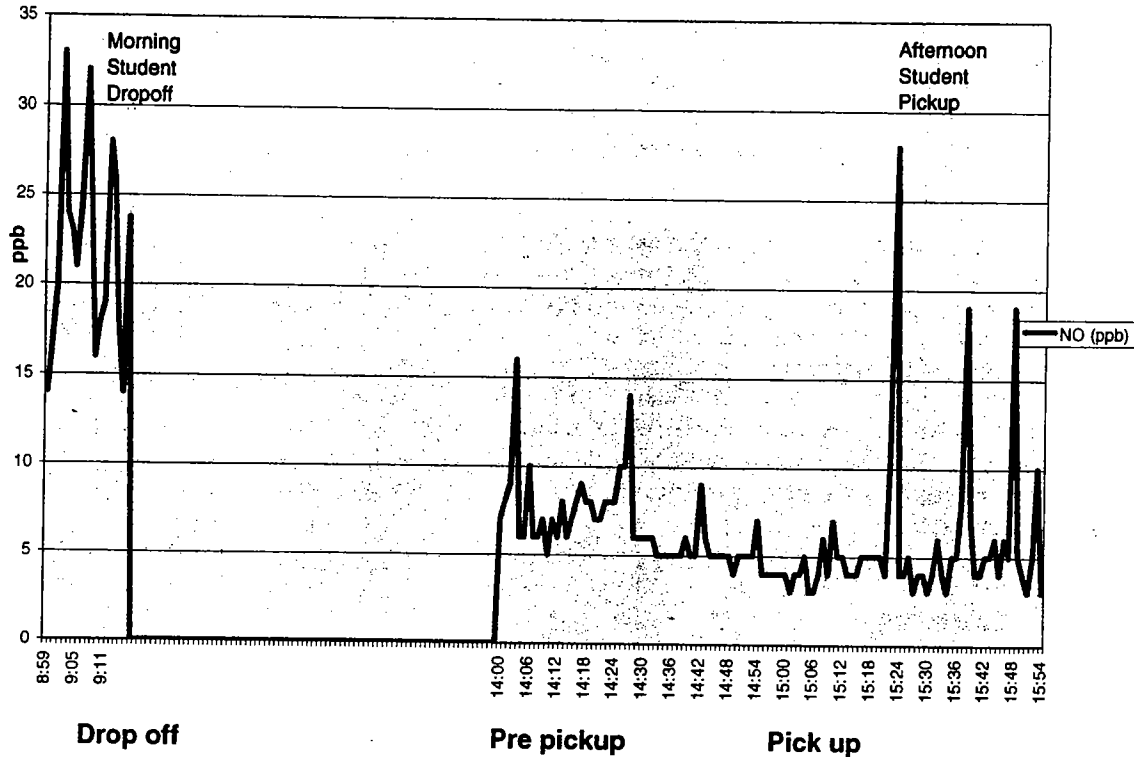


Figure 25 – Concentrations of NO at school drop off / pickup.

The PM₁₀ results for this sampling were disregarded in the afternoon since it began to snow, potentially affecting the particulate monitor. The NO data show an average of 24 ppb in the morning but remain mostly at 4-5 ppb in the afternoon, except for a few short spikes. As the measurements were being taken in the afternoon, it became clear that lower levels were being measured. One of the vehicle operators went out and checked the vehicles parked along the road. He found that 23 vehicles were parked in proximity to the school and all had their engines turned off. In other words, when the sampling vehicle arrived with no warning earlier in the day, NO levels averaged 24 ppb. In the afternoon, when drivers realized that air monitoring was in progress, they turned engines off and levels remained mostly at 4-5ppb. This made for an interesting experimental comparison between idling and non idling conditions outside the school.

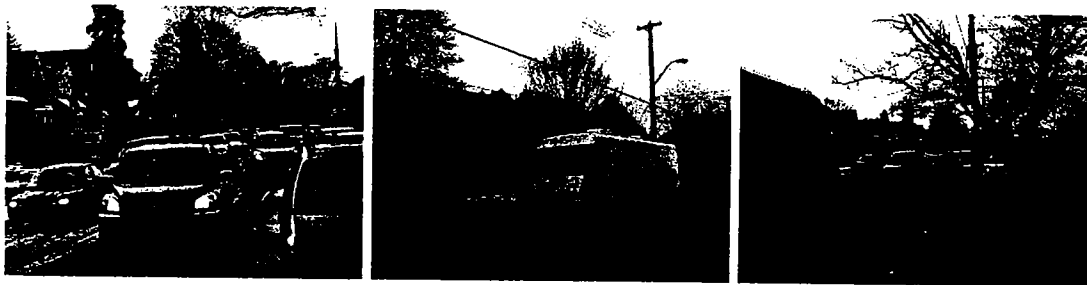


Figure 26 – Idling/Non-Idling Vehicles

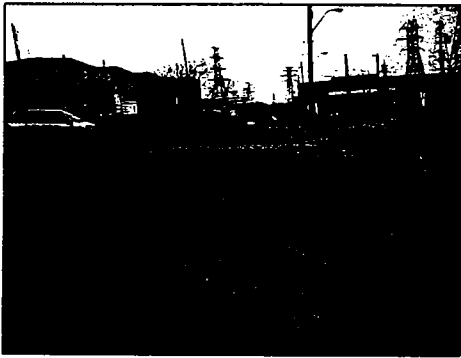
Road Dust Track Out and Re-suspension

Track out of material onto public roads and subsequent re-suspension of this material as airborne particles has been identified by MOE as a significant issue in the industrial area of Hamilton. City staff also focused attention on this issue with enhanced road cleaning pilot studies and the proposed purchase of advanced technology road cleaning equipment.

As noted above, MOE identified a number of target areas for monitoring these effects.

The monitoring results for these areas, and some additional areas, showed extremely high levels of airborne particles when the road dust was disturbed by large trucks.

Brampton Street



Strathearne Avenue

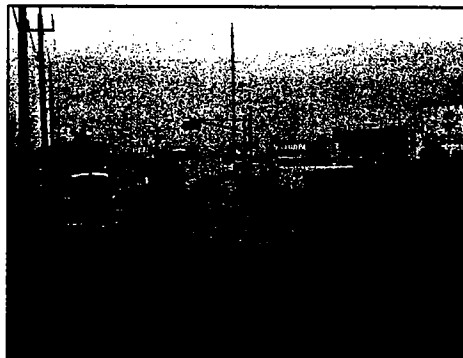


Figure 27 – Track Out and Road Dust Re-suspension Photos

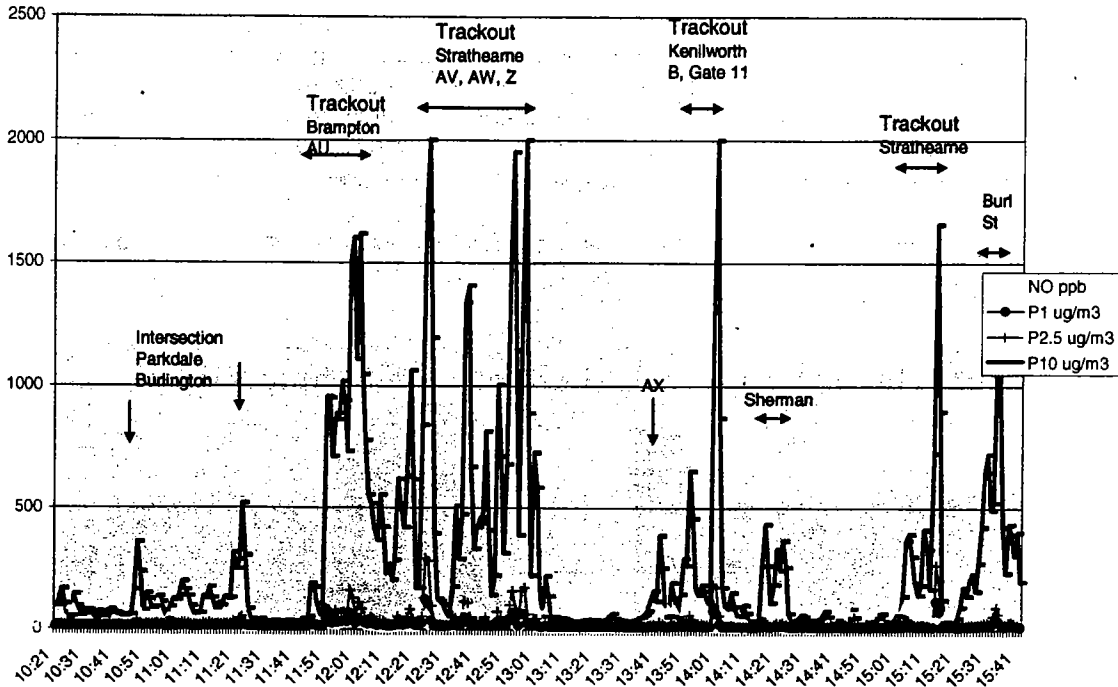


Figure 28 – Track out 13 January

Road dust data from a number of target areas were consolidated in a single graph. Clearly these issues have a much wider occurrence than just in the Northeast industrial area of the city. Eighteen locations were monitored with high concentrations of airborne particles due to re-suspended dust and fourteen of these were linked to dirt track-out from specific facilities.

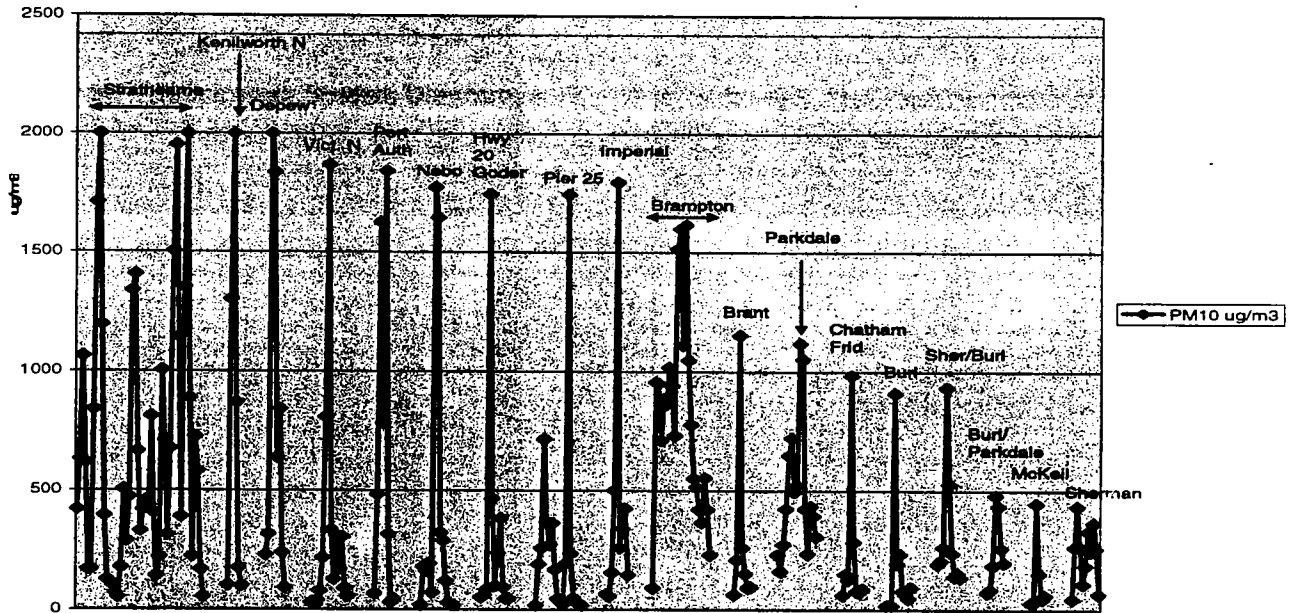


Figure 29 – PM₁₀ Road Dust/Track out, 18 Locations Monitored, 14 Sources Identified

Observation of specific facilities will be discussed with MOE in support of a wider control initiative involving all stakeholders, including road cleaning city staff.

It has been suggested that these particles are merely “nuisance dust” due to their large size, i.e. they are not inhalable and therefore would not cause health impacts. However, lung defense mechanisms do not have sharp cutoffs for particle size and a number of larger particles penetrate into the lung. In addition, these particles may contain toxic components not measured in this study.

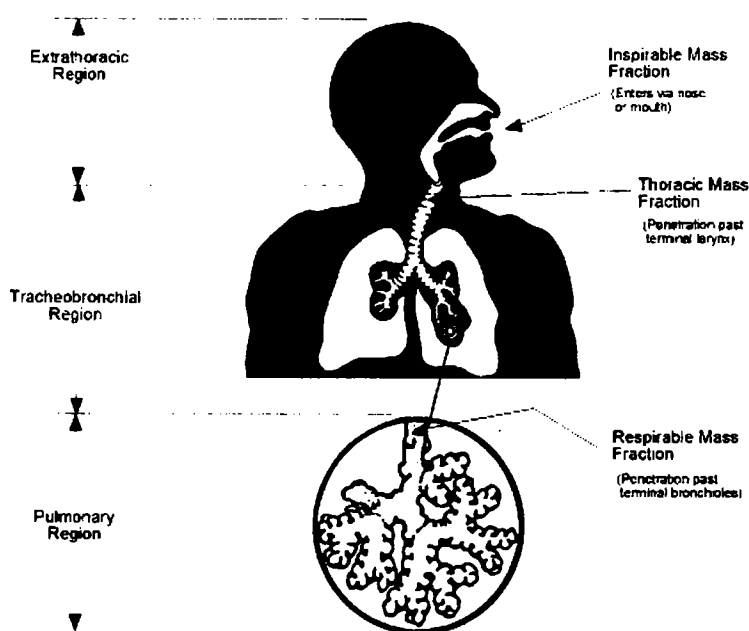


Figure 30 – Respiratory System Diagram.

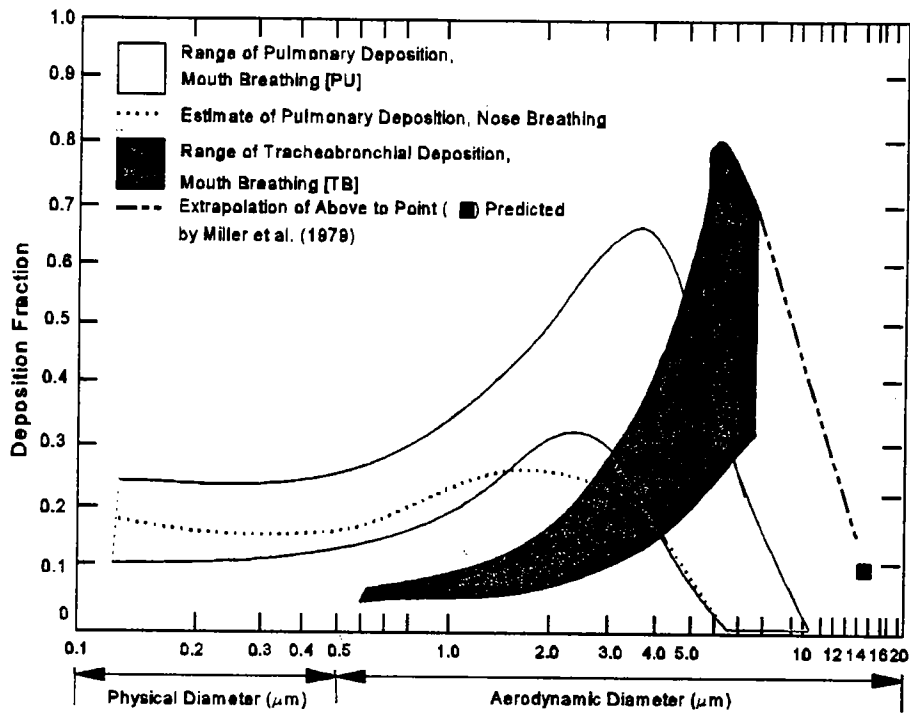


Figure 31 – Lung Penetration Curves By Particle Size

Since the Grimm particulate monitor measures PM_{10} (inhalable), $\text{P}_{2.5}$ (respirable) and P_1 (fine) particles simultaneously, these measurements provided an excellent opportunity to examine the size distribution of airborne particles in re-suspended road dust and find out if there is a significant component of smaller particles.

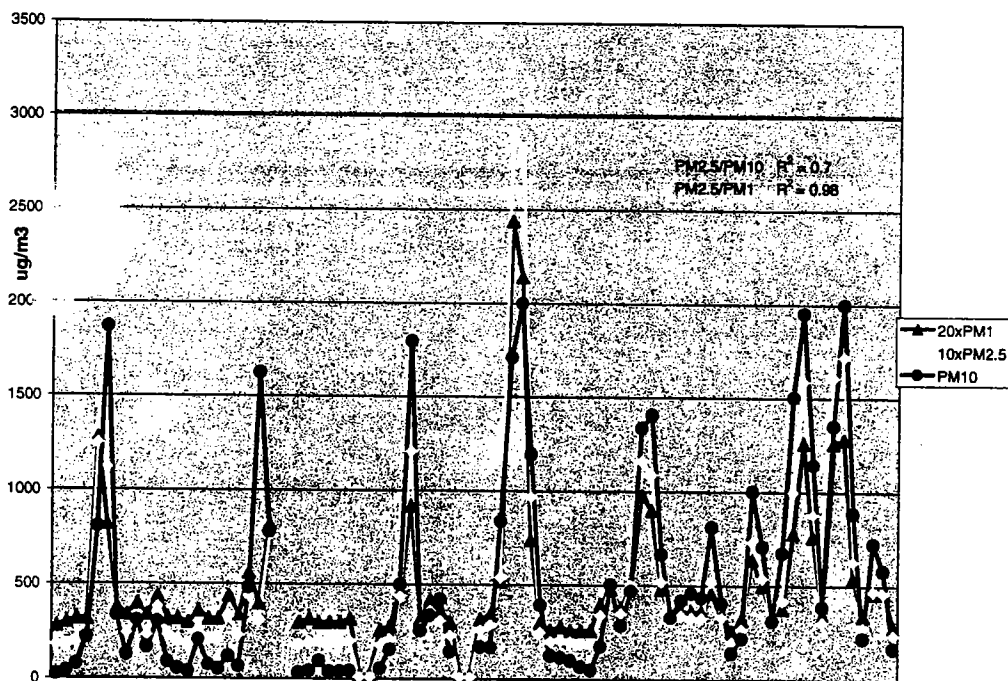


Figure 32 – Re-suspended Road Dust , Covariance, 20x PM_{10} , 10x $\text{PM}_{2.5}$, PM_{10}

Very high concentrations of inhalable (2000 ug/m^3), respirable (300 ug/m^3) and smaller (125 ug/m^3) particles are present in these clouds of road dust, with strong correlations between the sizes.

Point Sources

As mentioned previously, the point sources in the Hamilton region fall into five well-defined geographic areas. All five areas were sampled, with varying degrees of success.

- This type of mobile survey has limitations. The actual sampling time is of relatively short duration compared to fixed network sampling and specific industrial processes causing emissions may or may not be operating at any given time.

In particular, the sampling took place in the winter months and the aggregate operations in the east and west mountain areas did not appear to be in significant production during this time. Some emissions were detected, including track out related emissions, however it appeared that summer monitoring while these industries are in full production would yield more significant results. In another case, the actual emission point was at a different address than that provided.

Point sources monitored included large integrated steel industries, steel byproducts processors, recycling/scrap operations, foundries, chemical plants, storage piles, agricultural materials processing, brick manufacturing, university operations, vegetable oil processing, carbon black manufacturing, rail shunting/truck transfer and a cogeneration natural gas plant.

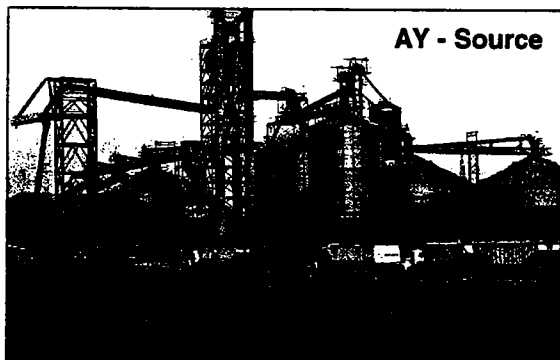
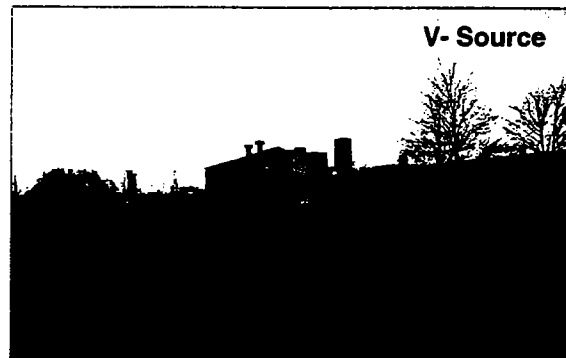
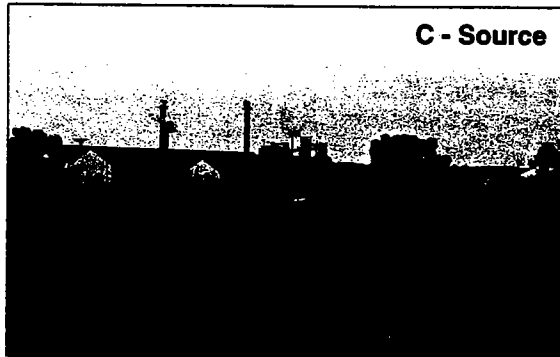
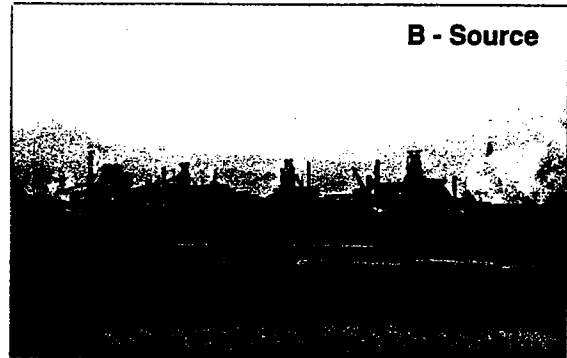
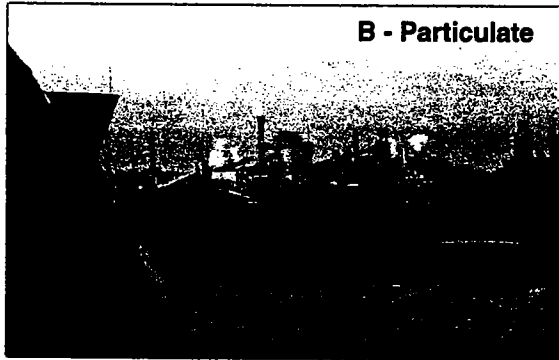


Figure 33 – Point Source Photos

While sampling point sources, local traffic emissions of NO_x and particulate tended to obscure the point source contributions, see below.

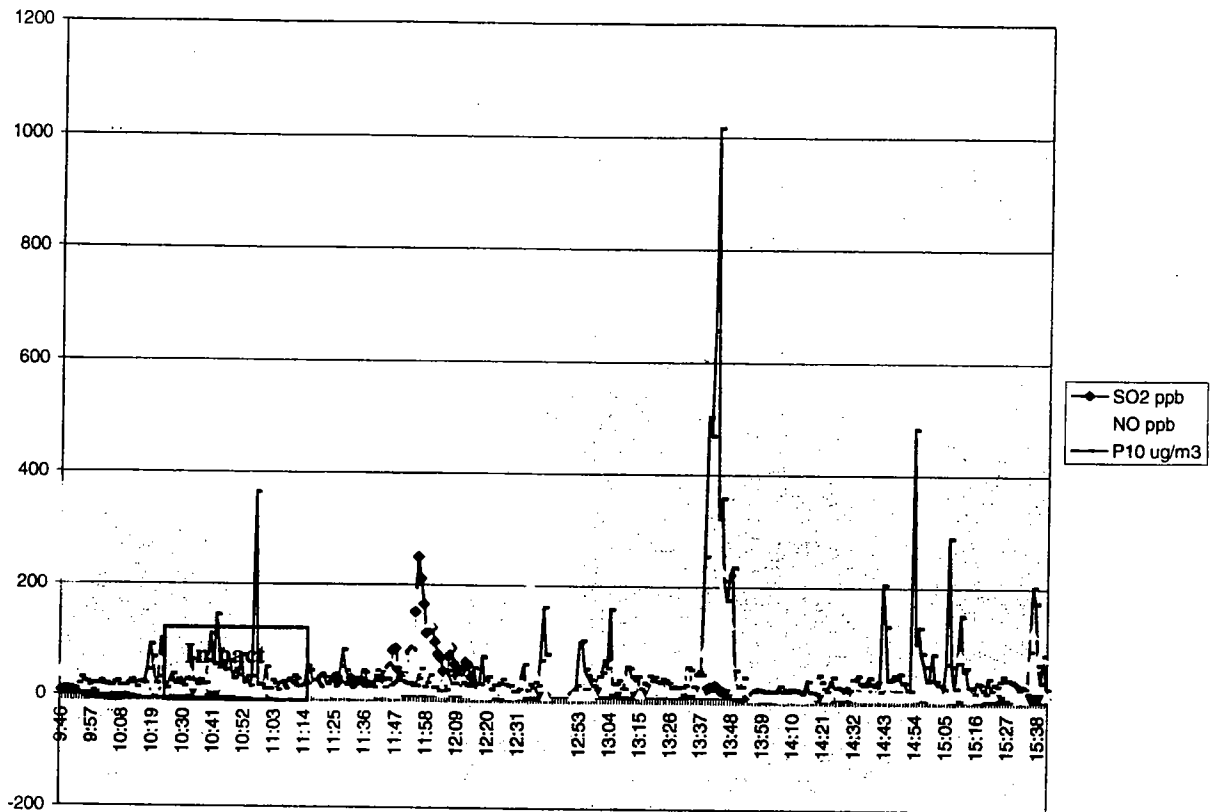


Figure 34 – All Scans 21 March, 2006

Several strategies were employed to overcome this effect.

Careful choice of sampling location with respect to the industry, nearby roads and wind direction was necessary otherwise passing traffic, including diesel trucks, could lead to interferences. The relatively slow response time of the continuous monitoring instruments exacerbated this effect. Wind direction data from the nearest meteorological tower was also checked and the active GIS map on the laptop was used to identify probable plume impact areas, see Fig. 37 below.

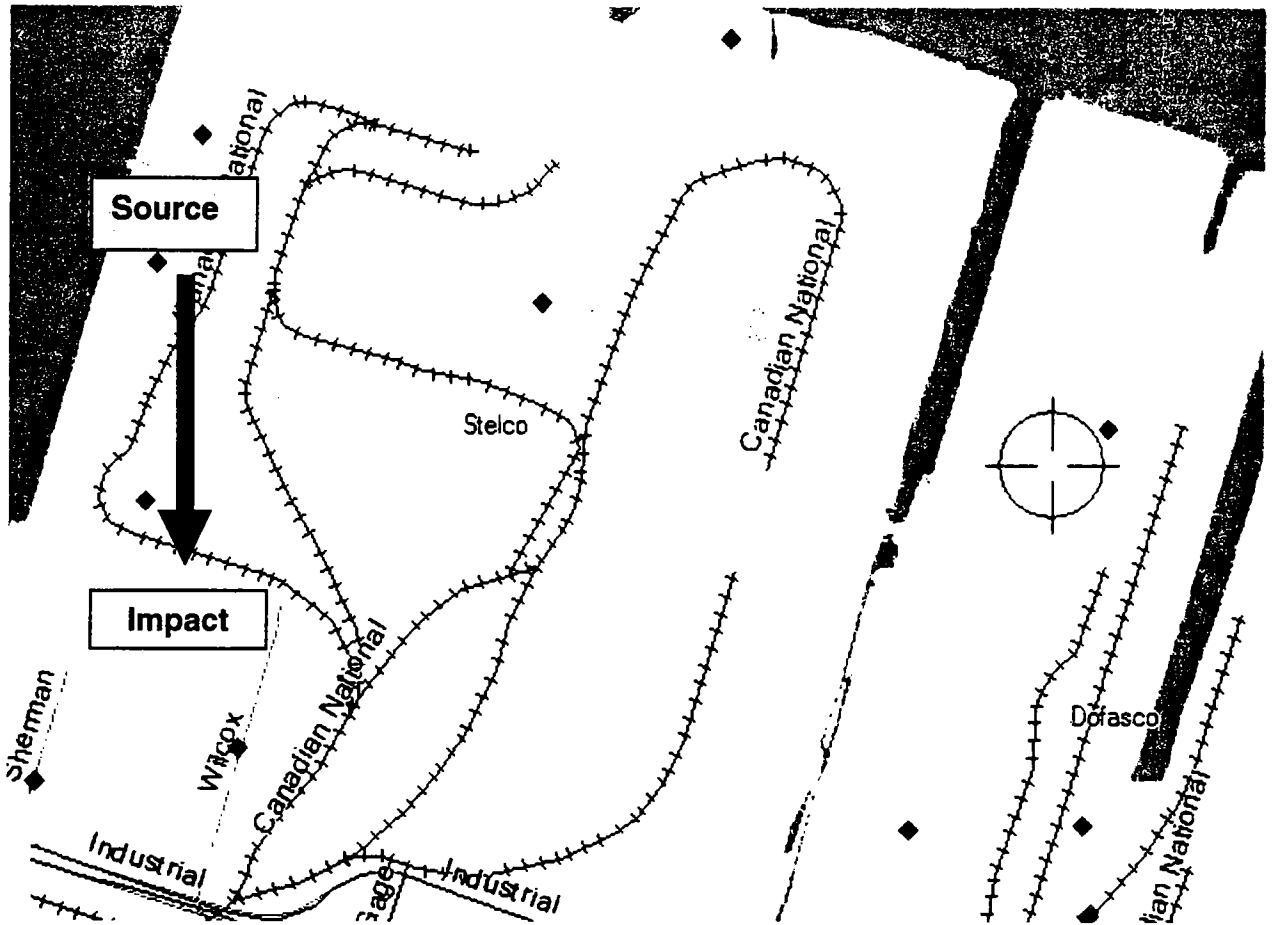


Figure 35 – Plume Back Tracking

Visual observations of steam plumes from the emission sources were used to refine monitoring locations.

SO₂ concentrations are nearly all caused by point sources, so SO₂ "hits" were used to confirm that monitoring was taking place in the plume impact area (for sources emitting this contaminant).

These data were also used as a tracer for point source impacts in the later data analysis, see Figs. 38, 39 below.

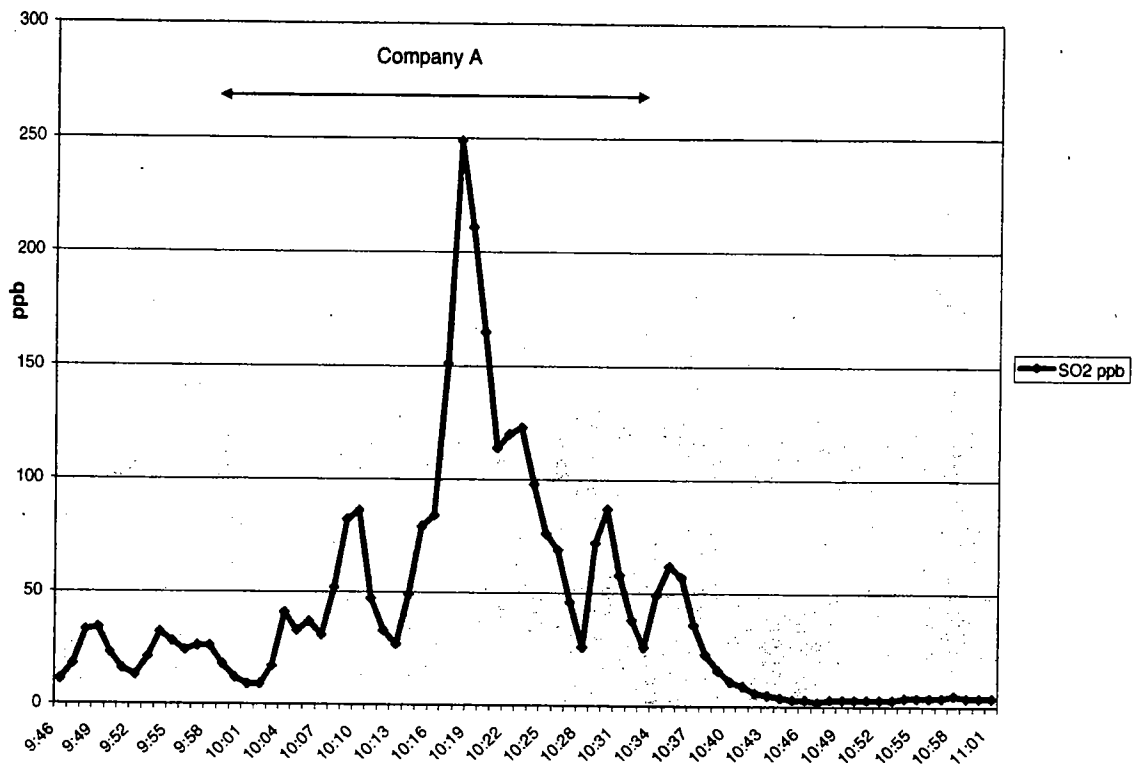


Figure 36 – SO₂ Concentrations from Company A, Stationary Sampling

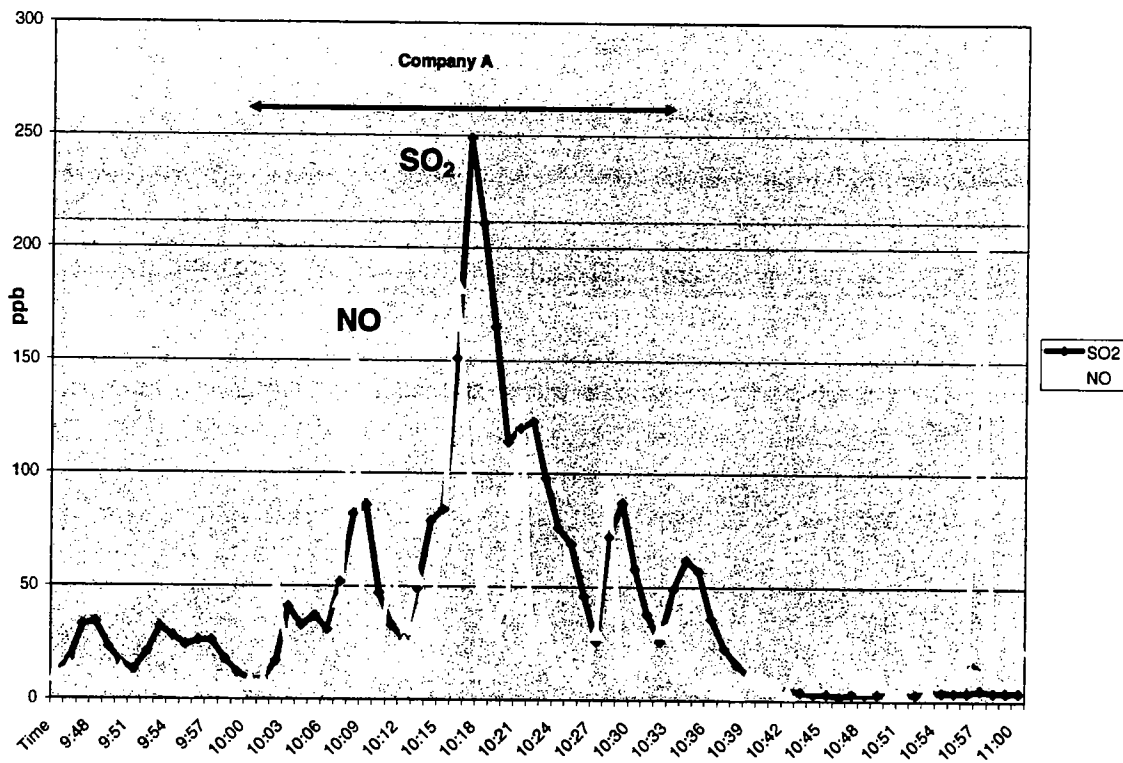


Figure 37- NO Company A, Stationary Sampling, identified by association with SO₂

Use of this suite of techniques enabled identification and ranking of a number of specific sources.

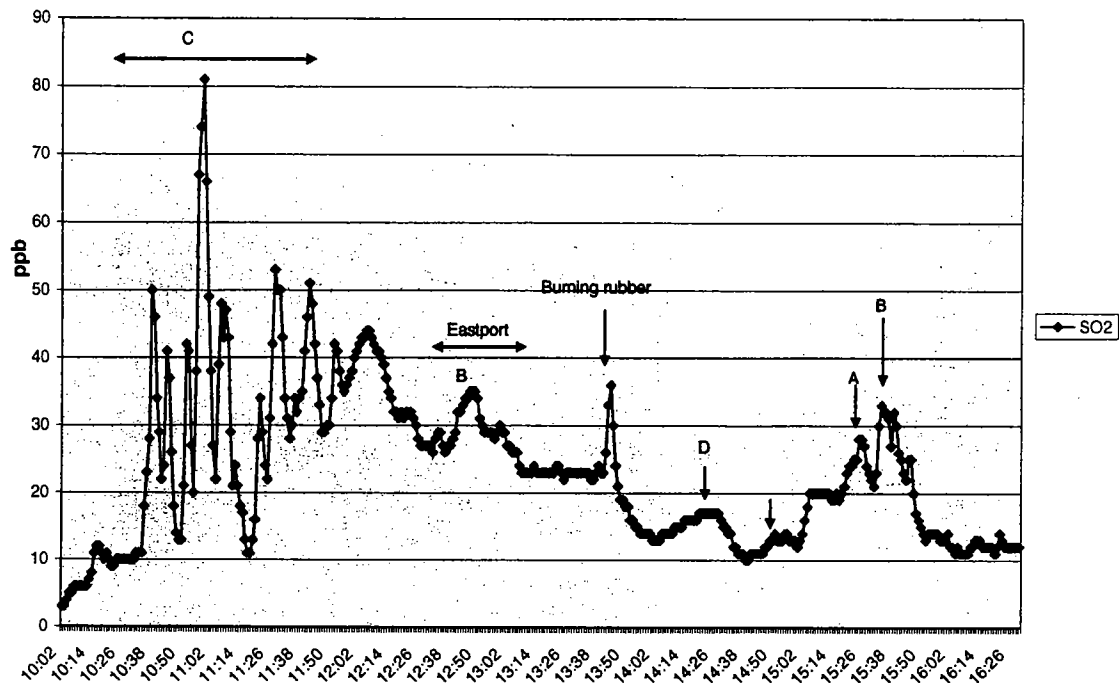


Figure 38 – 19 Jan, 2006, SO₂

These data could then be ranked in order of ambient peak impacts.

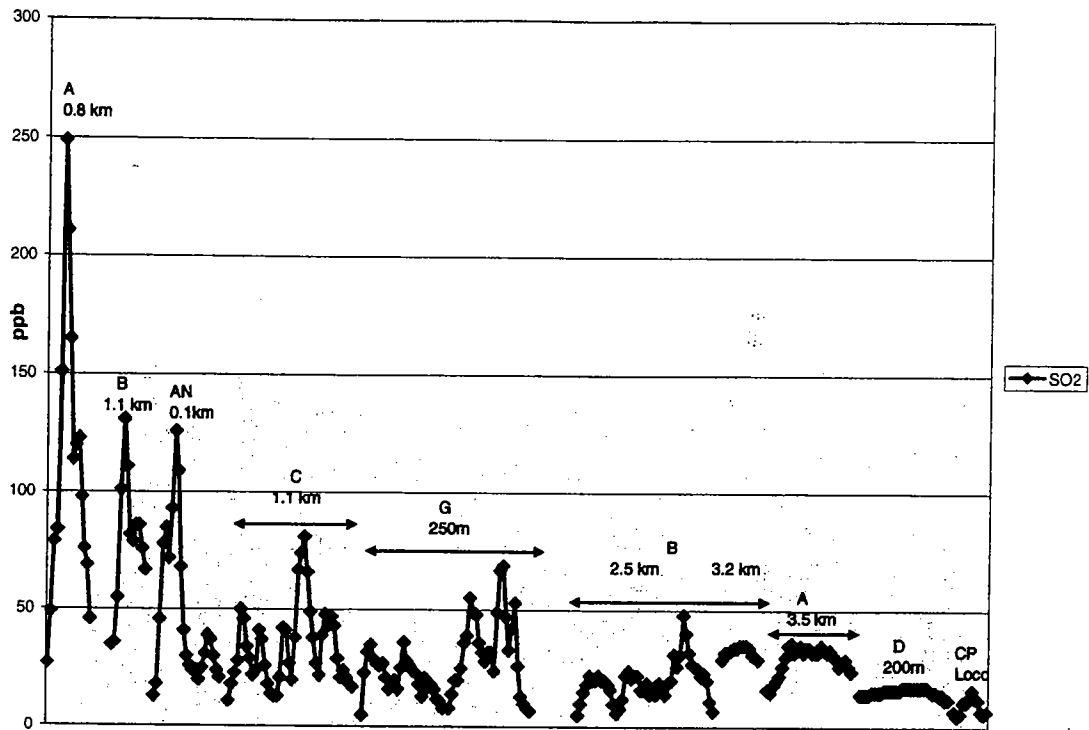


Figure 39 – SO₂ Data Peaks

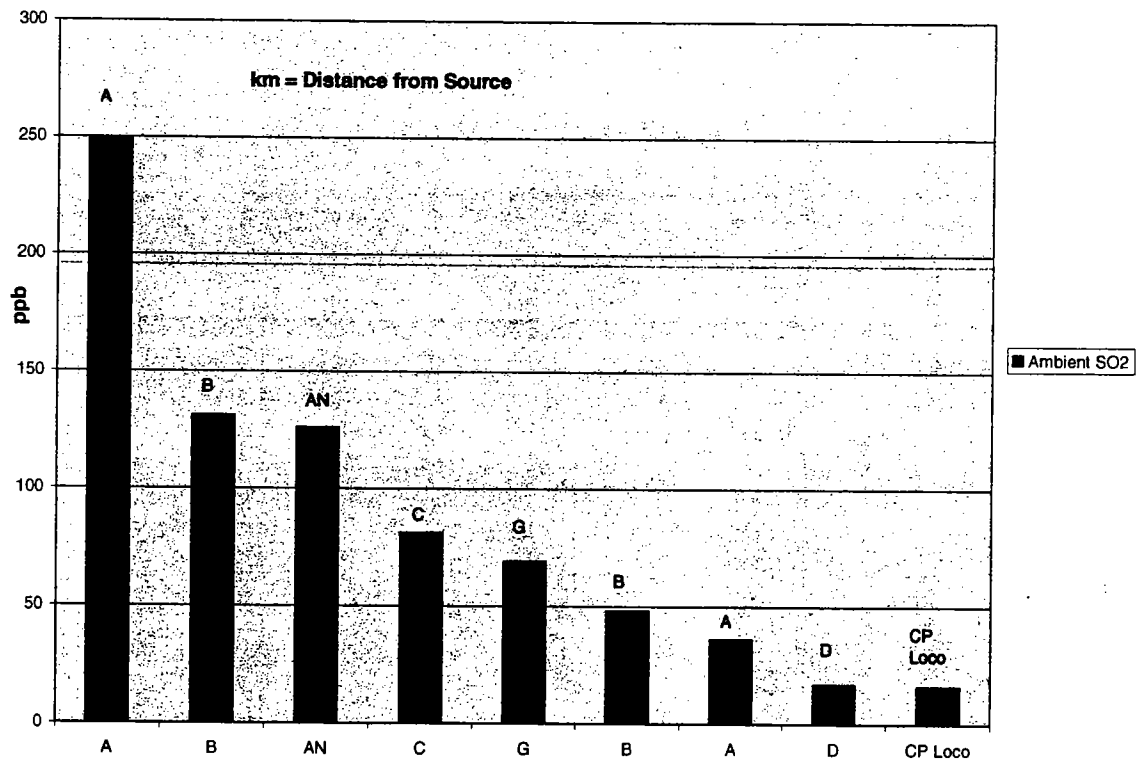


Figure 40 – Ambient SO₂ Peak Values

SO₂ Point Sources: A-Integrated Steel, B-Integrated Steel, AN- Steel Byproducts, C-Carbon Black, G-Steel, B-Integrated Steel, A-Integrated Steel, D-Lime, CP-Rail Yard.

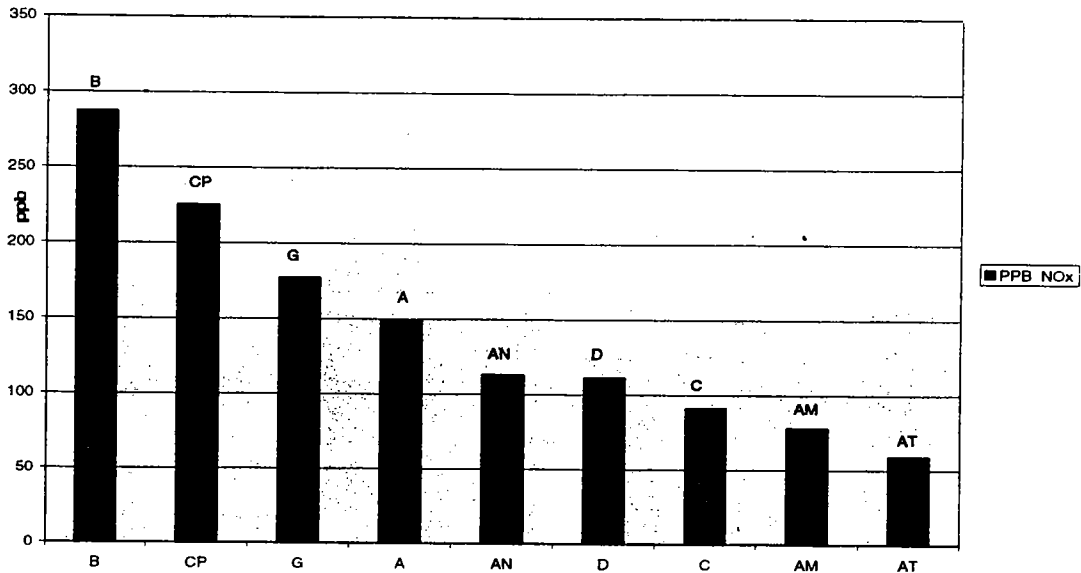


Figure 41 – Ambient NO Peak Values

NO Point Sources: B-Integrated Steel, CP-Rail Yard, G-Steel, A-Integrated Steel, AN- Steel Byproducts, D-Lime, C-Carbon Black, AM-Cogeneration, AT-Chemical.

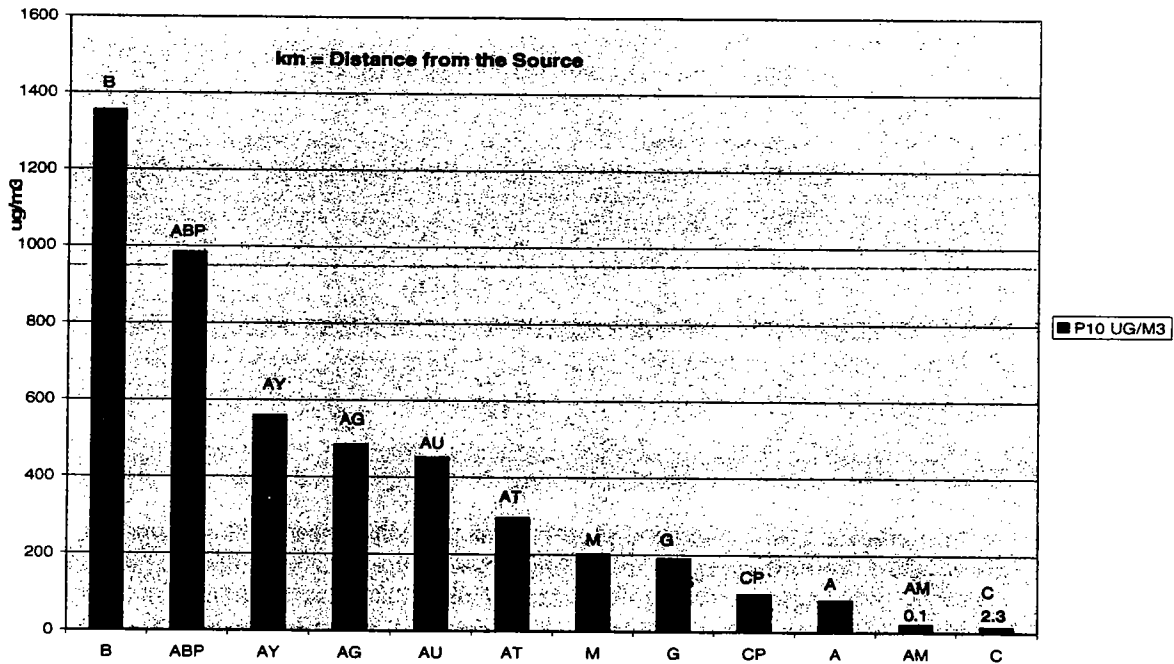


Figure 42 – Ambient PM₁₀ Peak Values

PM₁₀ Point Sources: B-Integrated Steel, ABP-Recycling, AY-Agricultural Product Handling, AG-Aggregate or AZ-Steel Handling, AU-Recycling, AT-Chemical, M-Foundry, G-Steel, CP-Rail Yard, A-Integrated Steel, AM-Natural Gas Cogeneration Facility, C-Carbon Black.

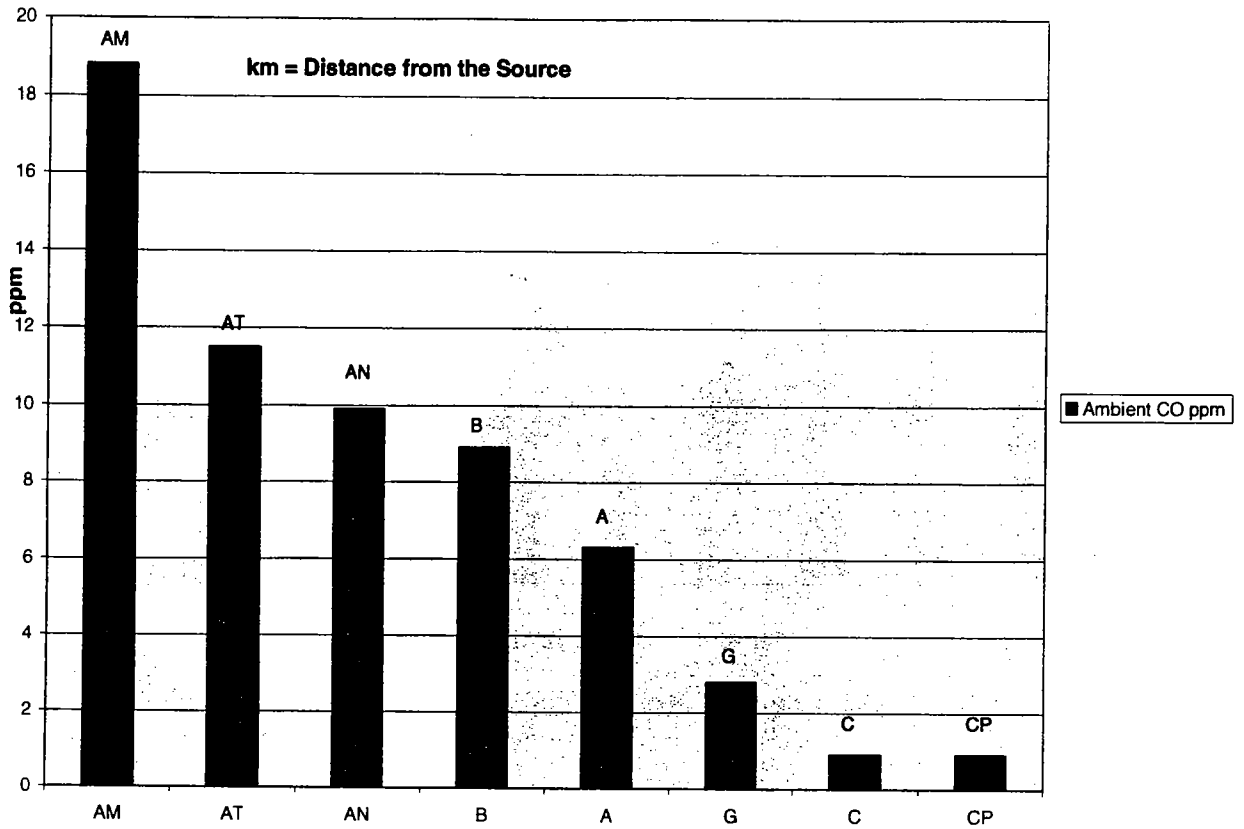


Figure 43 – Ambient CO Peak Values

CO Point Sources: AM-Cogeneration, AT-Chemical; AN- Steel Byproducts; B-Integrated Steel; A-Integrated Steel; G-Steel; C-Carbon Black; CP-Rail Yard.

Comparison of NPRI to Ambient Data from this Study

It is interesting to compare the point source emission estimates from the NPRI with the actual ambient peak values of the contaminants. Tonnes emissions are approximately normalized to ppb, ppm or $\mu\text{g}/\text{m}^3$. Since measurements were made at available locations at varying distances from sources, distance from source is included in the following charts. A detailed modeling exercise was beyond the scope of this project.

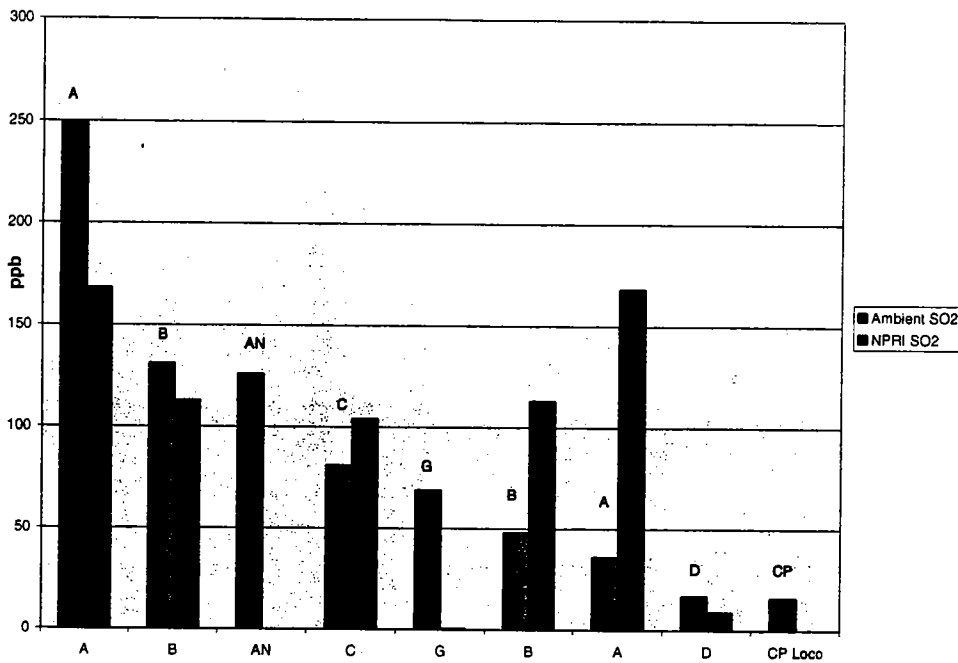


Figure 44 – SO₂ Ambient vs. NPRI

For SO₂: A-Integrated Steel, B-Integrated Steel, and C-Carbon Black emissions vs. ambient agree fairly well, given the different distances and additional dilution from emission point to measurement location. AN-Steel Byproducts, G-Steel and CP-Rail Yard ambient downwind concentrations do not reflect NPRI. They have significant ambient concentrations yet either zero or very small NPRI SO₂ emission estimates, i.e., it appears that NPRI data for these sources do not exist or underestimate emissions. D-Lime did not appear to be in full operation.

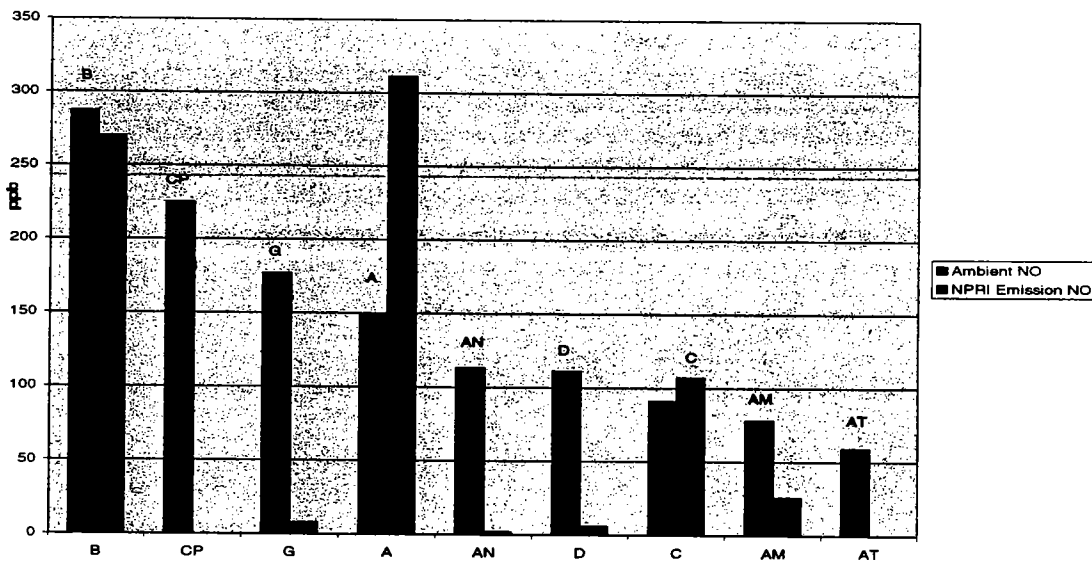


Figure 45 – NO Ambient vs. NPRI

For NO: B-Integrated Steel, C-Carbon Black, AM-Cogeneration and A-Integrated Steel emissions vs. ambient agree fairly well, given the different distances and additional dilution from emission point to measurement location. CP- Rail Yard, G-Steel, AN- Steel Byproducts, D-Lime and AT-Chemical show concentrations that do not reflect NPRI. They have significant ambient concentrations yet either zero or very small NPRI NO emission estimates, i.e., it appears that NPRI data for these sources do not exist or underestimate emissions.

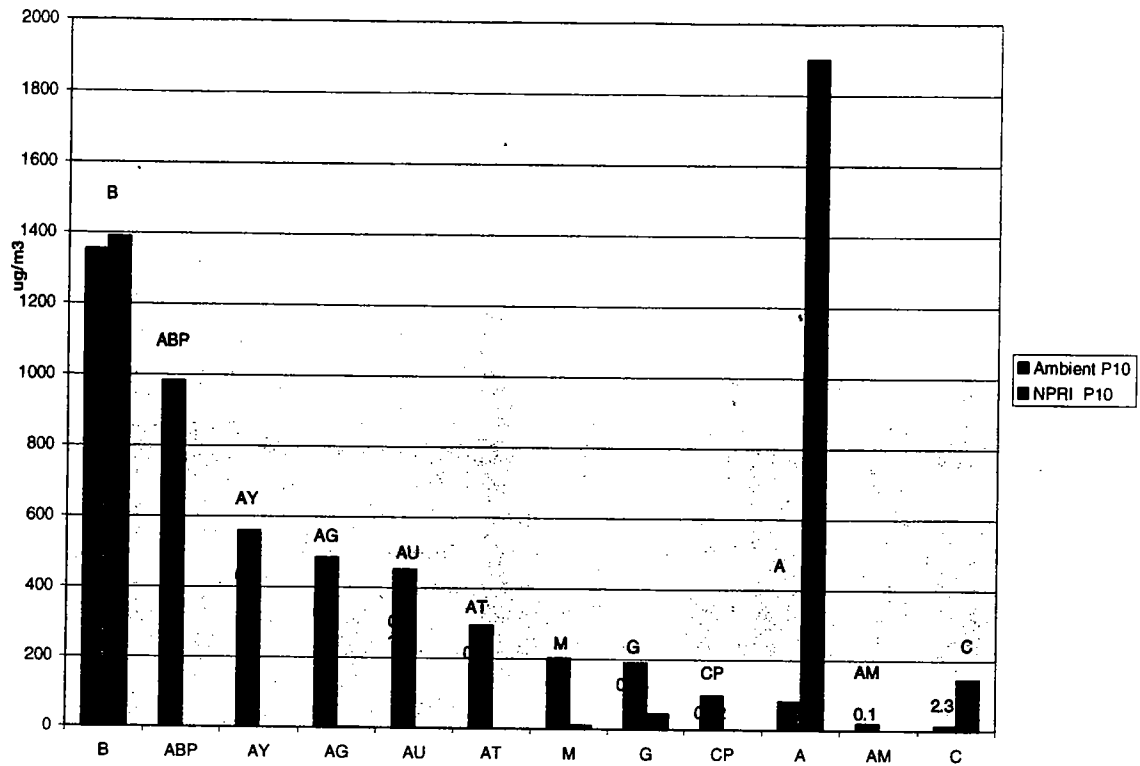


Figure 46 – PM₁₀ Ambient vs. NPRI

For PM₁₀:

B-Integrated Steel, G-Steel, C-Carbon Black and M-Foundry emissions vs. ambient agree fairly well, given the different distances and additional dilution from emission point to measurement location. ABP-Recycle/Scrap, AY-Agricultural Products Handling, AG-Aggregate or AZ-Steel Handling, AU-Recycling, AT-Chemical, CP- Rail Yard, A- Integrated Steel, and AM-Cogeneration show concentrations that do not reflect NPRI. They have significant ambient concentrations yet either zero or very small NPRI PM₁₀ emission estimates, i.e., it appears that NPRI data for these sources do not exist or underestimate emissions, except for A-Integrated Steel where emissions are lower than NPRI.

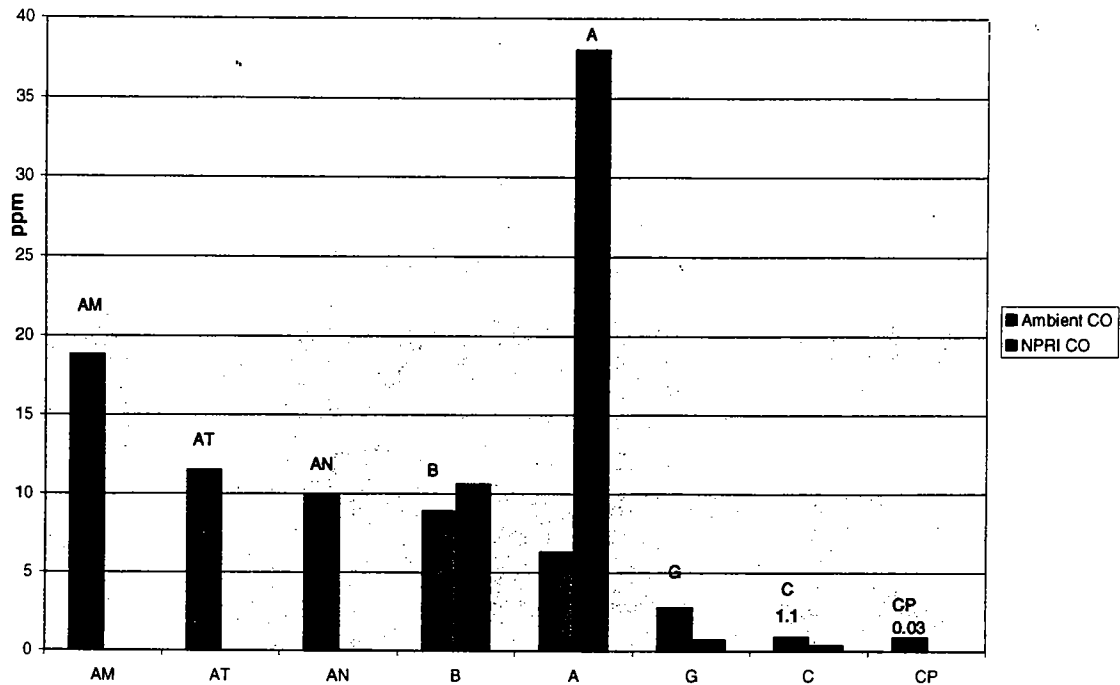


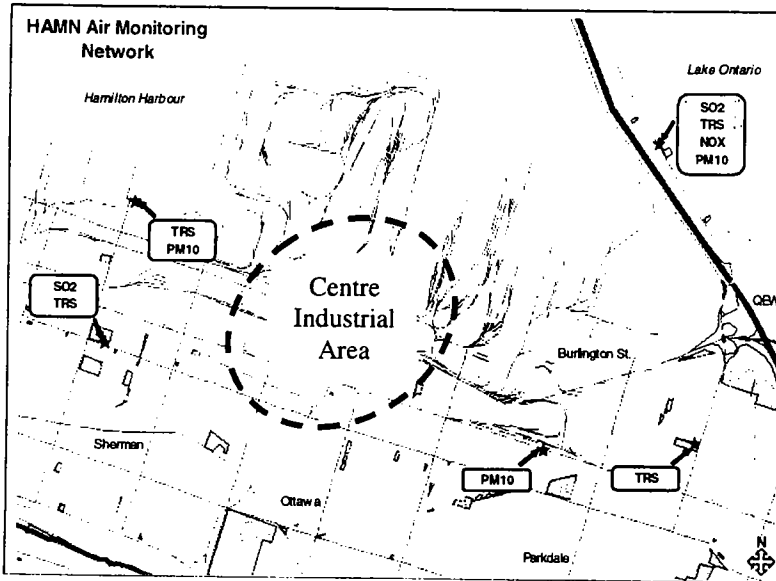
Figure 47 – CO Ambient vs. NPRI

For CO: B-Integrated Steel, G-Steel and C-Carbon Black emissions vs. ambient agree fairly well, given the different distances and additional dilution from emission point to measurement location. AM-Cogeneration, AT-Chemical, AN- Steel Byproducts and CP- Rail Yard show concentrations that do not reflect NPRI. They have significant ambient concentrations yet either zero or very small NPRI emissions, i.e., it appears that NPRI data for these sources do not exist or underestimate emissions, except for A-Integrated Steel where emissions are lower than NPRI. Highest levels of ambient CO were measured downwind of a natural gas cogeneration facility.

Existing Air Monitoring Network Stations

The existing continuous monitoring network focuses on TRS, SO₂, and PM₁₀, with one NO_x monitor, see below

Locations of Continuous Air Monitoring Equipment



Locations of Non-Continuous Air Monitoring Equipment

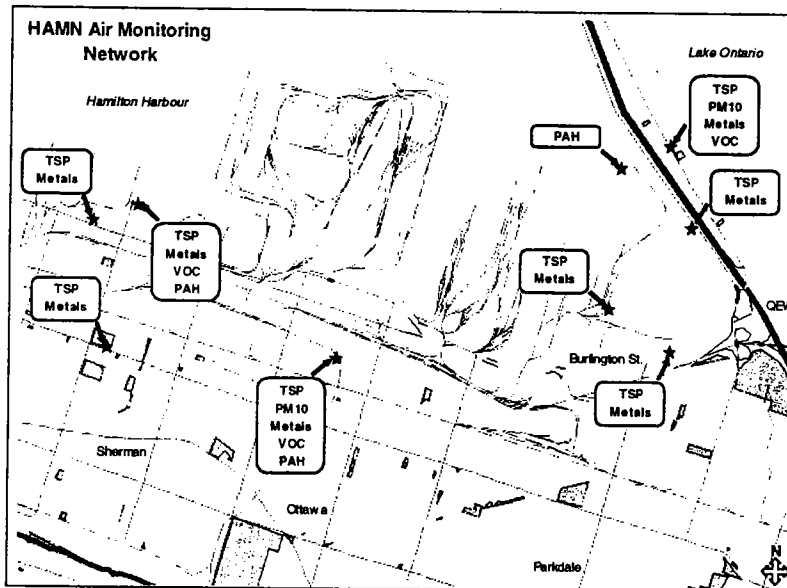


Figure 48 – HAMN Industrial Air Monitoring Network

Since the highest health impact pollutant is NO_x, consideration should be given to enhancing NO_x monitoring in the network. In addition, the centre of the NE Industrial area (Sherman) has no continuous monitors. The other areas identified in the NPRI, East, West Mountain, West Hamilton/Frid and Stoney Creek would also benefit from increased coverage.

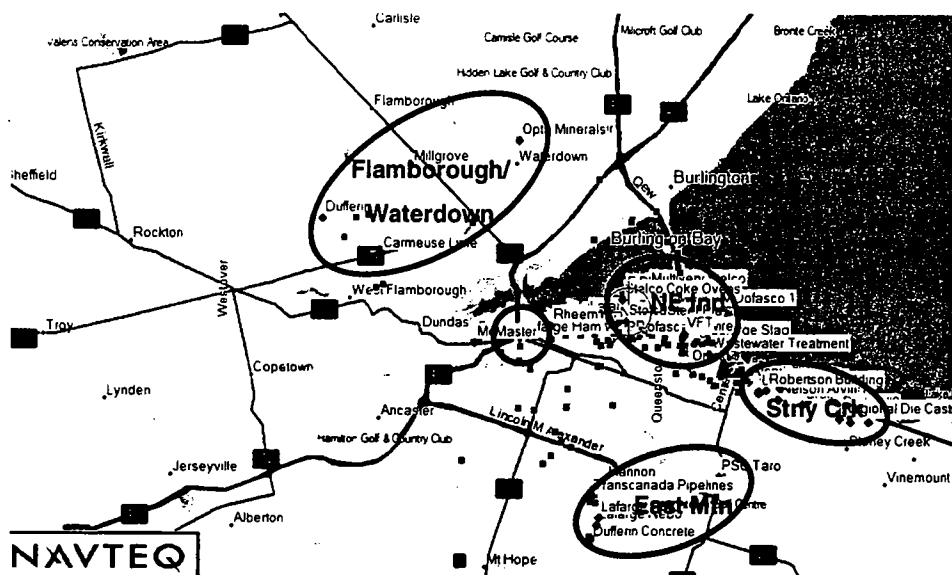


Figure 49 – Industrial Emission Areas of Hamilton

11. Limitations and Conclusions

This survey had both generic and specific limitations.

Mobile surveys in general have the advantage that the monitors can be moved around to identify pollution impacts and focus on the most affected areas. Anticipated and unanticipated impacts can be located and quantified.

A disadvantage is that usually monitoring can only be conducted for relatively short periods of time. Industrial processes may vary in emission outputs and in some cases may not be operating at all while monitoring is being conducted. Meteorological conditions including wind speed, wind direction, precipitation, snow cover and road wetness all vary widely and affect or reduce monitoring outcomes through plume dilution and location, atmospheric accumulation, precipitation washout or road dust suppression.

Specifically for this survey, a very large number of monitoring targets were originally identified through evaluation of previous data including NPRI and discussions with stakeholders. Because of the limited time available, relatively short periods of monitoring could be allocated to individual sources. In addition the entire survey was conducted during the winter months, without the opportunity to evaluate other seasonal conditions, e.g. spring or fall inversions, high smog days in summer or different industry operating conditions (aggregates).

Additional monitoring, either mobile or fixed network, would be required to fill these gaps. Despite these limitations the survey gathered much valuable data on the sources and ambient concentrations of health related pollutants, including data related to residential and industrial areas, roadways, vehicle idling, both at stoplights and a school, 14 road dust track out/re-suspension problem locations and 15 point sources of significance.

