Air Quality Assessment Related to Traffic Congestion at Sarnia's Blue Water Bridge

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EXECUTIVE SUMMARY

Heightened security at the Blue Water Bridge international border in Sarnia has resulted in long delays especially for the large trucks that use this as a point of entry into the United States. In turn, these delays have caused long lines of idling trucks - sometimes several kilometres in length - on 402 Highway, the main access road to the bridge. These lines can persist for hours at a time, several days per week.

These long and persistent queues have raised concern among local residents about the impact of the truck emissions on local air quality. Diesel truck emissions are related to a variety of health effects, as well as impacts on the environment. Problems associated with high levels of particulate matter include: damage to agricultural crops, vegetation, and homes; corrosion; reduced visibility and impacts on human health. VOC are known to contribute to smog and may have other health effects.

The Ministry has been monitoring air quality in the Sarnia area for many years to determine the sources of emissions and levels of air contaminants. This report presents an assessment of the air quality impacts of the traffic emissions along the 402 Highway based upon a special short term air quality surveys conducted for this purpose. The study took place during selected days in the summer of 2004.

The key results of the study are highlighted below:

- During normal traffic movement (free flowing traffic - no delays), the average increase in particulate matter adjacent to the road was minimal.

- During periods of long truck delays increases in particulate matter above ambient conditions were measured at distances from a few metres to 300 metres from the Highway 402.

- The level of the increased particulate matter was dependent upon traffic volume, length of delays and meteorological conditions (wind direction and speed).

- The greatest increase in particulate matter (TSP, PM_{10} and $PM_{2.5}$) was in close vicinity (less then 50 metres) to the road and decreased with distance from the road.

- For all particle sizes the particulate levels measured were half those measured in the Windsor’s, Huron Church Road study reported in March 2004.

- During the surveys, ministry staff experienced odours, believed to be from the residential trash in idling trucks delivering Ontario waste to a Michigan landfill site. Odours from decaying trash are normally related to volatile organic compounds, total reduced sulphurs, etc. Volatile organic compounds (VOC) measurements did not detect any traces of these compounds.

- The monitoring results suggested that the noise barrier located on both sides and adjacent to Highway 402 resulted in particulate matter accumulating near its vicinity. In some cases increases in particulate matter appeared to have trapped the particulate between the two walls and for a short distance from the downwind wall.

- Ministry staff has addressed monitoring constraints through modelling the traffic emissions with a current air dispersion model. In general the model was successful in replicating the results from the monitoring program and re-confirm that that traffic influences is confined to 100 to 400 metres downwind of Highway 402.

PART 1: CONTEXT

Introduction

During the last several years, traffic across the Blue Water Bridge between Canada and the United States has increased significantly. The last several years have also seen a dramatic increase in security at the Canada-U.S. border. The combination of these factors has often resulted in long truck delays which can range from minutes up to several hours. This causes truck queues that may range several kilometres along 402 Highway, the highway leading to the bridge. Since these queues continue to move extremely slowly, the trucks sit with their engines idling and occasionally moving a few feet and then returning to an idle. This creates a several- kilometre-long source of particulate and other pollutants running through a mainly residential section of north Sarnia. This, in turn, has caused concerns about air quality in these areas.

Figure 1: A typical border delay can cause long lines of idling trucks.

A similar air quality study was completed assessing the potential impacts of idling trucks, during long traffic delays at the Ambassador Bridge border in Windsor. An electronic version of the report "Preliminary Air Quality Assessment Related to Traffic Congestion at Windsor's Ambassador Bridge" is posted on the Ministry of the Environment internet website http://www.ene.gov.on.ca/air.htm.

In the Sarnia area, the traffic conditions and volumes at the Blue Water Bridge are different than experienced at the Ambassador Bridge access route in Windsor. There are many factors that can effect the particulate concentrations at the two access routes. Some are listed in the following table:

Table 1: Sarnia and Windsor traffic conditions and volumes			
Sarnia's Highway 402		**Windsor's Huron Church Road**	
No traffic lights		In excess of 10 traffic lights	
Constant flow of commuter traffic		Stop and go commuter traffic	
Minimal rush hour traffic volume		Heavy rush hour traffic volume	
Five metre noise barrier		No noise barrier	
Two lane freeway		Three lane city road	
Sarnia's Blue Water Bridge Yearly Traffic Volumes		**Windsor's Ambassador Bridge Yearly Traffic Volumes**	
Passenger Cars	3,766,299	Passenger Cars	6,185,328
Trucks	1,753,069	Trucks	3,268,793
Buses and Misc.	7,668	Buses and Misc.	76,277
Total	5,525,036	Total	9,530,398

Information source: Border Transportation Partnership Study

Air Pollution

Air pollution, and in particular smog, are major problems in Southwestern Ontario.

Ontario's large population - a third of Canada's total - and proximity to the United State's most populated region subject it to increased smog, acid rain and persistent organic pollutants. Flow of transboundary air pollutants from the United States account for up to 50 per cent of smog in Southwestern Ontario. In June 2000, the Ontario Medical Association estimated that:

> "Ontario is forecast to suffer in the order of 1,900 premature deaths, 9,800 hospital admissions, 13 thousand emergency-room visits and 46 million illnesses as a result of air pollution". [i]

The principal sources of air pollution are related to human activity. They include transportation, industrial activity such as fossil fuel-fired power generation, iron

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[i] http://www.oma.org/phealth/smogexec.htm

and steel production, cement and concrete manufacturing, petroleum refining, pulp and paper production, base-metal smelting and chemical processing. Residential wood stoves can also be a significant contributor to air pollution in parts of Ontario.

Some of the more common pollutants in Ontario's air include particulate matter (PM), nitrogen oxides (NO_X), sulphur dioxide (SO_2), carbon monoxide (CO), volatile organic compounds (VOC) such as benzene, toxic metals such as mercury, ground-level ozone (O_3), polycyclic aromatic hydrocarbons (PAH) and dioxins and furans.

Diesel Emissions

Most heavy duty trucks operating in North America rely on diesel engines. Diesel engines produce emissions that are lower in hydrocarbons, carbon monoxide, and carbon dioxide than emissions from gasoline engines. However, diesel engines also emit a complex mixture of gases and fine particulate that contains hundreds of chemical compounds, many known to be toxic. These include nitrogen oxides which are ozone precursors and components of urban smog, known or suspected carcinogenic substances such as benzene, polycyclic aromatic hydrocarbons, arsenic and formaldehyde. Much of this microscopic particulate is small enough to be inhaled deeply into the human lungs. Exposure to high levels of particulate of any sort is known to lead to increased incidence of respiratory illnesses.

These emissions can have a larger impact as vehicles release their exhaust at street level. Pedestrians and people living and working along the truck routes are exposed to these nearly undiluted emissions. As well, the "stop and go" traffic, as in the case of lines of trucks waiting to cross the bridge are known to lead to the highest emission rates per vehicle. In particular the British Government Highways Authority notes that:

> The highest emissions tend to be associated with low average speeds. Low speed journeys are typified by frequent stops and starts, accelerations and decelerations in response to traffic congestion or other disruptions of a vehicle's progress. These operations are inefficient in fuel usage and the operation of emission control systems. [ii]

The California Air Resources Board has formally designated diesel particulate as a "Toxic Air Contaminant."[iii] Documentation on "or" other health effects associated with diesel particulate include the following:

[ii] http://www.highways.gov.uk/roads/projects/AIRQUAL/12.htm

- Comprehensive Review of Potential Health Effects from Ambient Exposure to Exhaust from Diesel Engines. (Health Assessment Document for Diesel Engine Exhaust, May 2002, U.S. Environmental Protection Agency)

- The Proximity of Schools to Freeways and Major Truck Routes is Significantly Associated with Chronic Respiratory Symptoms in Children (Speizer and Ferris, 1973. Environmental Research 74(2): 122-32).

- Children admitted to hospital with an asthma diagnosis are significantly more likely to live in an area with high truck traffic (Edwards, Walter, et. al., 1994, Archives of Environmental Health 49(4): 233-7).

- Children living near major diesel thoroughfares are more likely to suffer from reduced lung function (Brunekreef, et. al., 1997. Epidemiology, 8(3): 298-303).

- Particulate in diesel exhaust bind to pollen in the air, exacerbating allergies and asthma (Knox, et. al., 1997. Clinical and Experimental Allergy 27(3):246-51, 1997 Mar).

Study Background

The Ministry's London Office conducted this study to determine the impact of truck traffic on local air quality. A series of short-term monitoring campaigns were undertaken to characterize levels of particulate and VOC (volatile organic compounds) in the neighbourhood of the bridge. Measurements were taken at various distances both upwind and downwind of 402 Highway to permit the separation of background and traffic contributions to local pollutant concentrations.

- The monitoring was timed to attempt to examine the influence of long truck queues that form when wait times increase at the international border.

- The study was conducted near the Ontario Court House on Christina Street near the entrance to the Canadian Customs at the Blue Water Bridge. This area was selected because of its proximity to residences and businesses.

- Results of the study have been shared with the Medical Officer of Health to ensure that any potential health concerns are addressed as quickly as possible.

- A zone of influence map was created from the monitoring results that assess the downwind particulate concentrations for different meteorological conditions.

PART 2: AIR MONITORING

Particulate Matter

The atmosphere contains a wide variety of very fine particles. These may be called particulate matter, dust, smoke, haze, aerosol, fumes, mist or other names, depending on the type of particle and who is describing it. These particles come both from man-made and natural sources, are composed of many different compounds and range considerably in size. Generally, the size (diameter) of individual particles ranges from 100 microns (1 micron = 1 µm = 1 millionth of a metre) down to one one-hundredth of a micron, or so. They may be liquid or solid and may be formed locally or come from long distances away. Larger particles tend to settle out of the atmosphere much more quickly and hence are more often associated with local sources. Fine particles, on the other hand, may travel a considerable distance. Particulate can be responsible for corrosion, soiling, damage to vegetation, reduction in visibility and may be injurious to health.

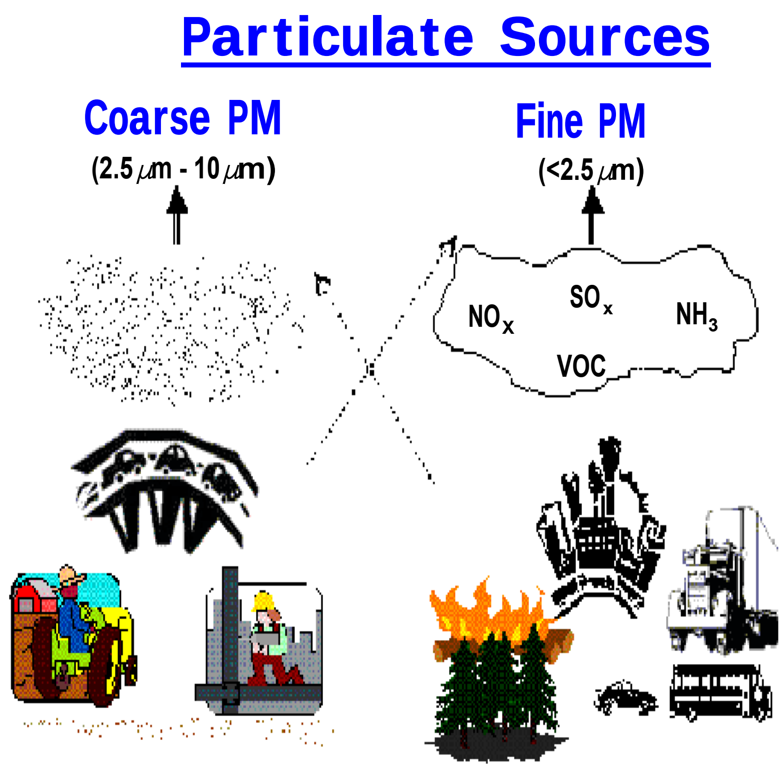


Figure 2: Particulate Sources

Total Suspended Particulate (TSP) is a generic term for all airborne particulate. Composition varies with place and season but normally includes soil particles, organic matter and nongaseous sulphur, metals and nitrogen compounds. The particles' diameters vary considerably from approximately 0.1 to 100 microns. [iv] Most particles greater than about 10 microns will be caught in the nose and throat, never reaching the lungs.

[iv] Since mass is proportional to volume which varies as the cube of the diameter, the heaviest particles may be a billon times heavier than the smallest ones.

The term PM_{10} (inhalable particulate) has been given to those particles that have a diameter of ten microns or less. Particles of this size are more likely to bypass the body's natural defences and reach the upper respiratory tract. This size fraction of particles will be caught by cilia lining the walls of the bronchial tubes, which will move particles up and out. PM_{10} can result from industrial activity, vehicle exhaust, residential wood combustion and entrainment of road dust. Natural sources include soil erosion, forest fires, volcanic activity and ocean spray.

The term $PM_{2.5}$ (respirable particulate) refers to that part of airborne particulate whose diameter is 2.5 microns or less. Particles of this size are able to penetrate deeper into the lungs, into regions where there are no cilia. Some removal mechanisms operate in the pulmonary region but because retention times range from one to two years these particles are most likely to have a negative health effect. Ambient $PM_{2.5}$ particles are usually formed from chemical reactions in the atmosphere and combustion processes. However, mechanical and natural mechanisms may also lead to its formation. Particulate control equipment is usually less efficient at removing small particles.

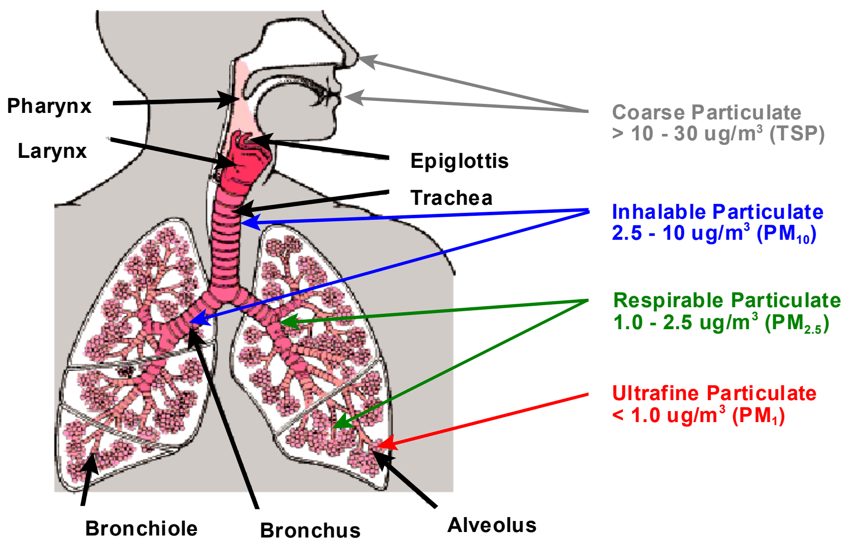


Figure 3: Particulate Matter and the Respiratory System

The above diagram illustrates how far different particle sizes could possibly penetrate into the respiratory system. Because human lungs have a large surface area and because people consume so much air, lungs are the greatest source of exposure to air pollution. Several recently published community health studies indicate that significant respiratory and cardiovascular-related problems are associated with exposure to particle levels well below the existing particulate matter standards. These negative effects include premature death, hospital admissions from respiratory causes, and increased respiratory symptoms.

Particulate Monitoring

The Ministry used *GRIMM Dust Monitors* ™ to conduct the traffic particulate surveys. They have been designed for continuous unattended operation and can determine levels of TSP, PM_{10}, $PM_{2.5}$ and PM_1 simultaneously. The instrument operates by measuring the scattering of light from a small diode laser in a sealed chamber. It determines particle concentrations in each of the predetermined size categories. Other sensors in the instrument can measure temperature; pressure and humidity, while an attached wind sensor can give wind speed and direction information.

Volatile Organic Compounds (VOC)

Volatile Organic Compounds (VOC) are carbon-based chemicals that have a high vapour pressure, which means that they exist as a gas at normal temperatures and pressures. [v]

The term VOC is generally applied to organic solvents, certain paint additives, spray can propellants, fuels (such as gasoline and kerosene), petroleum distillates, dry cleaning products and many other industrial and consumer products ranging from office supplies to building materials. VOC are also naturally emitted by a number of plants and trees.

Figure 4: GRIMM Particulate Monitor

VOC are an important health and environmental concern for several reasons:

- Some VOC can be hazardous to human health when inhaled. For example, benzene is a probable human carcinogen and toxic. Formaldehyde is both an irritant and a sensitizer [v].

- VOC emitting from out gassing of fabrics, building materials etc. are an important contributor to sick building syndrome.

[v] From http://ilpi.com/msds/ref/voc.html

- VOC such as hydrocarbon (gasoline, petroleum distillates) emissions from cars, chemical industries and trees are important contributors to photochemical smog.

VOC Monitoring

The Photovac™ is a portable gas chromatograph (GC). Gas chromatography is an analytical technique that can be used to separate certain gases including volatile organic compounds and allowing them to be individually identified.

The Photovac GC was used during this study and is capable of detecting over 50 volatile organic compounds. Benzene was of particular interest as it is readily detectable. It may be used to measure levels of VOC in the field in a variety of ways. It may sample directly from the atmosphere or analyse from a sample bag. A battery and weatherproof casing allow it to be used in the field under a wide variety of conditions. Data can be stored internally and viewed on a built in monitor or downloaded to a computer for later analysis.

Figure 5: Photovac Portable Gas Chromatograph

PART 3: PARTICULATE MONITORING RESULTS

Study Description

Particulate data were recorded for nine days and were obtained from portable particulate samplers. Measurements were taken for TSP, PM_{10}, $PM_{2.5}$, PM_1 and meteorological parameters (wind speed and direction). Sampling locations varied from day to day and are shown on a map included for each day.

Results are presented for each monitoring date in tables and graphs in order to better illustrate the changes of particulate concentrations among the various sampling locations.

Figure 6: Typical Sampler Setup

Since the portable particulate monitors were in different places on different sampling days they will be identified separately for each set of sampling results. A portable particulate monitor labelled as DW1 indicates a monitor located near the road on the downwind side. DW2 indicates a monitor placed further downwind and DW3 was the monitor farthest downwind of the road. UW was the designation for the local “upwind” station and was placed in the neighbourhood of the road to ensure that there were no significant sources between it and the road but far enough away from the direct influence of the traffic. All labels include a dash and another number e.g. DW2-50 or UW-50. The -50 indicates the distance the monitor was located in metres (e.g. -50 equals 50 metres) from Highway 402.

Co-ordinates were available for the monitoring sites, enabling daily maps to be created to better visualize the monitoring locations.

Appendix E includes all the graphs and tables which display the real-time data for various particulate sizes.

Appendix F includes an air dispersion summary and modelled results for a variety of traffic and meteorological conditions.

Appendix A provides a useful level of comparison, we established to assess particulate concentrations. For convenience in this document, we refer to these as Levels of Concern.

Particulate Size	**Level of Concern**
TSP	100 µg/m^3
PM_{10}	50 µg/m^3
$PM_{2.5}$	45 µg/m^3

Sarnia Overview Maps

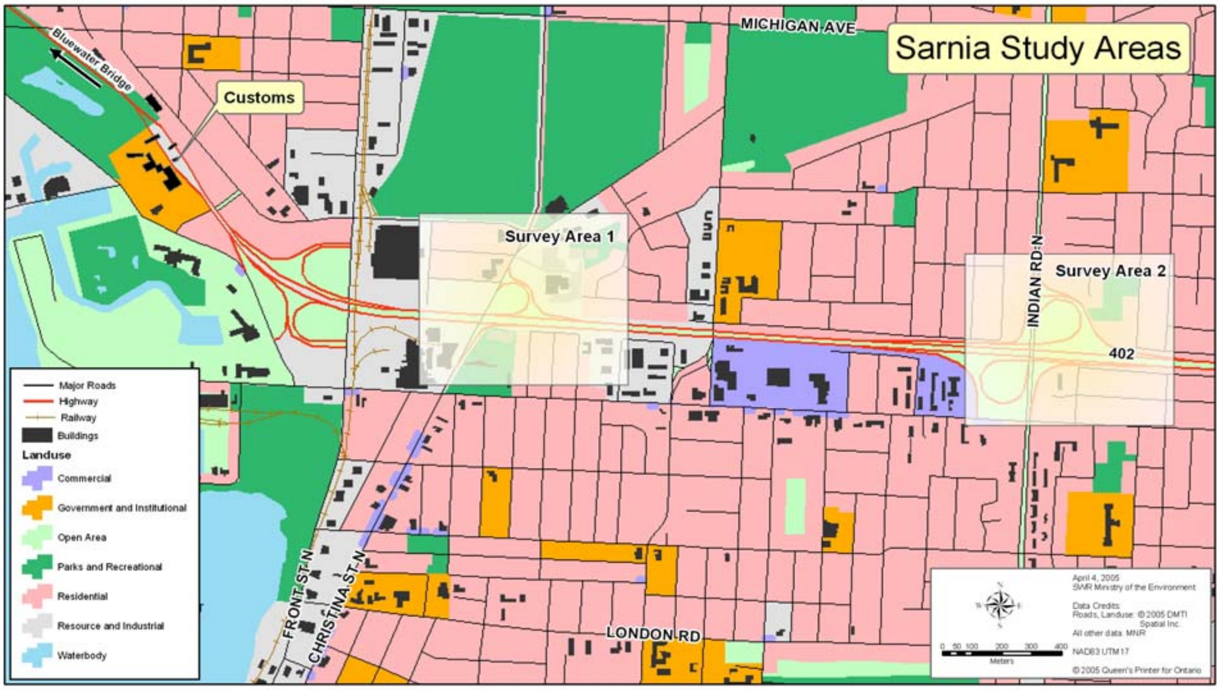


Figure 7: Sarnia Overview

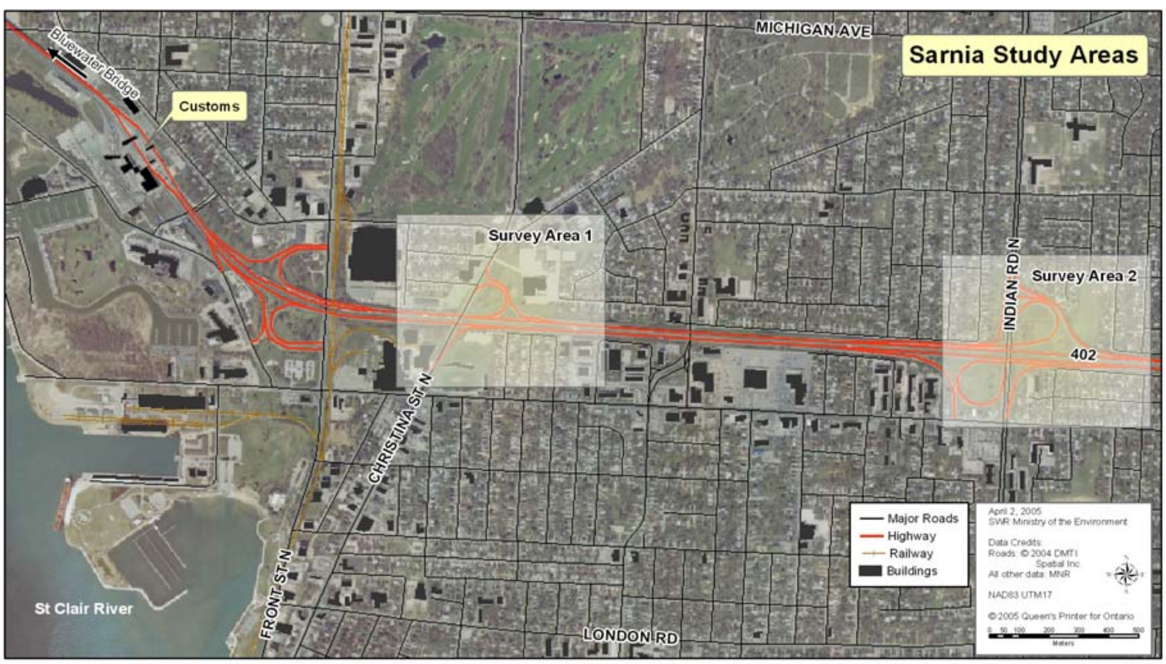


Figure 8: Arial Photograph Overview Map

Aerial Photographs of Survey Areas

Figure 9: Survey Area 1– Highway 402 and Christina Street North

Figure 10: Survey Area 2– Highway 402 and Indian Road North

August 5, 2004, Highway 402 Diesel Truck Air Survey Results

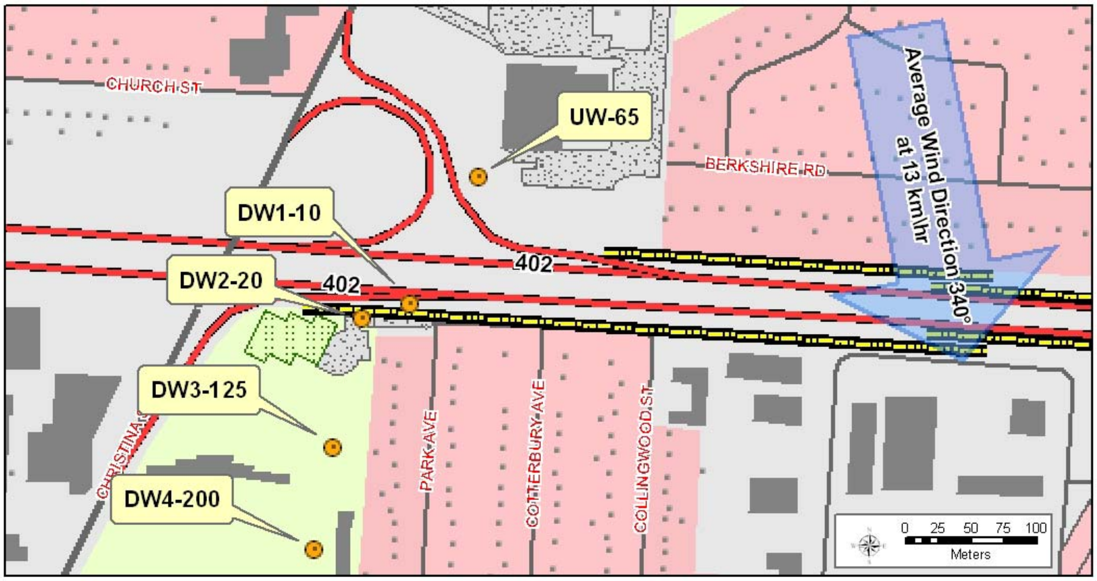


Figure 11: Map of August 5, 2004, Sampler Locations

During the sampling period, winds were gusty and from the north and were of moderate strength (averaging about 13 km/hr). Traffic volumes were normal but truck traffic was delayed with queues extending past the samplers during the entire sampling period. Background particulate levels for $PM_{2.5}$ were in the "Very Good" AQI category (see Appendix A).

Measurements are available from five monitoring stations. An upwind monitor, **UW-65** was placed in the lot of the Ontario Provincial Court Buildings 65 metres from the westbound lane of Highway 402. A downwind monitor **DW1-10** was placed inside the noise barrier 10 metres from the eastbound lane of Highway 402 and three others, **DW2-20, DW3-125** and **DW4-200** on the opposite side of the noise barrier at 20, 125 and 200 metres from the eastbound lane of Highway 402 located in the open soccer field of Norm Perry Park.

TSP and PM_{10} levels were high at the **DW1-10** the inside location of the noise barrier and **DW2-20** the outside location of the noise barrier and dropped rapidly thereafter. Background particulate levels were reached within 250 metres from the highway.

Figure 11 displays the monitoring results for each downwind location (bars) and trendlines[1] (dotted lines) for TSP and PM_{10}. The trendline for TSP would reach

[1] Say we have a set of data, (x_i, y_i). If we have reason to believe that there exists a **linear relationship** between the variables **x** and **y**, we can plot the data and draw a "best-fit" *straight line* (trendline) through the data. See Appendix D for a further detailed explanation.

background concentrations at approximately 220 metres and PM_{10} at approximately 280 metres. Although the monitoring results still show concentration increases of 1 to 1.5 μg/m³ at 200 metres, the fact that the data was nearly at zero μg/m³ at 125 metres would suggest that at 200 metres some other influence other than truck traffic is affecting the results. The most likely source of the increases to particulate matter was the particulate being re-entrained into the air mass from the soccer field grass.

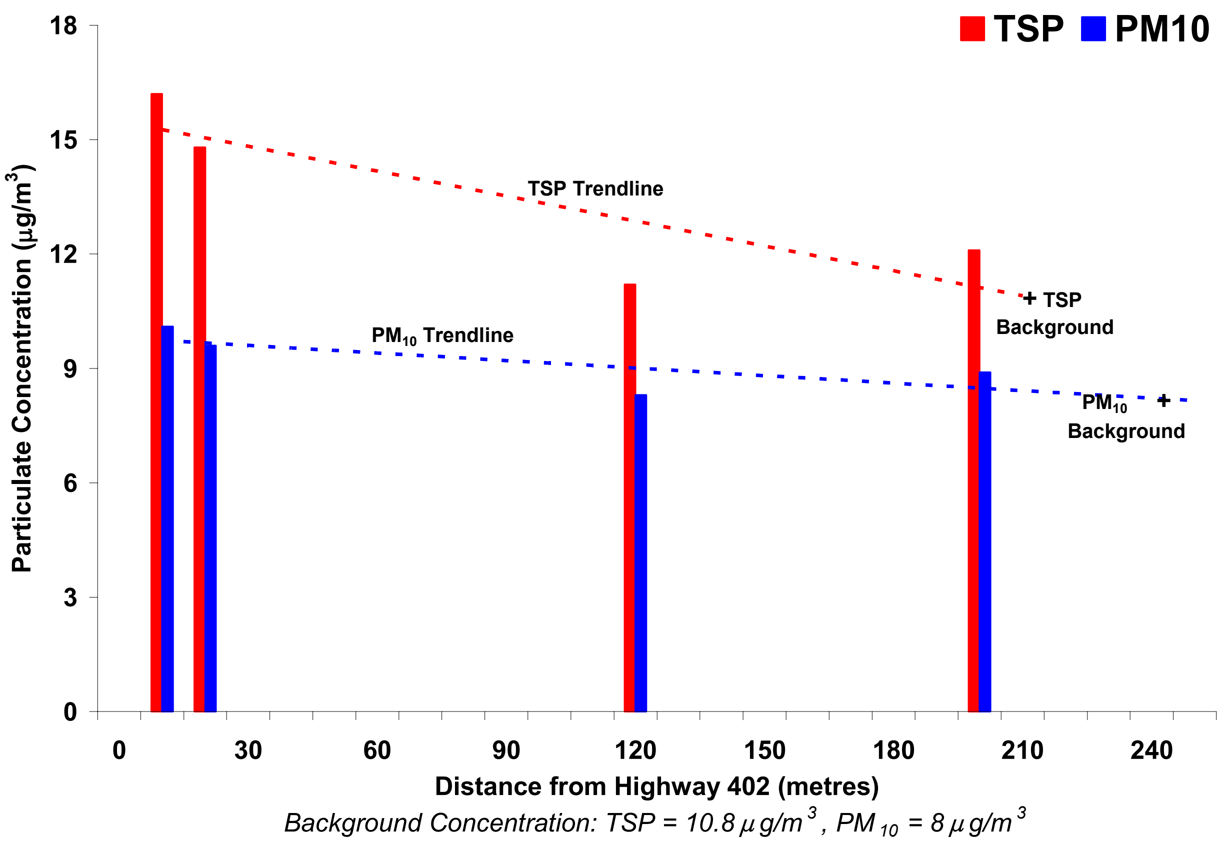


Figure 12: August 5, 2004, Survey Results for TSP and PM_{10}

$PM_{2.5}$ and PM_1 results measured virtually no increases over background particulate concentrations and therefore were not included in the above graph.

In conclusion, for August 5, 2004, the impact of delayed trucks traffic on TSP and PM_{10} particulate levels was light at the roadside decreasing to very light or nearly background by 125 metres. The impact of delayed trucks traffic on $PM_{2.5}$ and PM_1 particulate levels remained at background levels from the roadside to all sampled distances, which indicates no measurable traffic impacts.

August 9, 2004, Highway 402 Diesel Truck Air Survey Results

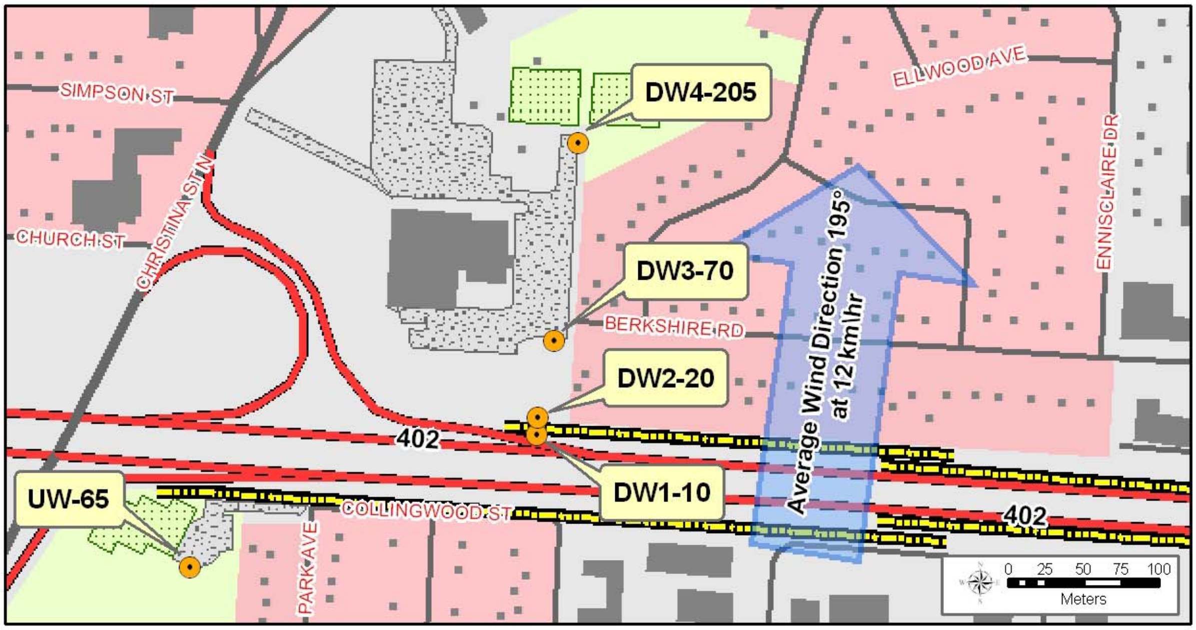


Figure 13: Map of August 9, 2004, Sampler Locations

During the sampling period, winds were consistently from the south and were of moderate strength (averaging about 12 km/hr). Traffic volumes were normal but truck traffic delays were intermittent at the beginning (09:30 am) of the survey and became heavy at 11:00 am with queues extending past the samplers during the rest of the sampling period. Background particulate levels for $PM_{2.5}$ were in the "Good" AQI category (see Appendix A).

Measurements are available from five monitoring stations. An upwind monitor, **UW-65** was placed in the open soccer field 65 metres from the eastbound lane of Highway 402. A downwind monitor **DW1-10** was placed inside the noise barrier 10 metres from the westbound lane of Highway 402 and three others, **DW2-20, DW3-70** and **DW4-205** on the opposite side of the noise barrier at 20, 70 and 205 metres from the westbound lane of Highway 402 located in the lot of the Ontario Provincial Court Buildings.

TSP and PM_{10} levels were high at the **DW1-10** the inside location of the noise barrier and **DW2-20** the outside location of the noise barrier and dropped rapidly thereafter. Background particulate levels were reached by the time the air reached 70 metres from the highway.

Figure 13 displays the monitoring results for each downwind location (bars) and trendlines (dotted lines) for TSP and PM_{10}. The trendline for TSP would reach background concentrations at approximately 150 metres and PM_{10} was at approximately 190 metres. In this case the monitoring results from **DW3-70** and **DW4-205** were below background concentrations indicating no measurable traffic impacts by 70 metres from Highway 402.

$PM_{2.5}$ and PM_1 levels showed virtually no measurable traffic impacts at any distance from Highway 402 and therefore were not included in the following graph.

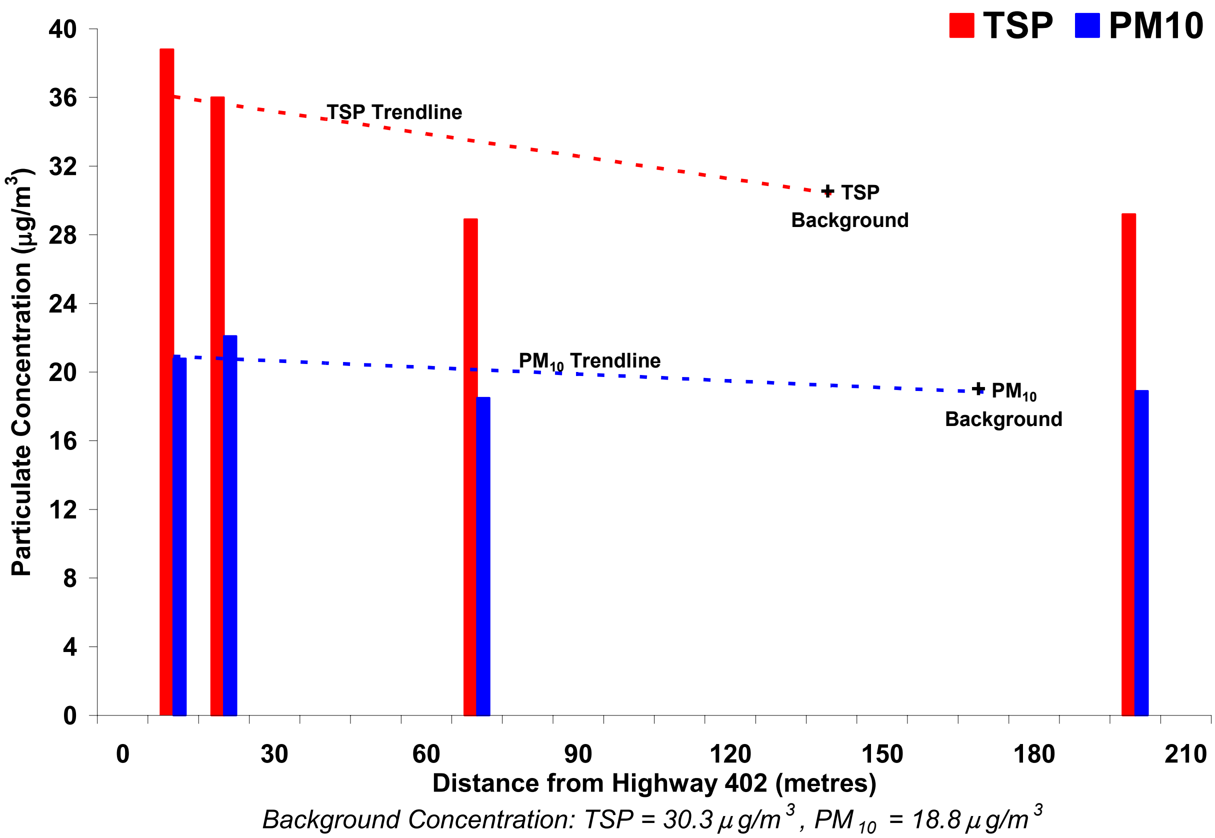


Figure 14: August 9, 2004, Survey Results for TSP and PM_{10}

In conclusion, for August 9, 2004, the impact of delayed trucks traffic on particulate levels was light at the roadside decreasing to very light or background by 70 metres.

August 26, 2004, Highway 402 Diesel Truck Air Survey Results

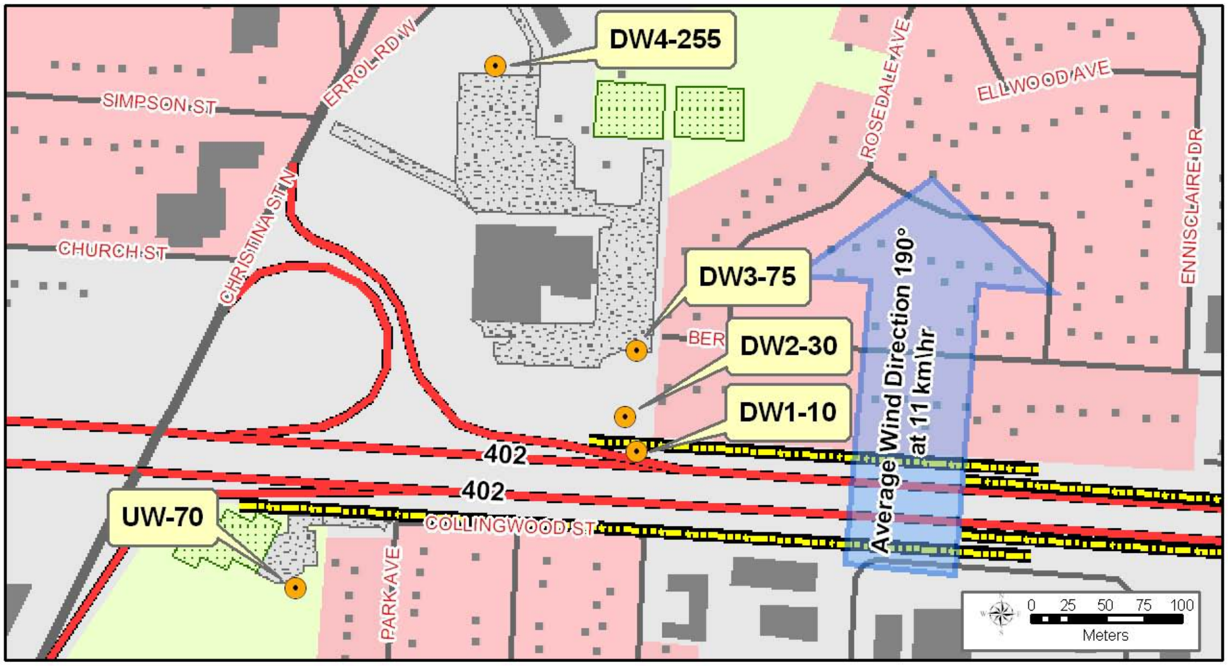


Figure 15: Map of August 26, 2004, Sampler Locations

During the sampling period, winds were consistently from the south and were of moderate strength (averaging about 11 km/hr). Traffic volumes were normal but truck traffic was delayed with queues extending past the samplers during the entire sampling period. Background particulate levels for $PM_{2.5}$ were in the "Moderate" AQI category (see Appendix A).

Measurements are available from five monitoring stations. An upwind monitor, **UW-70** was placed in the open soccer field 70 metres from the eastbound lane of Highway 402. A downwind monitor **DW1-10** was placed inside the noise barrier 10 metres from the westbound lane of Highway 402. Three other monitors, **DW2-30, DW3-75** and **DW4-255** where placed on the opposite side of the noise barrier at 30, 75 and 255 metres from the westbound lane of Highway 402 located in the lot of the Ontario Provincial Court Buildings.

TSP and PM_{10} levels were highest at **DW1-10** the inside location of the noise barrier and dropped by half by the time it reach the outside area of the noise barrier. Particulate levels dropped steadily from the **DW2-30** the outside location of the noise barrier and reached background levels within 255 metres **(DW4-255)** from Highway 402.

$PM_{2.5}$ and PM_1 levels were highest at **DW1-10** the inside location of the noise barrier and dropped by more than half by the time it reach the **DW2-30** the outside location of the noise barrier. Small increases re-occurred in the particulate levels at **DW3-75** and dropped steadily thereafter. The most likely source of particulate matter increases at

DW3-75 is that smaller particle sizes tend to carry further before finally settling out and impacting the environment.

Figure 15 and 16 displays the monitoring results for each downwind location (bars) and trendlines (dotted lines) for TSP, PM_{10} $PM_{2.5}$ and PM_1, which would intercept within approximately 300 metres. The results indicate that by approximately 255 metres there is no longer any measurable influence from the Highway 402.

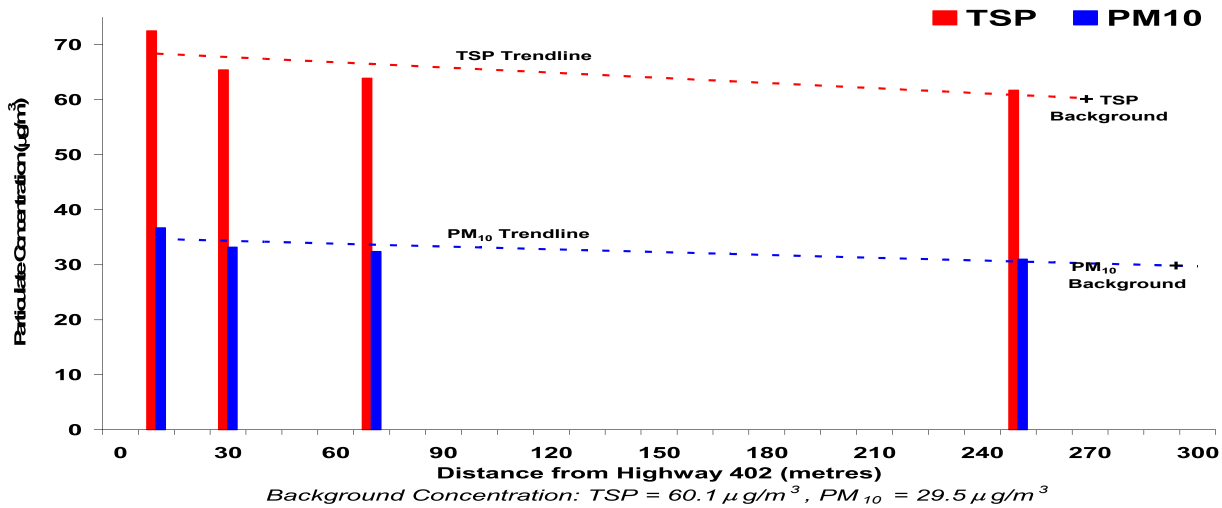


Figure 16: August 26, 2004, Survey Results for TSP and PM_{10}

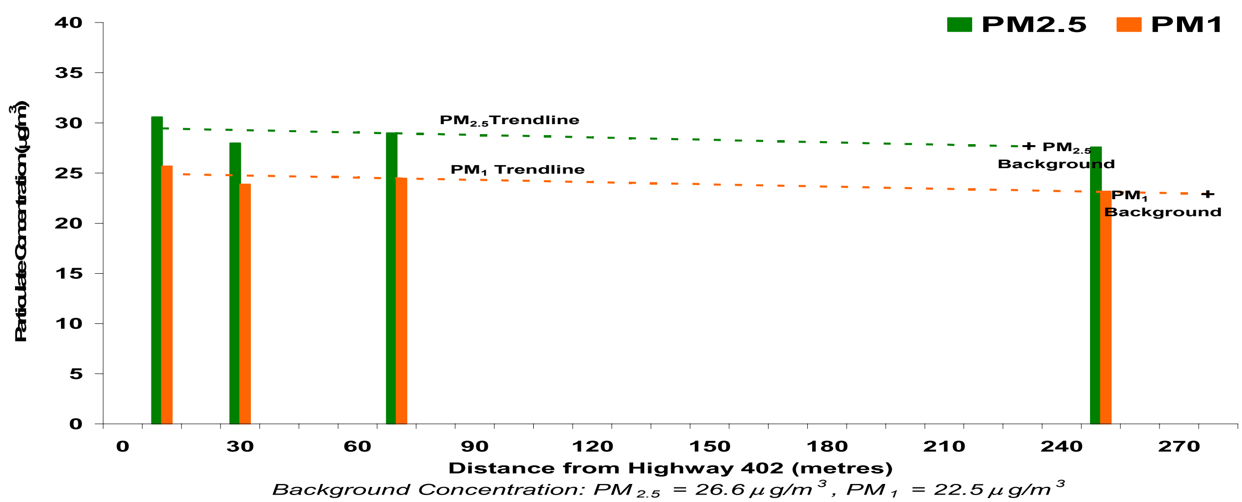


Figure 17: August 26, 2004, Survey Results for $PM_{2.5}$ and PM_1

In conclusion, for August 26, 2004, the impact of delayed trucks traffic on particulate levels was moderate at the roadside decreasing to very light or nearly background by 255 metres.

September 1, 2004, Highway 402 Diesel Truck Air Survey Results

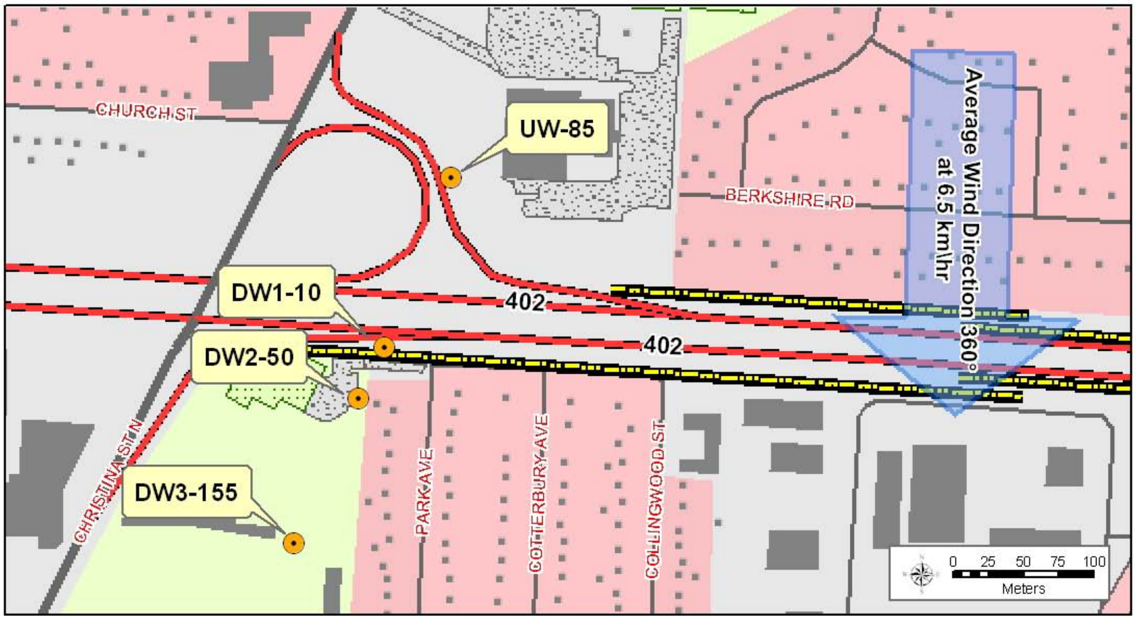


Figure 18: Map of September 1, 2004, Sampler Locations

During the sampling period, winds were consistently from the north and were light (averaging about 6.5 km/hr). Traffic volumes were normal but truck traffic was delayed with queues extending past the samplers during the entire sampling period. Background particulate levels for $PM_{2.5}$ were in the "Very Good" AQI category (see Appendix A).

Measurements are available from four monitoring stations. An upwind monitor, **UW-85** was placed in the lot of the Ontario Provincial Court Buildings 85 metres from the westbound lane of Highway 402. A downwind monitor **DW1-10** was placed inside the noise barrier 10 metres from the eastbound lane of Highway 402 and two others, **DW2-50** and **DW3-155** on the opposite side of the noise barrier at 50 and 155 metres from the eastbound lane of Highway 402 located in the soccer field.

TSP and PM_{10} levels were highest at **DW1-10** the inside location of the noise barrier and dropped by half by the time it reach **DW2-50** the outside location of the noise barrier. Particulate levels dropped steadily from the outside area of the noise barrier and reached background levels by the time the air reached **DW3-155** or 155 metres from the highway.

$PM_{2.5}$ and PM_1 levels were highest at inside location of the noise barrier and dropped to background levels by the time it reach the **DW2-50** or 50 metres from the outside area of the noise barrier.

During this sampling survey VOC samples were taken both upwind and downwind of Highway 402. No measurable traces of VOC's were detected.

Figure 18 and 19 displays the monitoring results for each downwind location (bars) and trendlines (dotted lines) for TSP, PM_{10} $PM_{2.5}$ and PM_1 which would intercept at approximately 100 to 150 metres. The monitoring results indicated that by approximately 155 metres there is no longer any measurable influence from the delayed trucks.

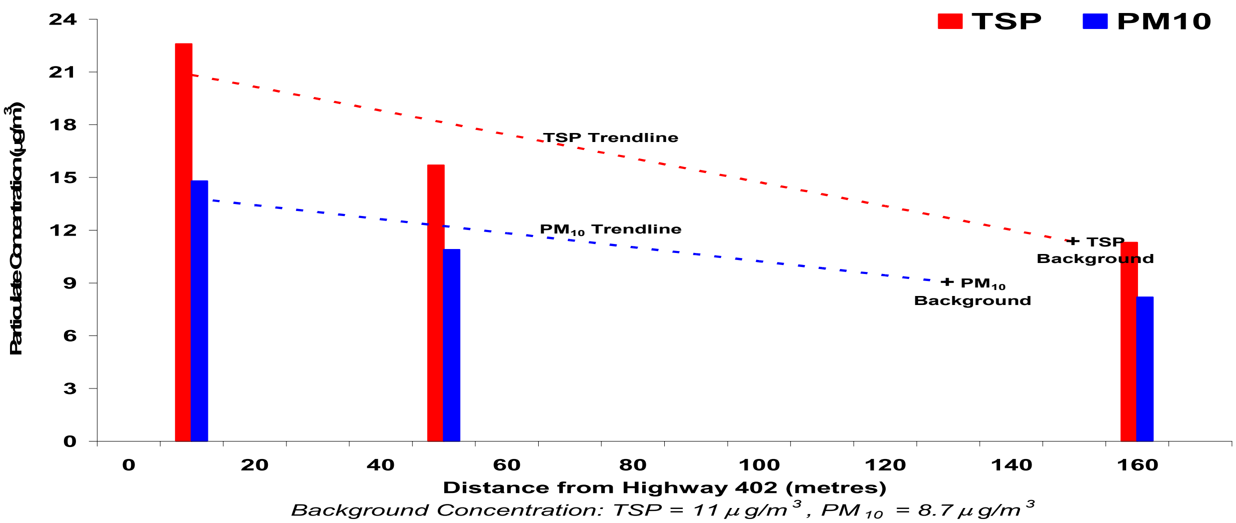


Figure 19: September 1, 2004, Survey Results for TSP and PM_{10}

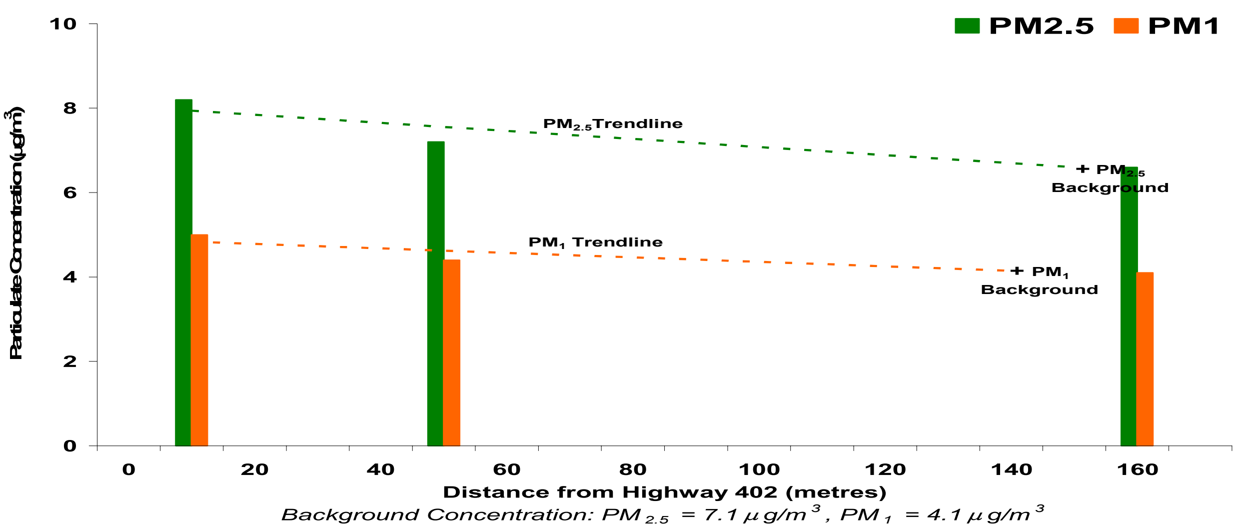


Figure 20: September 1, 2004, Survey Results for $PM_{2.5}$ and PM_1

In conclusion, for September 1, 2004, the impact of delayed trucks traffic on particulate levels was moderate at the roadside decreasing to very light or nearly background by 155 metres.

September 3, 2004, Highway 402 Diesel Truck Air Survey Results

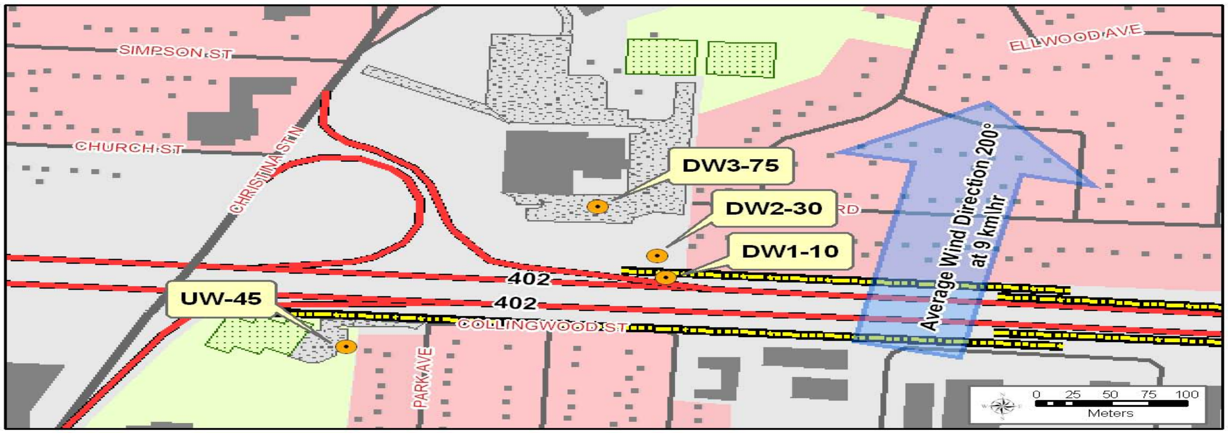


Figure 21: Map of September 3, 2004, Sampler Locations

During the sampling period, winds were consistently from the south and were moderate (averaging about 9 km/hr). Traffic volumes were normal, there were no border delays during the sampling period. The results represent free flowing (undelayed) traffic conditions. Background particulate levels for $PM_{2.5}$ were in the "Moderate" AQI category (see Appendix A).

Measurements are available from four monitoring stations. An upwind monitor, **UW-45** was placed in the open soccer field 45 metres from the eastbound lane of Highway 402. A downwind monitor **DW1-10** was placed inside the noise barrier 10 metres from the westbound lane of Highway 402. Two other monitors, **DW2-30** and **DW3-75** were placed on the opposite side of the noise barrier at 30 and 75 metres from the westbound lane of Highway 402 located in the lot of the Ontario Provincial Court Buildings.

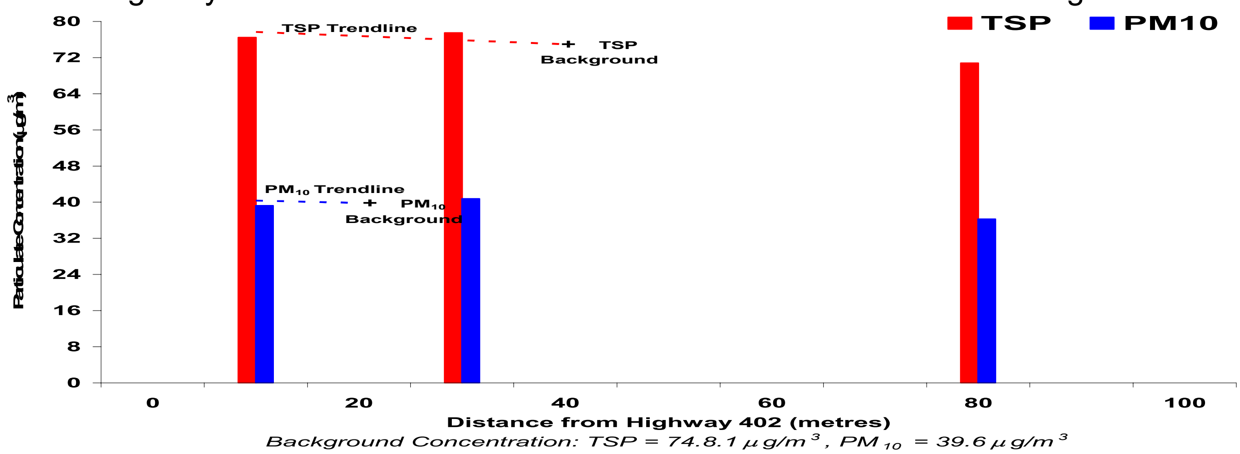


Figure 22: September 3, 2004, Survey Results for TSP and PM_{10}

In conclusion, there was very little difference between upwind and downwind particulate levels, indicating that undelayed traffic does not significantly increase particulate concentrations.

September 8, 2004, Highway 402 Diesel Truck Air Survey Results

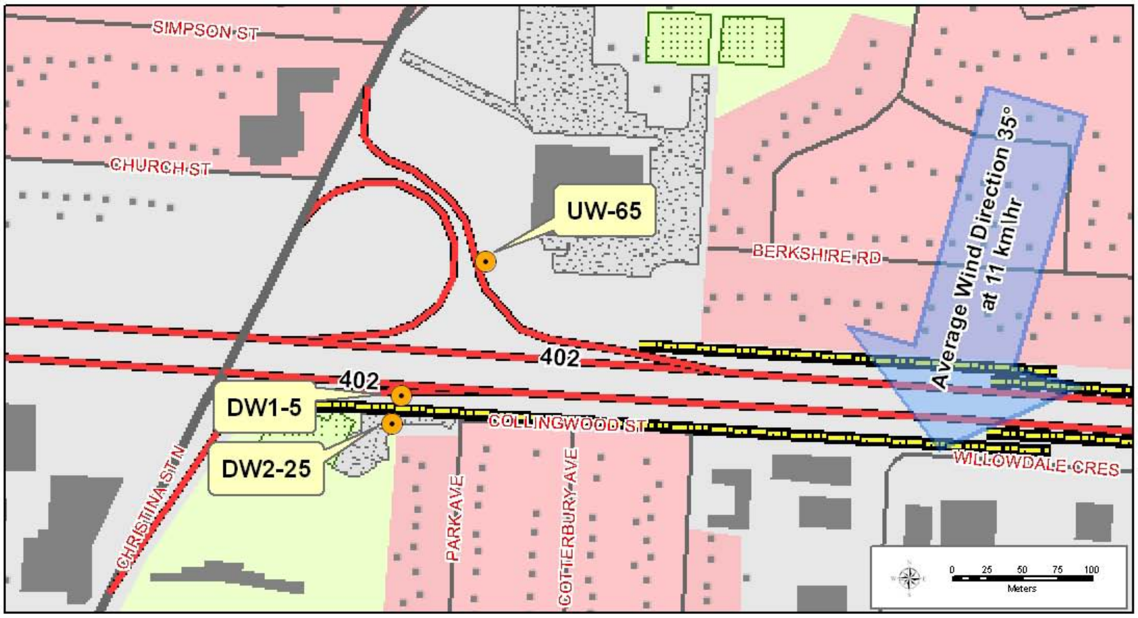


Figure 23: Map of September 8, 2004, Sampler Locations

During the sampling period, winds were consistently from the north and were moderate (averaging about 11 km/hr). Traffic volumes were normal but truck traffic was delayed with queues extending past the samplers during the entire sampling period. Background particulate levels for $PM_{2.5}$ were in the "Very Good" AQI category (see Appendix A).

Measurements are available from three monitoring stations. An upwind monitor, **UW-65** was placed in the lot of the Ontario Provincial Court Buildings 65 metres from the westbound lane of Highway 402. A downwind monitor **DW1-5** was placed inside the noise barrier 5 metres from the eastbound lane of Highway 402 and one other, **DW2-25** on the opposite side of the noise barrier at 25 metres from the eastbound lane of Highway 402 located in the parking lot for the soccer field.

Particulate levels dropped steadily from the outside location of the noise barrier and the monitoring results did not indicate in this case when background levels were reached.

Figure 23 and 24 displays the monitoring results for each downwind location (bars) and trendlines (dotted lines) for TSP, PM_{10} $PM_{2.5}$ and PM_1 monitoring results. The results indicate that by approximately 25 metres the particulate levels had reduced by half.

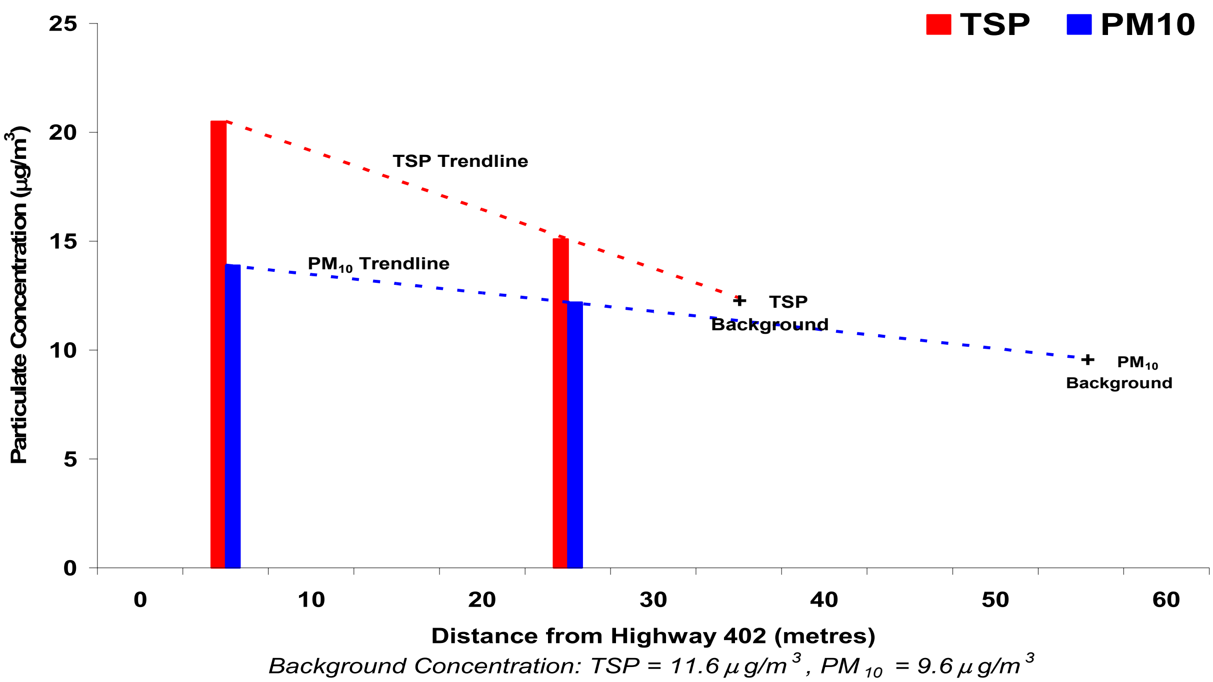


Figure 24: September 8, 2004, Survey Results for TSP and PM_{10}

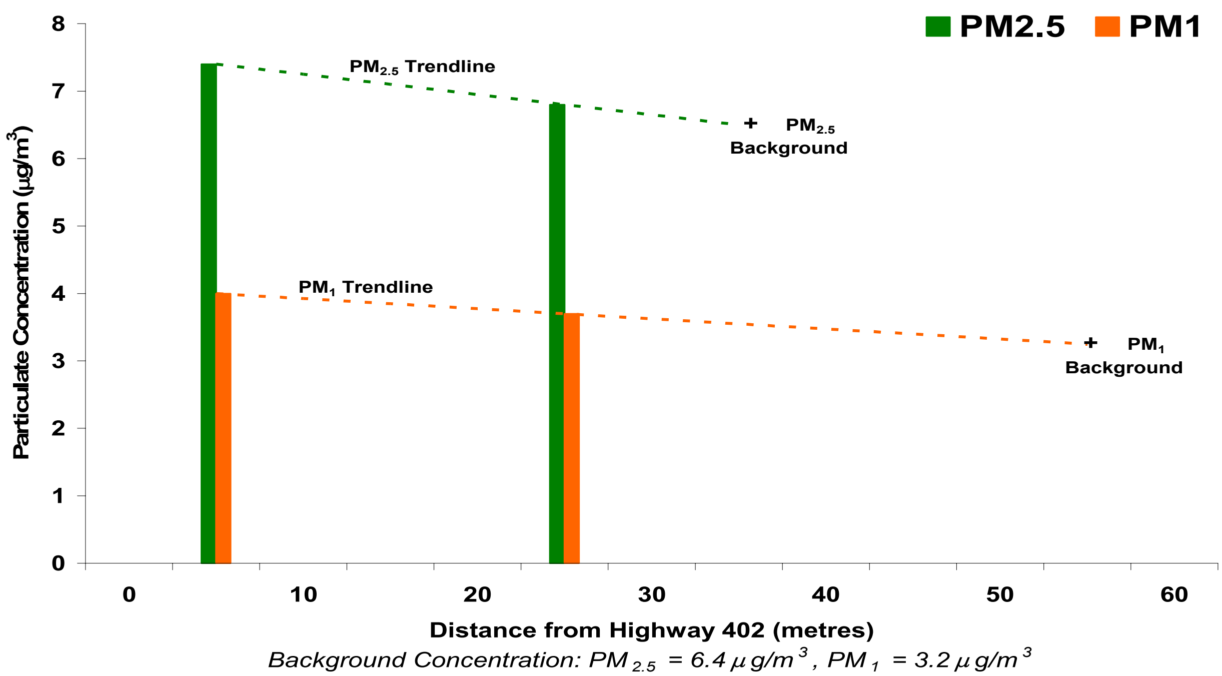


Figure 25: September 8, 2004, Survey Results for $PM_{2.5}$ and PM_1

In conclusion, for September 8, 2004, the impact of delayed trucks traffic on particulate levels was light to moderate at the roadside decreasing to very light by a distance of 25 metres.

September 13, 2004, Highway 402 Diesel Truck Air Survey Results

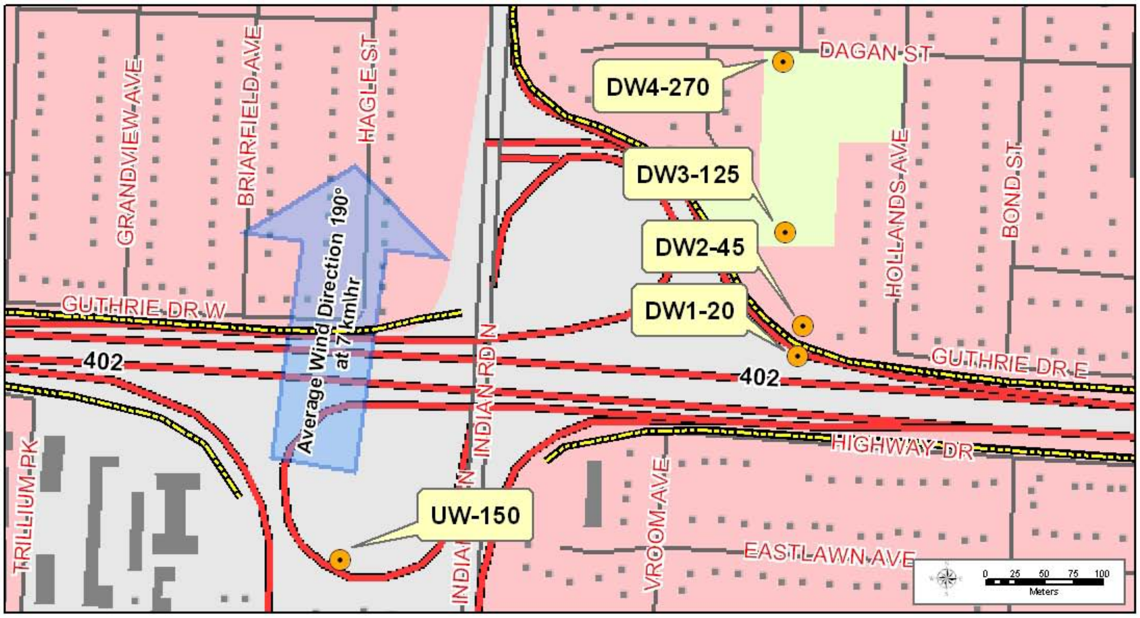


Figure 26: Map of September 13, 2004, Sampler Locations

During the sampling period, winds were consistently from the south and were light (averaging about 7 km/hr). Traffic volumes were normal but truck traffic delays were intermittent at the beginning (08:45 am) of the survey and disappeared by 02:00 pm. Background particulate levels for $PM_{2.5}$ were in the "Moderate" AQI category (see Appendix A).

Measurements are available from five monitoring stations. An upwind monitor, **UW-150** was placed in the open area of the highway interchange at Indian Road, 150 metres from the eastbound lane of Highway 402. A downwind monitor **DW1-20** was placed inside the noise barrier 20 metres from the westbound lane of Highway 402 and three others, **DW2-45, DW3-125** and **DW4-270** on the opposite side of the noise barrier at 45, 125 and 270 metres from the westbound lane of Highway 402 located in open parkland.

TSP, PM_{10} $PM_{2.5}$ and PM_1 levels were highest in the area located inside the noise barrier adjacent to Highway 402. Particulate levels dropped steadily from the outside of the noise barrier and approached background levels within **DW3-270** or 270 metres from the Highway 402.

Figure 26 and 27 displays the monitoring results for each downwind location (bars) and trendlines (dotted lines) for TSP and PM_{10} and in this case the lines do not intercept by the time the air mass has reached 270 metres. The results indicate that at a distance of 270 metres there is still a measurable influence from the delayed trucks.

$PM_{2.5}$ and PM_1 monitoring results and trendline would intercept at approximately 270 metres. The results indicate that by approximately 270 metres there is no longer any measurable influence from the delayed trucks.

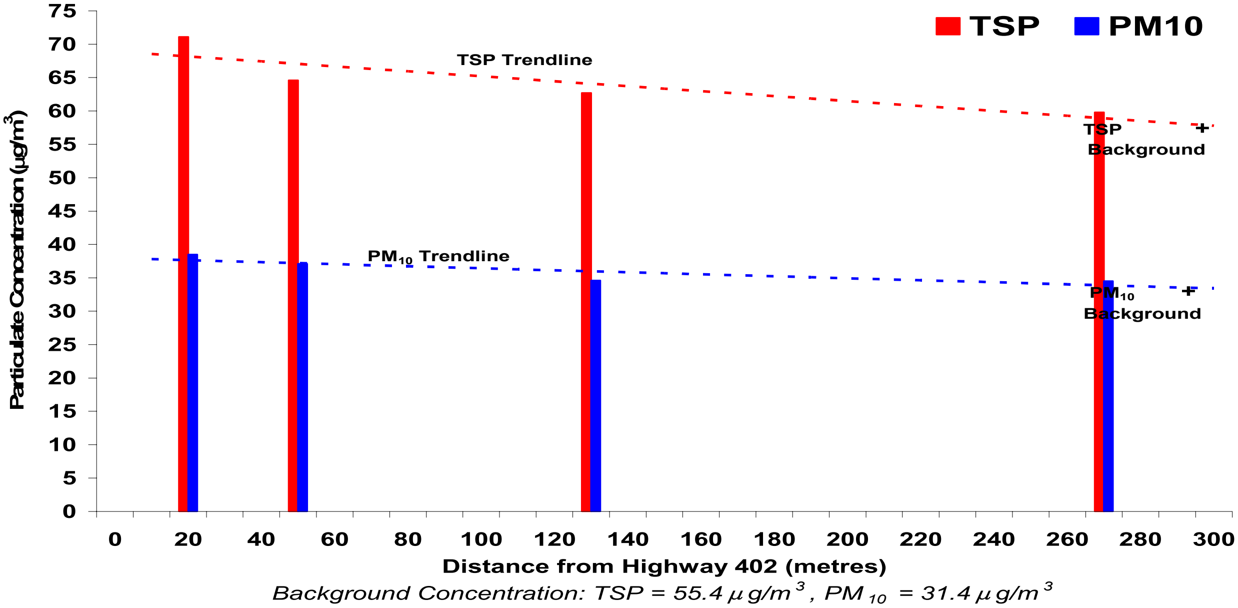


Figure 27: September 13, 2004, Survey Results for TSP and PM_{10}

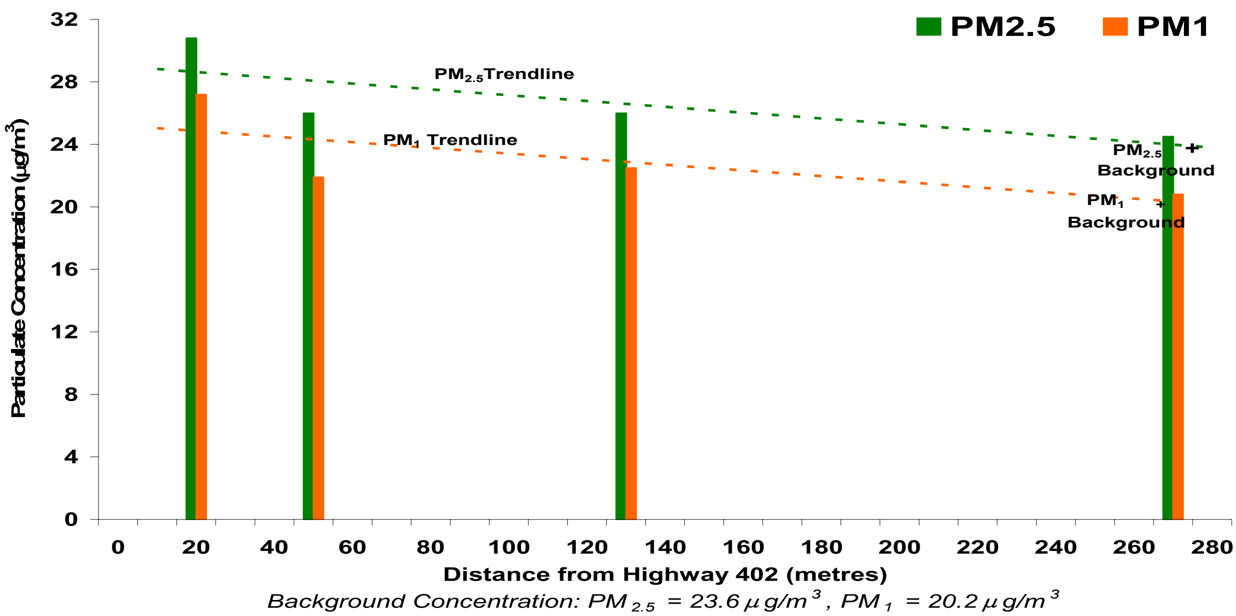


Figure 28: September 13, 2004, Survey Results for $PM_{2.5}$ and PM_1

In conclusion, for September 13, 2004, the impact of delayed trucks traffic on particulate levels was moderate to heavy at the roadside decreasing to very light by a distance of 300 metres.

September 21, 2004, Highway 402 Diesel Truck Air Survey Results

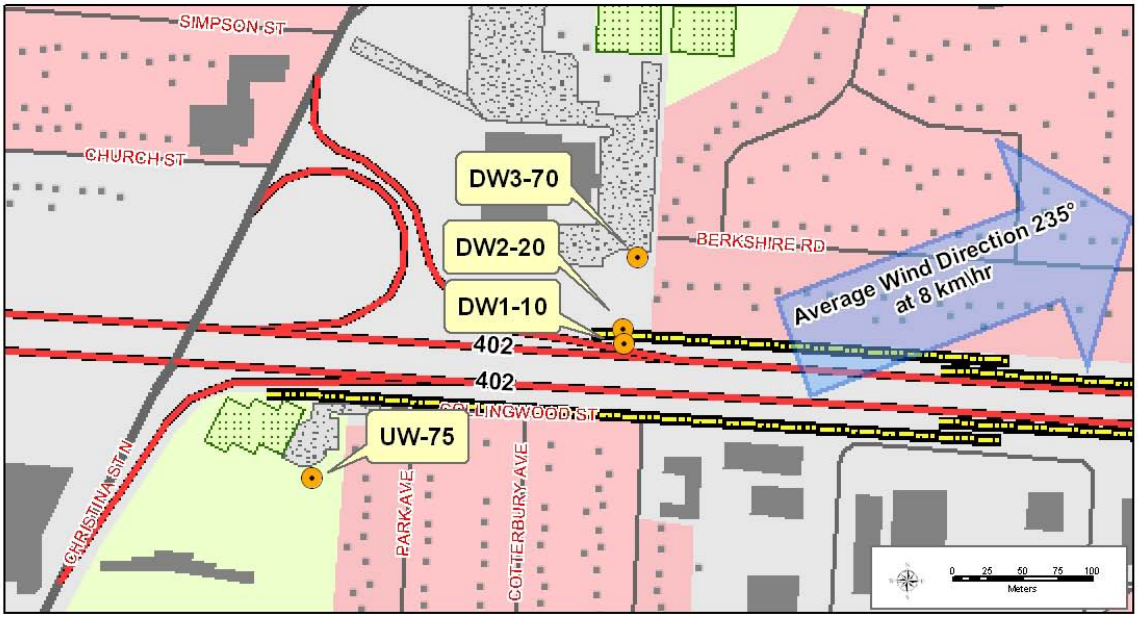


Figure 29: Map of September 21, 2004, Sampler Locations

During the sampling period, winds were consistently from the southwest and were of moderate strength (averaging about 8 km/hr). Traffic volumes were normal but truck traffic was delayed with queues extending past the samplers during the entire sampling period. Background particulate levels for $PM_{2.5}$ were in the "Very Good" AQI category (see Appendix A).

Measurements are available from four monitoring stations. An upwind monitor, **UW-75** was placed in the soccer field of Norm Perry Park 85 metres from the eastbound lane of Highway 402. A downwind monitor **DW1-10** was placed inside the noise barrier 10 metres from the westbound lane of Highway 402 and two others, **DW2-20** and **DW3-75** on the opposite side of the noise barrier at 20 and 70 metres from the westbound lane of Highway 402 located in the lot of the Ontario Provincial Court Buildings.

TSP, PM_{10} $PM_{2.5}$ and PM_1 levels were highest in the area located near the noise barrier adjacent Highway 402. Particulate levels dropped steadily from the outside location of the noise barrier but did not reduce to background levels.

Figure 29 and 30 displays the monitoring results for each downwind location (bars) and trendlines (dotted lines) for TSP, PM_{10}, $PM_{2.5}$ and PM_1, which do not intercept background levels by 70 metres indicating there is still a measurable influence from the delayed trucks. The trendlines indicate that at a distance of 170 to 275 metres there would be no measurable influence from the delayed trucks.

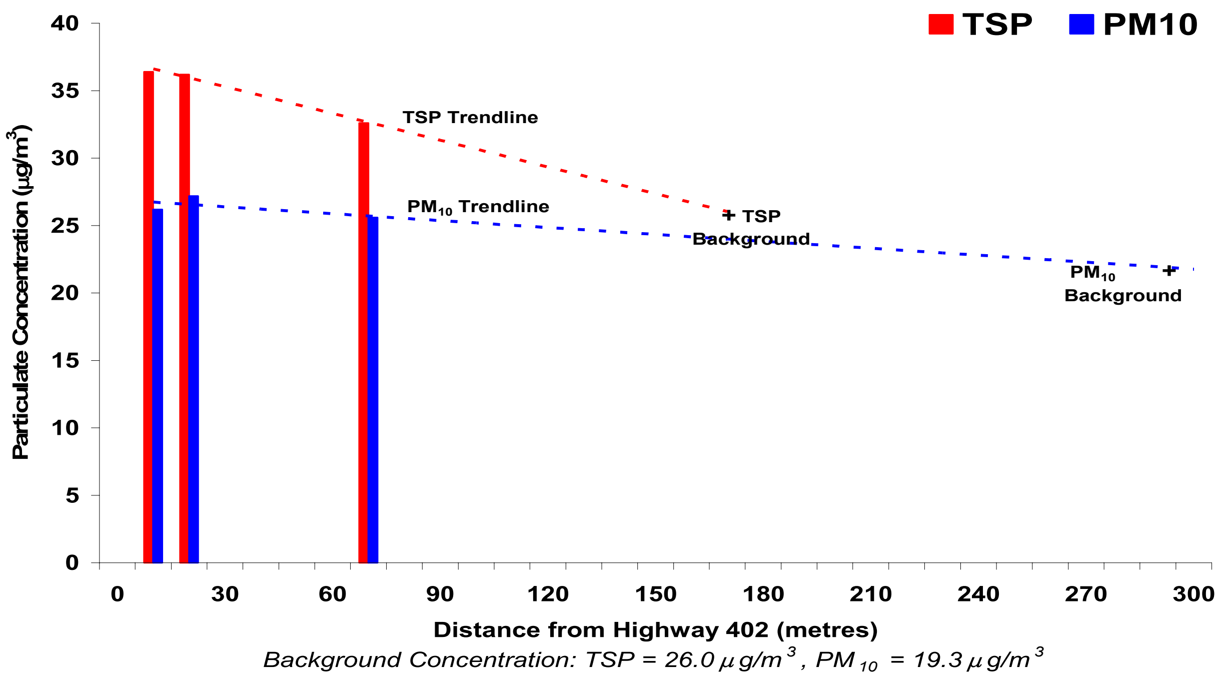


Figure 30: September 21, 2004, Survey Results for TSP and PM_{10}

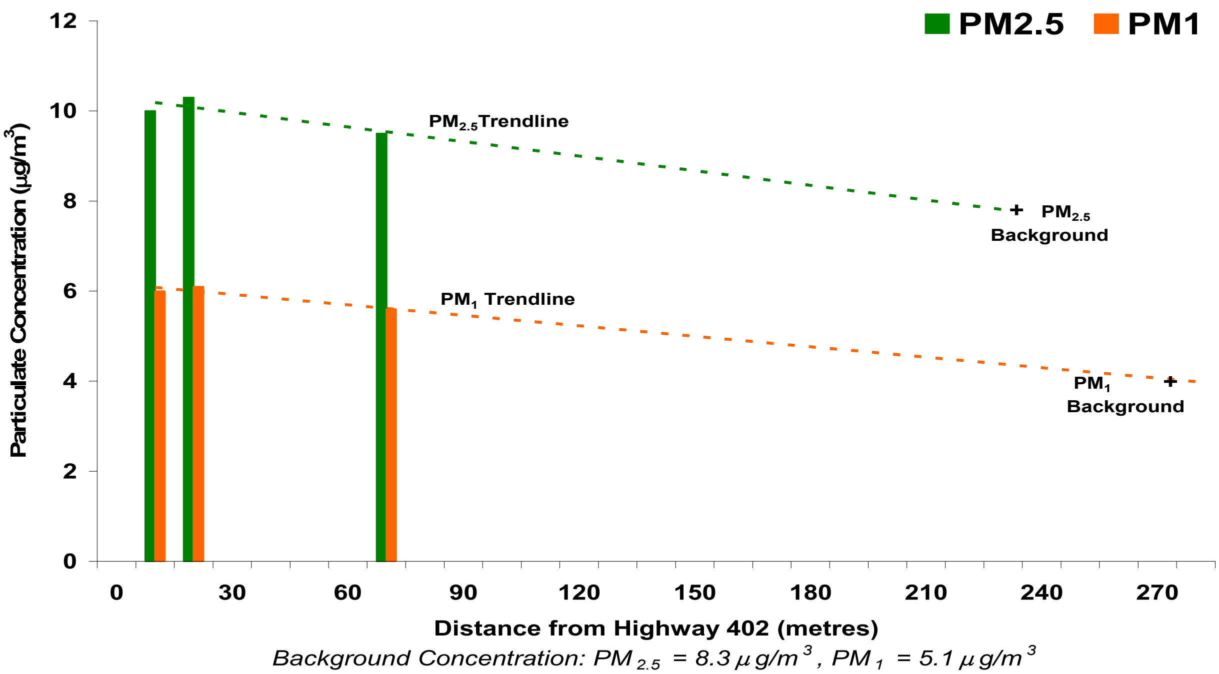


Figure 31: September 21, 2004, Survey Results for $PM_{2.5}$ and PM_1

In conclusion, for September 13, 2004, the impact of delayed trucks traffic on particulate levels was moderate at the roadside with a small decrease in levels by a distance of 70 metres.

September 23, 2004, Highway 402 Diesel Truck Air Survey Results

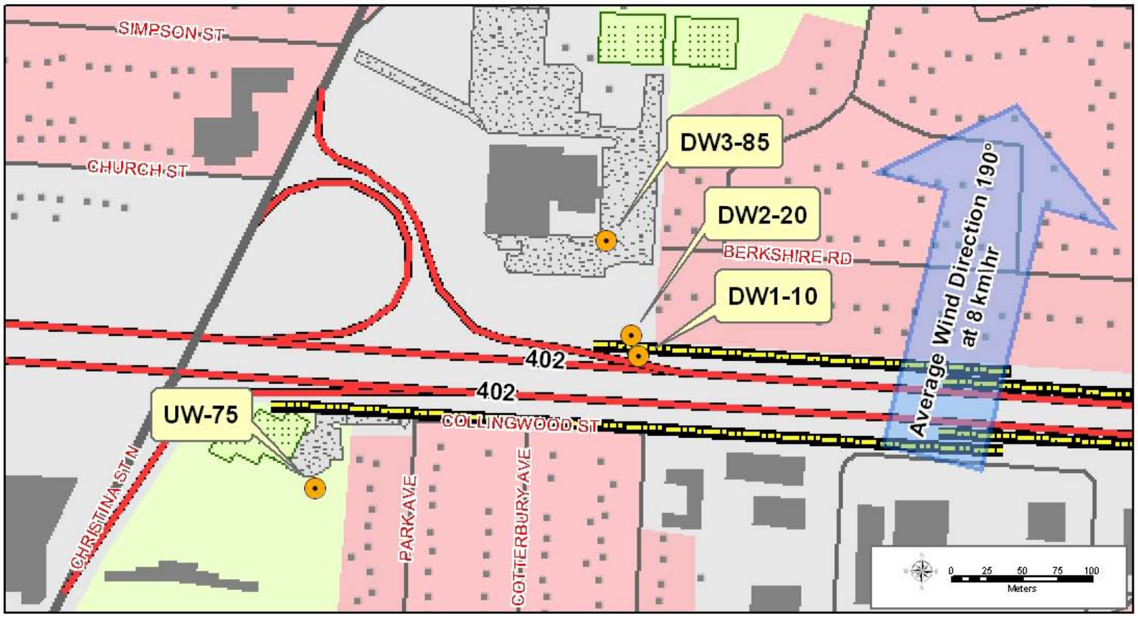


Figure 32: Map of September 23, 2004, Sampler Locations

During the sampling period, winds were consistently from the south and were light (averaging about 7 km/hr). Traffic volumes were normal but truck traffic was delayed with queues extending past the samplers during most of the sampling period. Background particulate levels for $PM_{2.5}$ were in the "Good" AQI category (see Appendix A).

Measurements are available from four monitoring stations. An upwind monitor, **UW-75** was placed in the open soccer field 75 metres from the eastbound lane of Highway 402. A downwind monitor **DW1-10** was placed inside the noise barrier 10 metres from the westbound lane of Highway 402. Two other monitors, **DW2-30** and **DW3-85** where placed on the opposite side of the noise barrier at 30 and 85 metres from the westbound lane of Highway 402 located in the lot of the Ontario Provincial Court Buildings.

TSP and PM_{10} levels were highest at both the inside and outside locations of the noise barrier and dropped steadily thereafter.

Figure 32 displays the monitoring results for each downwind location (bars) and trendlines (dotted lines) for TSP and PM_{10} which do not intercept background levels by 85 metres. The trendlines indicate that at a distance of 130 to 190 metres there would be no measurable influence from the delayed trucks.

$PM_{2.5}$ and PM_1 levels showed virtually no measurable traffic impacts at any distance from Highway 402 and therefore were not included in the following graph.

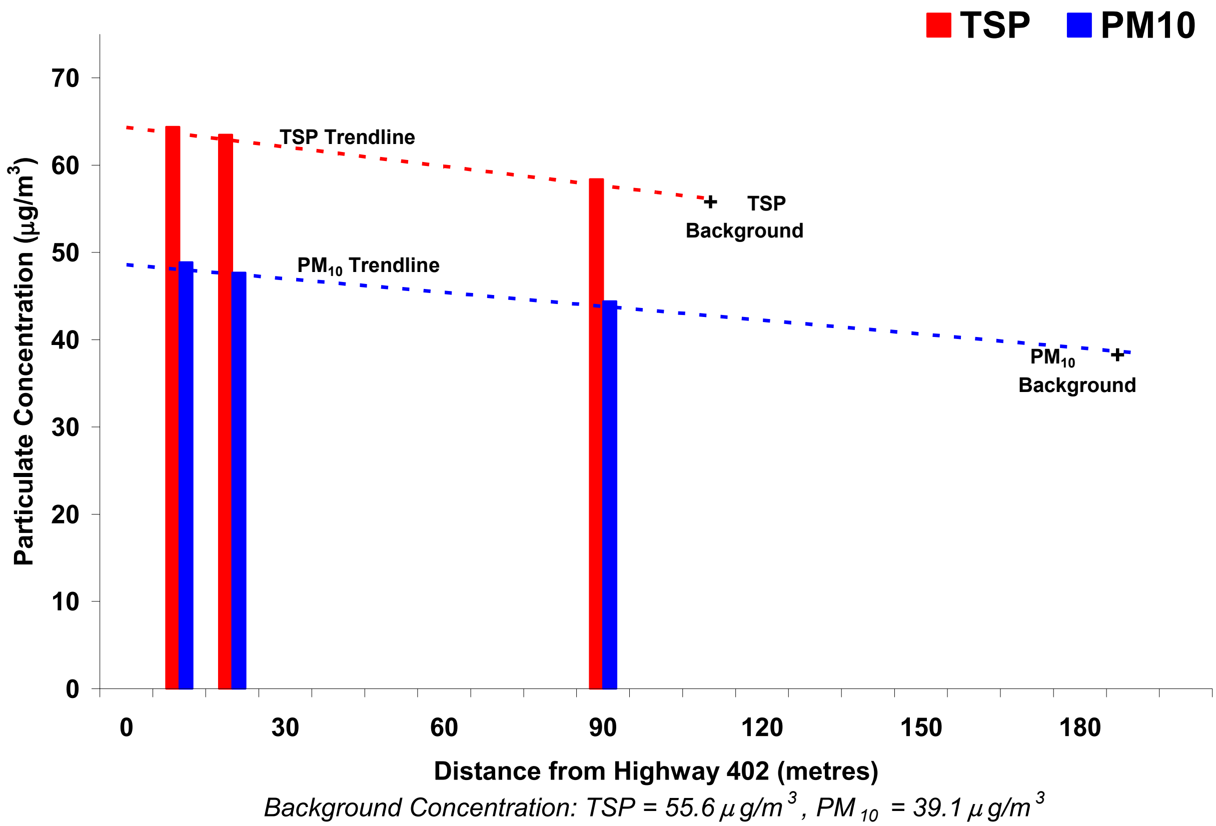


Figure 33: September 21, 2004, Survey Results for TSP and PM_{10}

In conclusion, for September 23, 2004, the impacts of delayed trucks traffic on particulate levels were moderate at the roadside with a small decrease in levels by a distance of 85 metres.

PART 4: MOBILE PARTICULATE SURVEYS

During the summer monitoring period, ministry staff conducted three additional mobile surveys. A monitor was placed in a fixed location some distance upwind of Highway 402 and a mobile monitor was then stationed for a short period of time (10 to 30 minutes) at different intervals (roadside to 250 metres) downwind from Highway 402.

Initially the mobile monitor was placed in close proximity to highway 402, usually upwind adjacent to the roadside. After the monitor had sampled for 10 to 30 minutes, it was moved to the median of Highway 402 and the process was repeated for another 10 to 30 minute period. This process was repeated until the monitor was finally located at least 100 metres from Highway 402.

Since the measurements at the different locations were not made simultaneously, changes in the background concentration could have changed, resulting in adding a bias to some of the measurements. This could give a false sense of the traffic contribution to the particulate at different distances from Highway 402. To compensate for this, all mobile measurements reported here were corrected by subtracting the upwind concentrations for the same sampling period. They are referred to below in the tables as “Difference (Mobile minus Upwind in μg/m3)”.

Figure 34: Monitoring truck impacts in the median and at the roadside

September 8, 2004, Highway 402 Diesel Truck Mobile Air Survey Results

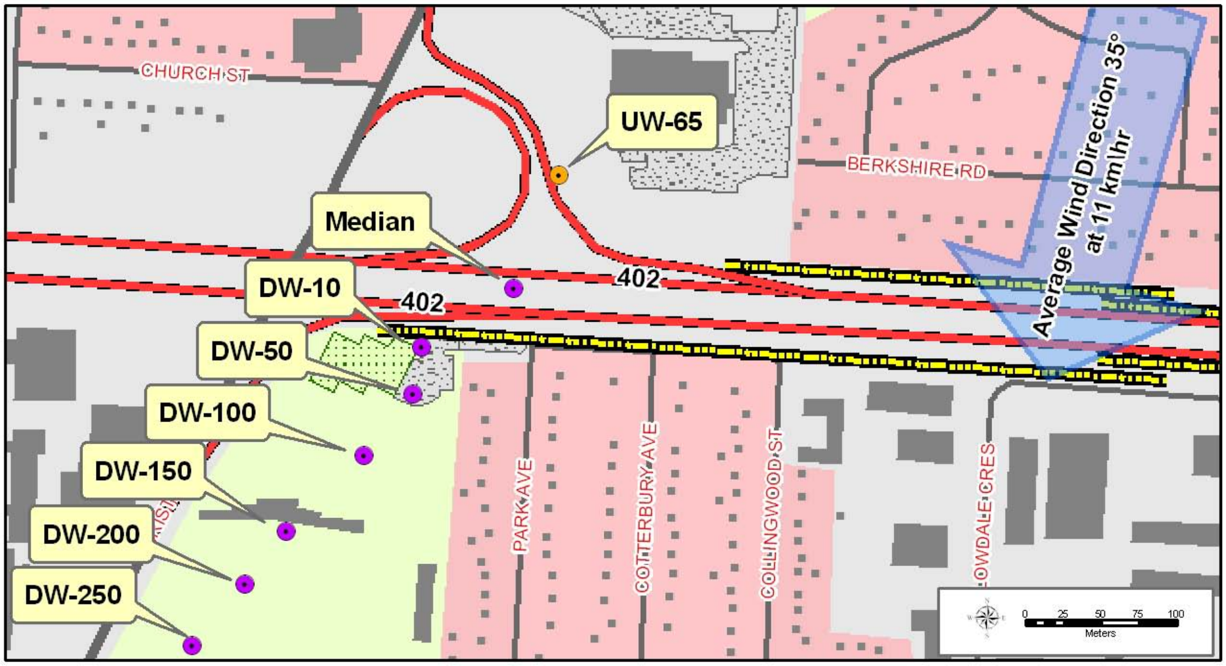


Figure 35: Map of September 8, 2004, Mobile Sampler Locations

The survey was performed in the morning between 09:30 and 12:45. During the sampling period, winds were consistently from the north and were moderate (averaging about 11 km/hr). Traffic volumes were normal but truck traffic was delayed with queues extending past the samplers during the entire sampling period.

The measurements started in the Highway 402 median for duration of 20 minutes. The sampler was then moved to beside the westbound lane adjacent to the noise barrier and measurements were taken for another 20 minute. This pattern was repeated in 50 metre intervals until the sampler was 250 metre downwind of Highway 402. The purple circles on the above map indicate the locations of the sampler during this survey.

Small increases were seen in close proximity to the noise barrier. By the time the sampler had reached 100 metres there was no longer any measurable influence from the delayed trucks.

Figure 35 displays the monitoring results for each downwind location (bars) and trendlines (dotted lines) for TSP, PM_{10} and $PM_{2.5}$. Results indicate only small particulate increases and trendlines indicate no influence from the delayed trucks from 200 to 430 metres. In this case the monitoring results from **DW-100** were approximately at background concentrations indicating no measurable traffic impacts by 100 metres from Highway 402.

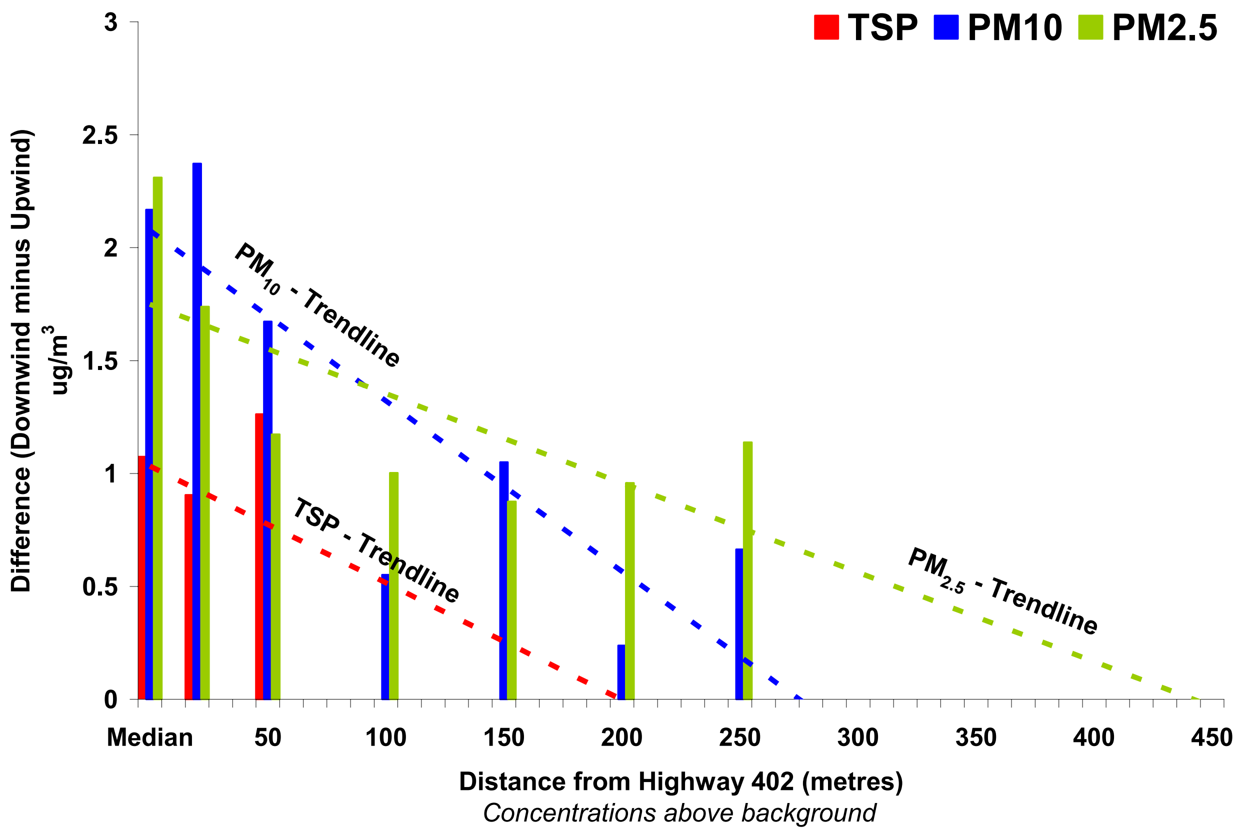


Figure 36: September 8, 2004, Mobile Survey Results TSP, PM_{10} and $PM_{2.5}$

In conclusion, for September 8, 2004, the impact of delayed trucks traffic on particulate levels were light to moderate at the roadside decreasing to very light by a distance of 25 metres.

September 21, 2004, Highway 402 Diesel Truck Mobile Air Survey Results

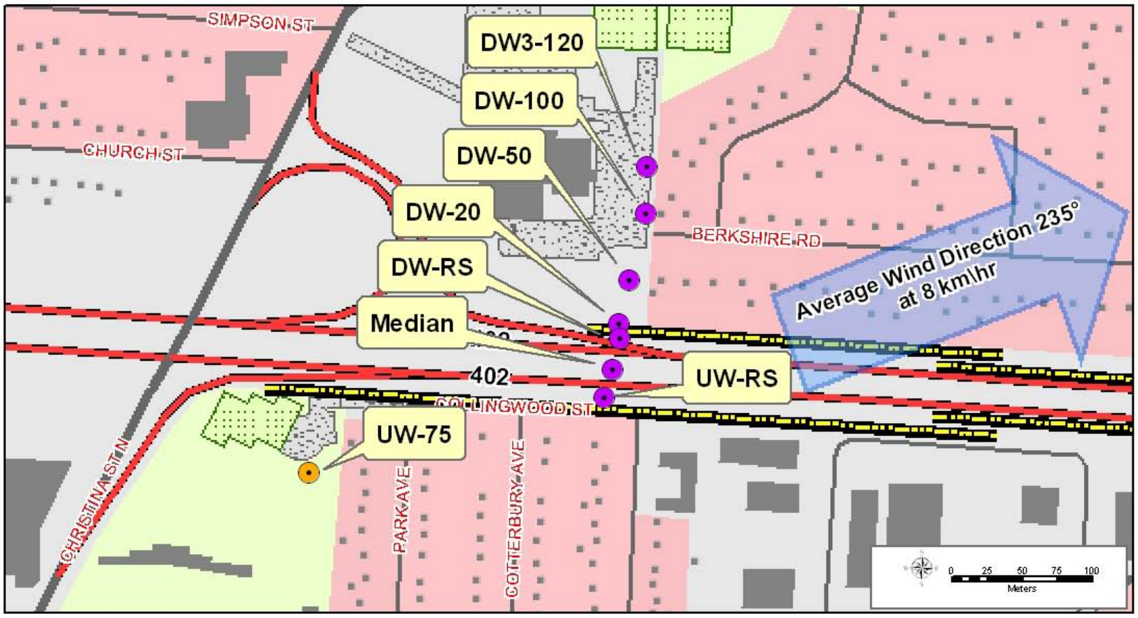


Figure 37: Map of September 21, 2004, Mobile Sampler Locations

During the sampling period, winds were consistently from the southwest and were of moderate strength (averaging about 11 km/hr). Traffic volumes were normal but truck traffic was delayed with queues extending past the samplers during the entire sampling period.

The measurements started adjacent to Highway 402 on the upwind side and measured for duration of 20 minutes. The sampler was then moved to the median and another 20 minute measurement was taken. This pattern was repeated at 10, 20, 50, and 100 and finally 120 metres downwind of Highway 402. The purple circles on the above map indicate the location of the sampler during this survey.

TSP and PM_{10} levels were highest at both the inside and outside of the noise barrier and dropped steadily thereafter and had reduced to background levels by a distance of 50 metres downwind of Highway 402.

Figure 37 displays the monitoring results for each downwind location (bars) and trendlines (dotted lines) for TSP, PM_{10} and $PM_{2.5}$. The trendlines indicate that by approximately 110 metres there was no longer any measurable influence from the delayed trucks.

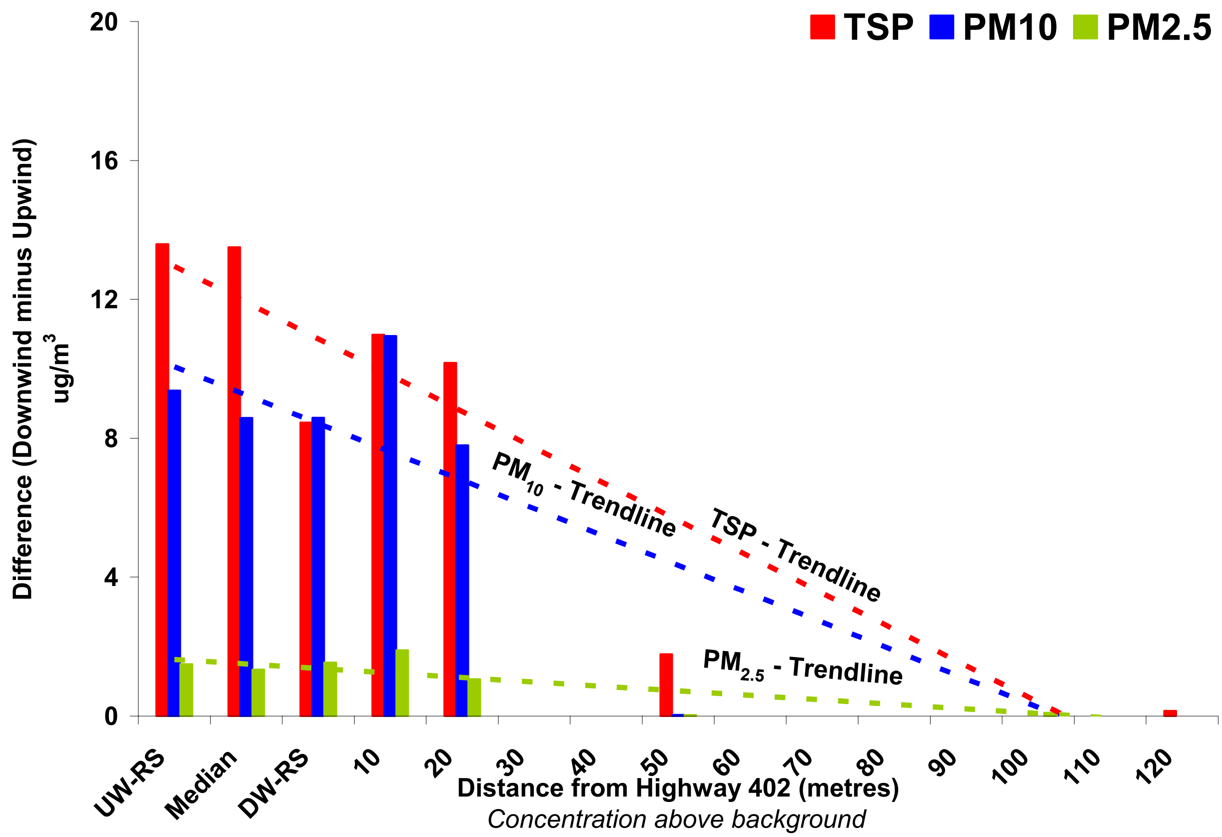


Figure 38: September 21, 2004, Mobile Survey Results TSP, PM_{10} and $PM_{2.5}$

In conclusion, for September 21, 2004, the impact of delayed trucks traffic on particulate levels were light to moderate at the roadside decreasing to very light by a distance of 50 metres.

September 23, 2004, Highway 402 Diesel Truck Mobile Air Survey Results

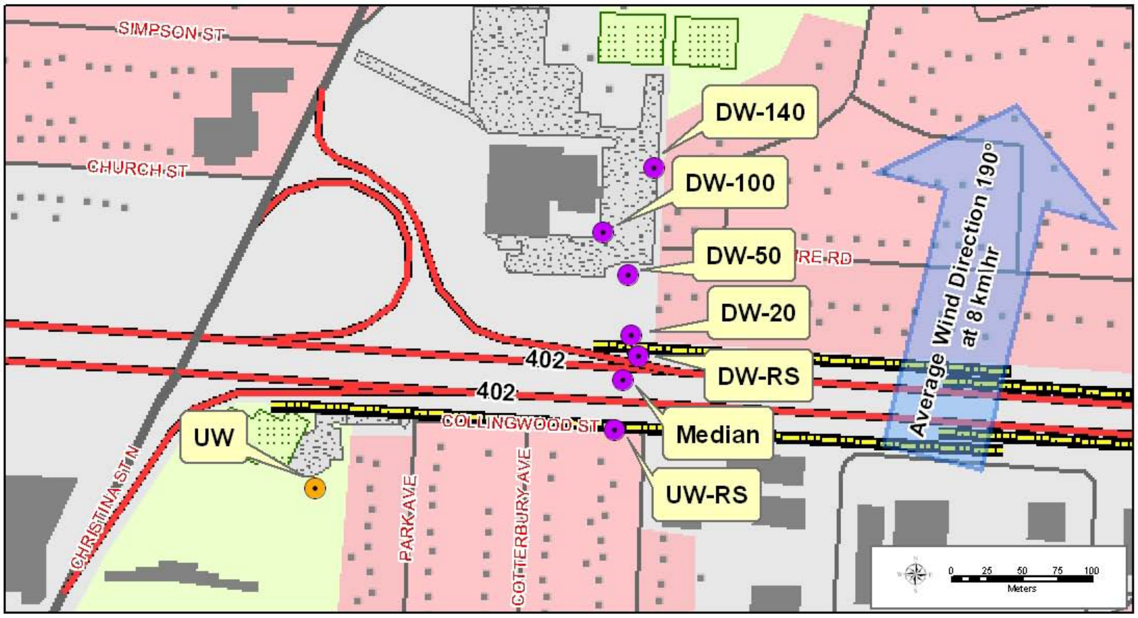


Figure 39: Map of September 23, 2004, Mobile Sampler Locations

During the sampling period, winds were consistently from the south and were of light strength (averaging about 7 km/hr). Traffic volumes were normal but truck traffic was delayed with queues extending past the samplers during most of the sampling period.

The measurements started adjacent to Highway 402 on the upwind side and measured for duration of 20 minutes. The sampler was then moved to the median and another 20 minute measurement was taken. This pattern was repeated at 10, 20, 50, and 100 and finally140 metres downwind of Highway 402. The purple circles on the above map indicate the location of the sampler during this survey.

TSP and PM_{10} levels were highest at both the inside and outside of the noise barrier and dropped thereafter and had reduced to background levels by a distance of 140 metres downwind of Highway 402.

Figure 39 displays the monitoring results for each downwind location (bars) and trendlines (dotted lines) for TSP and PM_{10}, the trendline would intercept at approximately 140 to 180 metres. The $PM_{2.5}$ trendline or measurements do not indicate by what distance there are no longer any measurable influence from the delayed trucks.

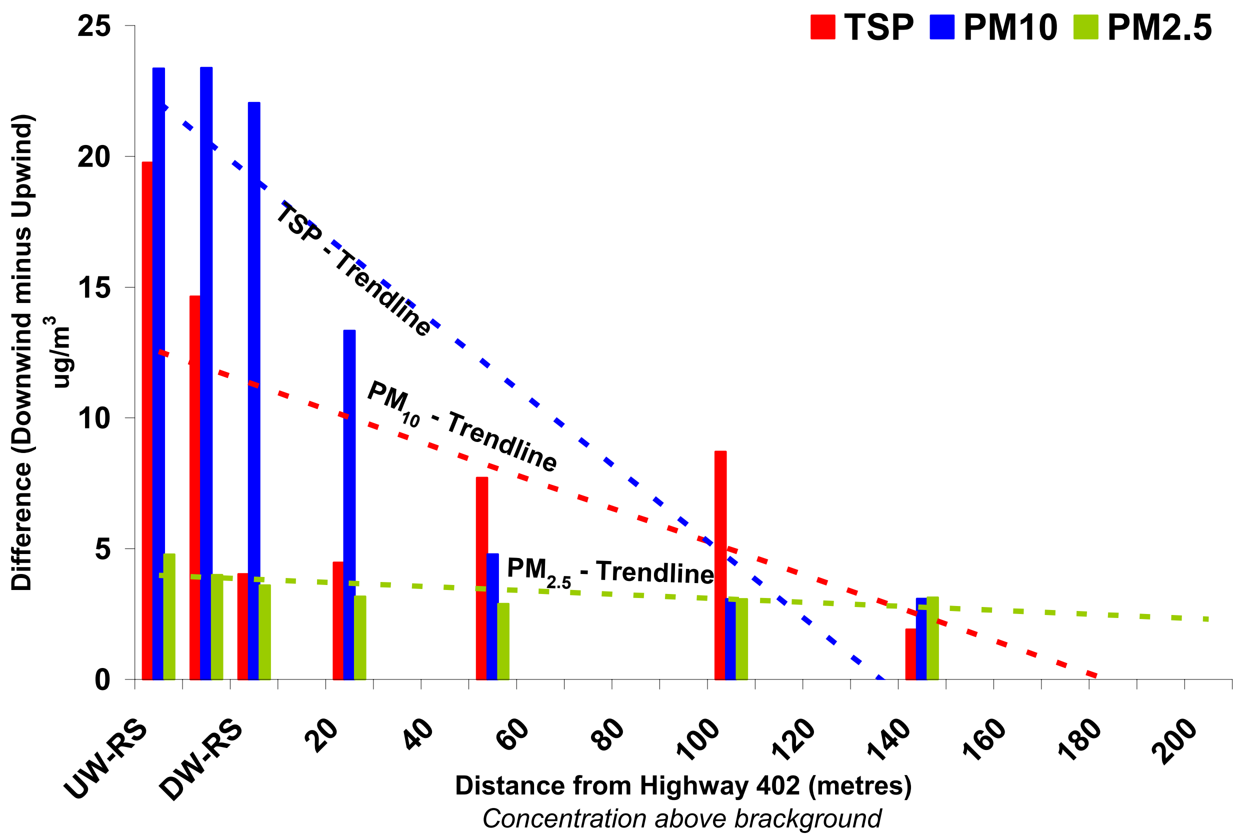


Figure 40: September 23, 2004, Mobile Survey Results TSP, PM_{10} and $PM_{2.5}$

In conclusion, for September 23, 2004, the impact of delayed trucks traffic on particulate levels were light to moderate at the roadside decreasing to very light by a distance of 140 metres.

PART 5: THE ZONE OF IMMEDIATE INFLUENCE

Survey results have been used to extrapolate particulate increases near Highway 402 during truck traffic delays. Figure 40 display a map “Zone of Immediate Influence” which depicts the average increase of particulate above ambient conditions based upon all survey results.

The following map and table show:

- Three zones adjacent to the road for which we have data: Zone 1 is closest to the road (0 to 25 metres). Zone 2 is the intermediate zone (25 to 100 metres) and Zone 3 is the zone farthest distance for the road (100 to 300 metres).

- Three particulate sizes: TSP, PM_{10} and $PM_{2.5}$.

- Average concentration increase over background levels for each particulate size and zone.

It is also important to remember the following:

- The map and table are based upon averaging of the surveys results. This, in turn, means that measurements reflect only a limited number of meteorological and traffic conditions.

- The measurements were mainly performed in an open field. Vegetation and buildings will change the way the particulate disperses and so different points at the same distance from the road may experience different contributions from the traffic.

- Not all points in a zone will experience the same effect at the same time. Generally, one side of the road will be downwind and one upwind. The upwind side will receive little or no influence from the road.

- These zones disregard the influence from all other sources and background contributions.

The following table suggest that:

- The contribution of the traffic is most pronounced in close proximity to Highway 402 (0 to 25 metres).

- Particulate increases due to truck delays rapidly decreases with distance from Highway 402.

- Beyond the third zone, the contribution from the road was minimal and masked by other influences.

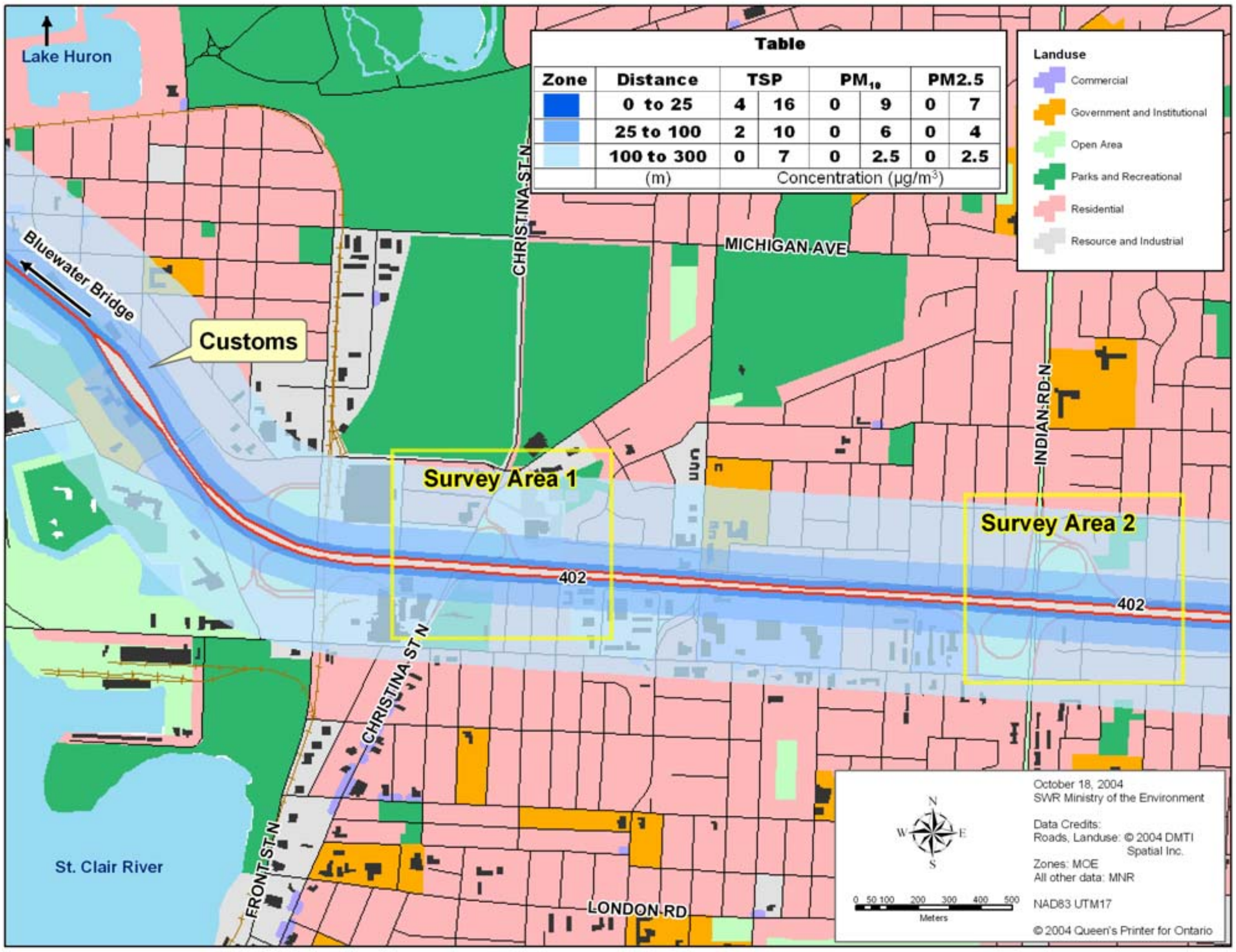


Figure 41: Map "Zone of Immediate Influence"

Distance from 402	TSP		PM_{10}		$PM_{2.5}$	
	Min - Max	Average	Min - Max	Average	Min - Max	Average
0 to 25	4 - 16	9	0 - 9	10	0 - 7	7
25 to 100	2 - 10	5	0 - 6	6	0 - 4	3
100 to 300	0 - 7	2	0 - 2.5	4	0 - 2.5	2

metres *Concentration (ug/m³)*

Table 2: Distance from Highway 402 Particulate Impacts

PART 6: SUMMARY AND CONCLUSIONS

General

The sampling results are summarized below. Results are based on real time data from the portable particulate monitors. Statistical analysis was not carried out for these results**.** To accurately assess the data and determine relationship between different meteorological conditions, traffic volumes and background concentrations, data sets covering a longer period are required.

Total Suspended Particulate (TSP)

- During free flowing (no delays) traffic, TSP levels were 2 to 3 µg/m^3 above background levels near the road and decreased with distance from the road.
- When long border delays were experienced, the TSP levels showed larger increases of 4 to 16 µg/m^3 near the road and decreased sharply as distance from the road increased.
- In some cases increases in TSP suggest that there are possibly other influences at work other than diesel exhaust, e.g. road dust or tire wear.

Inhalable Particulate Matter (PM_{10})

- During free flowing (no delays) traffic, minimal PM_{10} level increases (by no worse than 0 to 1 µg/m^3).
- When long border delays were experienced, the PM_{10} levels varied from 6 µg/m^3 on average to levels as high as 10 µg/m^3.
- Generally, PM_{10} levels dropped with increasing distance from the road with no appreciable difference above background by 300 metres.

Respirable Particulate Matter ($PM_{2.5}$) and Ultrafine Particulate (PM_1)

- During free flowing (no delays) traffic, $PM_{2.5}$ levels showed very minor increases near the road and increased slightly further from the road. The distance to which those increases were felt was not determined in this study.
- When long border delays were experienced, the $PM_{2.5}$ levels varied anywhere from 0 µg/m^3 to 7 µg/m^3 depending upon meteorological conditions.

- Generally, $PM_{2.5}$ levels increased with increasing distance from the road but by 250 metres from the road $PM_{2.5}$ levels were approaching background levels.

Volatile Organic Compounds (VOC)

- All of the VOC samples results exhibited no increase to VOC background levels.

Odours

- During the surveys ministry staff experienced odours from the residential trash in the idling waste trucks delivering Ontario waste to a Michigan landfill site. Odours from decaying trash are normally related to volatile organic compounds. In some cases the human sense of smell can detect lower concentrations of VOCs than can scientific equipment. Ministry of the Environment measurements did not detect any traces of these compounds.

Highway 402 Noise Barrier

Highway 402, noise barrier produces disturbed areas of airflow downwind, called wakes. In these wakes, wind speed is reduced and rapid changes in wind speed and direction, called turbulence, are experienced. Figure 41 depicts some possible turbulence scenarios.

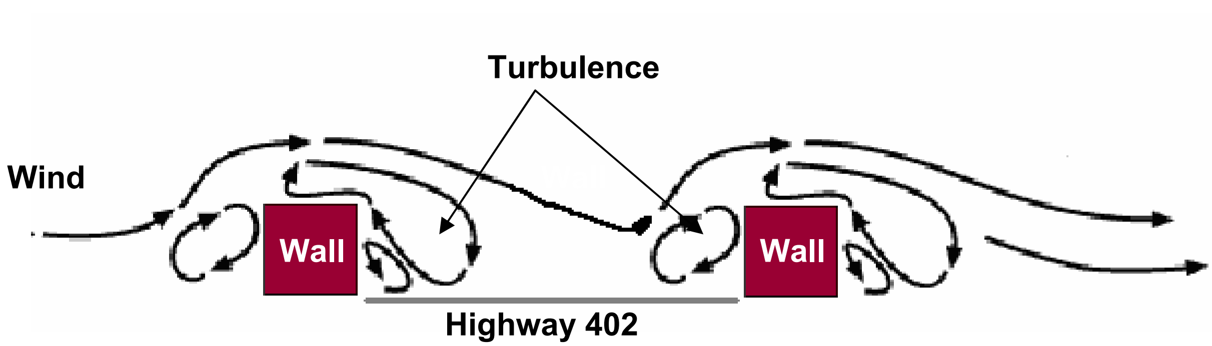


Figure 42: Possible Turbulence Scenarios

Figure 43: Monitoring truck impacts downwind of Highway 402 wall in Sarnia

Highway walls may obstruct the wind at a distance of 5 to 10 wall heights downwind of the wall. The Highway 402 wall, averages from 3 to 4 metres in height and therefore turbulence can occur downwind of this wall from 15 to 40 metres. The ministry's monitoring results suggested that the wall resulted in particulate matter accumulating near its vicinity. In some cases increases in particulate matter appeared to have trapped the particulate between the two walls and for a short distance from the downwind wall. The extent of the particulate containment was not part of this study's purpose. Further research would be required to come to any determination of the barrier effect on particulate matter.

Further information on highway noise barriers is in Appendix C.

Comparison of Windsor and Sarnia Results

The following figure indicate the average particulate concentration over a distance of 200 metres from the monitoring surveys conducted in the Windsor and Sarnia areas. The graphs clearly indicates that particulate impacts experienced from truck traffic emissions caused by border delays at the Sarnia's, Highway 402 were about half as much as those measured during the Windsor study on Huron Church Road.

In the Sarnia area, the traffic volumes were only half that of the Windsor volumes and the traffic conditions are considerably lighter than in Windsor. This in turn would easily explain why the concentration increases in the Sarnia area are half of those in Windsor.

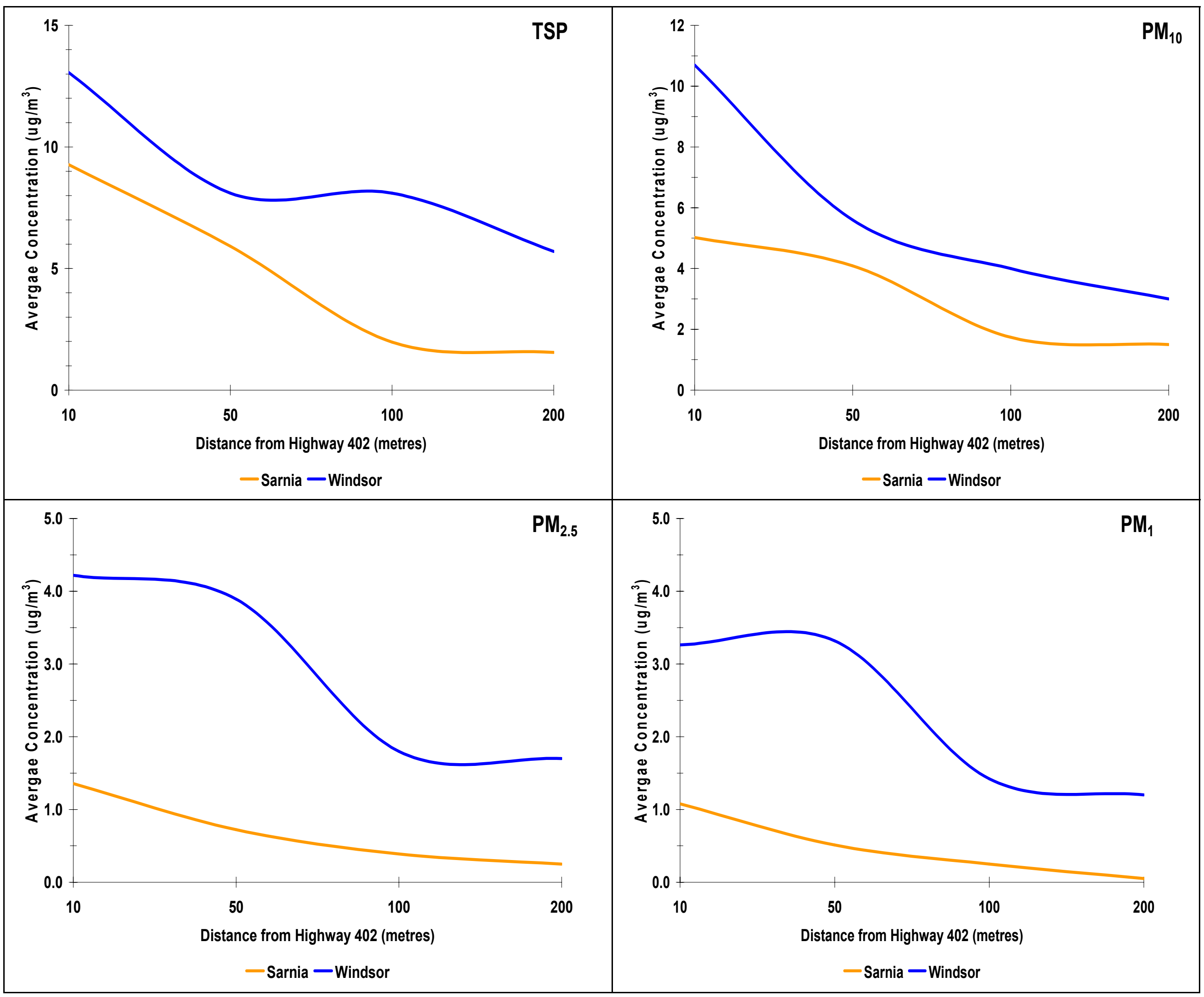


Figure 44: Comparison Graphs of Windsor and Sarnia Particulate Results

APPENDICES

APPENDIX A: LEVELS OF CONCERN FOR PARTICULATE MATTER

The Ministry of the Environment does not currently have standards for various sizes of particulate. Only TSP is regulated. Thus, to provide a useful level of comparison, we have had to use other criteria to assess particulate concentration. For convenience in this document, we refer to these as Levels of Concern. The Ambient Air Quality Criteria (AAQC) for Ontario is the maximum concentration or level (based on potential effects) of a contaminant that is desirable or considered acceptable in ambient air.

- Under Ontario Regulation 346, sources are required to limit their emissions of suspended particulate matter, such that the concentration mathematically predicted at a point-of-impingement (POI) does not exceed 100 μg/m^3 in any half hour period. The half-hour POI is meant to exclude the normal presence of background particulate levels. The half-hour POI is mainly used for emission modelling, and throughout this report, a one-hour average for TSP of 100 μg/m^3 was used as the level of concern.

- On November 18, 1997, Ontario introduced an interim AAQC for PM_{10} of 50 μg/m^3 based on a 24-hour average. The PM_{10} interim AAQC was based upon the potential health effects and serves as Ministry policy to provide guidance for environmental protection decisions in Ontario. Throughout this report, a one-hour average for PM_{10} of 50 μg/m^3 was used as the level of concern.

- The Canada Wide Standard (CWS) concentration for 24-hour $PM_{2.5}$ is 30 μg/m^3. The standard for $PM_{2.5}$ is based on a complex calculation that involves using the 98th percentile of the measurements annually, averaged over three consecutive years. The $PM_{2.5}$ CWS was agreed by all provinces and is to be achieved by the year 2010.

  The Ministry's Environmental Monitoring and Reporting Branch has determined that a three-hour average concentration of 45 μg/m^3 for $PM_{2.5}$ is statistically equivalent to the 24-hour CWS. (See Appendix 2 for a discussion of the AQI). In the case of this report we have adopted a 1-hour average for $PM_{2.5}$ of 45 μg/m^3 as the level of concern.

Particulate Size	Level of Concern
TSP	100 μg/m^3
PM_{10}	50 μg/m^3
$PM_{2.5}$	45 μg/m^3

Table 3: Level of Concern" Used for This Report

APPENDIX B: THE AIR QUALITY INDEX - OVERVIEW

(From **http://www.airqualityontario.com/science/aqi_description.cfm**)

Overview:

The Air Quality Index (AQI) is an indicator of air quality, based on hourly pollutant measurements of some or all of the six most common air pollutants: sulphur dioxide, ozone, nitrogen dioxide, total reduced sulphur compounds, carbon monoxide and fine particulate matter.

State-of-the-art air monitoring stations, operated by the Ministry across the province, forms the Air Quality Index (AQI) network.

The ministry takes real-time air quality data from its AQI monitoring sites to produce AQI readings for each location. AQI readings are reported to the public and news media at set intervals each day. The public can access the index values by calling the ministry's automatic telephone answering device (English recording: 1-800-387-7768 or in Toronto 416-246-0411. French recording: 1-800-221-8852). The AQI can also be obtained from the ministry's Web site: www.airqualityontario.com

How an AQI is determined:

At the end of each hour, the concentration of each pollutant that the AQI station monitors is converted into a number ranging from zero upwards, using a common scale, or index. The pollutant with the highest number at a given hour becomes the AQI reading. As the air quality changes, the AQI reading increases or decreases. The lower the AQI reading, the cleaner the air.

Table 4: Health Effects of Different AQI Levels Caused by Fine Particulate Matter

Category	AQI	$PM_{2.5}$ (μg/m^3)	Health Effects
Very Good	0 – 15	0 – 11	Sensitive populations may want to exercise caution.
Good	16 – 31	12 – 22	Sensitive populations may want to exercise caution.
Moderate	32 – 49	23 – 45	People with respiratory disease at some risk.
Poor	50 – 99	46 – 90	People with respiratory disease should limit prolonged exertion. General populations at some risk.
Very Poor	100 or over	> 90	Serious respiratory effects during light physical activity; people with heart disease; the elderly and children at high risk. Increased risk for general population.

APPENDIX C: NOISE BARRIERS:

(Adapted from the U.S. Department of Transportation Federal Highway Administration)

Noise barriers are solid obstructions built between the highway and the homes along the highway. Effective noise barriers can reduce noise levels by ten to fifteen decibels, cutting the loudness of traffic noise in half. Barriers can be formed from earth mounds along the road (usually called earth berms) or from high, vertical walls. Earth berms have a very natural appearance and are usually attractive. However, an earth berm can require quite a lot of land, if it is very high. Walls take less space. They are usually limited to eight meters in height because of structural and aesthetic reasons. The Ontario, Ministry of Transportation limits the height of vertical walls to 5 metres in height because of structural and aesthetic reasons. Noise walls can be built out of wood, stucco, concrete, masonry, metal, and other materials.

Highway 402, 4 metre high Noise Barrier

Figure 45: Noise Barriers

Barriers do have limitations. For a noise barrier to work, it must be high enough and long enough to block the view of a road. Noise barriers do very little good for homes on a hillside overlooking a road or for buildings which rise above the barrier. Openings in noise walls for driveway connections or intersecting streets greatly reduce the effectiveness of barriers. In some areas, homes are scattered too far apart to permit noise barriers to be built at a reasonable cost.

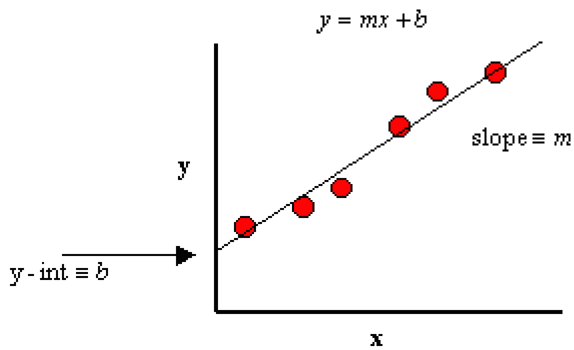
Overall, public reaction in Ontario to highway noise barriers is positive. There is, however, a wide diversity of specific reactions to barriers. Residents adjacent to barriers have stated that conversations in households are easier, sleeping conditions are better, a more relaxing environment is created, windows are opened more often, and yards are used more in the summer. Perceived non-noise benefits include increased privacy, cleaner air, improved view and sense of ruralness, and healthier lawns and shrubs. Negative reactions have included a restriction of view, a feeling of confinement, a loss of air circulation, a loss of sunlight and lighting, and poor maintenance of the barrier. Most residents near a barrier seem to feel that barriers effectively reduce traffic noise and that the benefits of barriers outweigh the disadvantages of the barriers.

APPENDIX D: LINEAR REGRESSION AND EXCEL

Sample data:

For a set of data, (x_i, y_i) , shown at the left. If there is reason to believe that there exists a **linear relationship** between the variables **x** and **y**, we can plot the data and draw a "best-fit" *straight line* (trendline) through the data. In the example below, the relationship is governed by the familiar equation $y = mx + b$. We can then find the **slope, *m*,** and **y-intercept, *b*,** for the data, which are shown in the figure below.

x	y
1.0	2.6
2.3	2.8
3.1	3.1
4.8	4.7
5.6	5.1
6.3	5.3



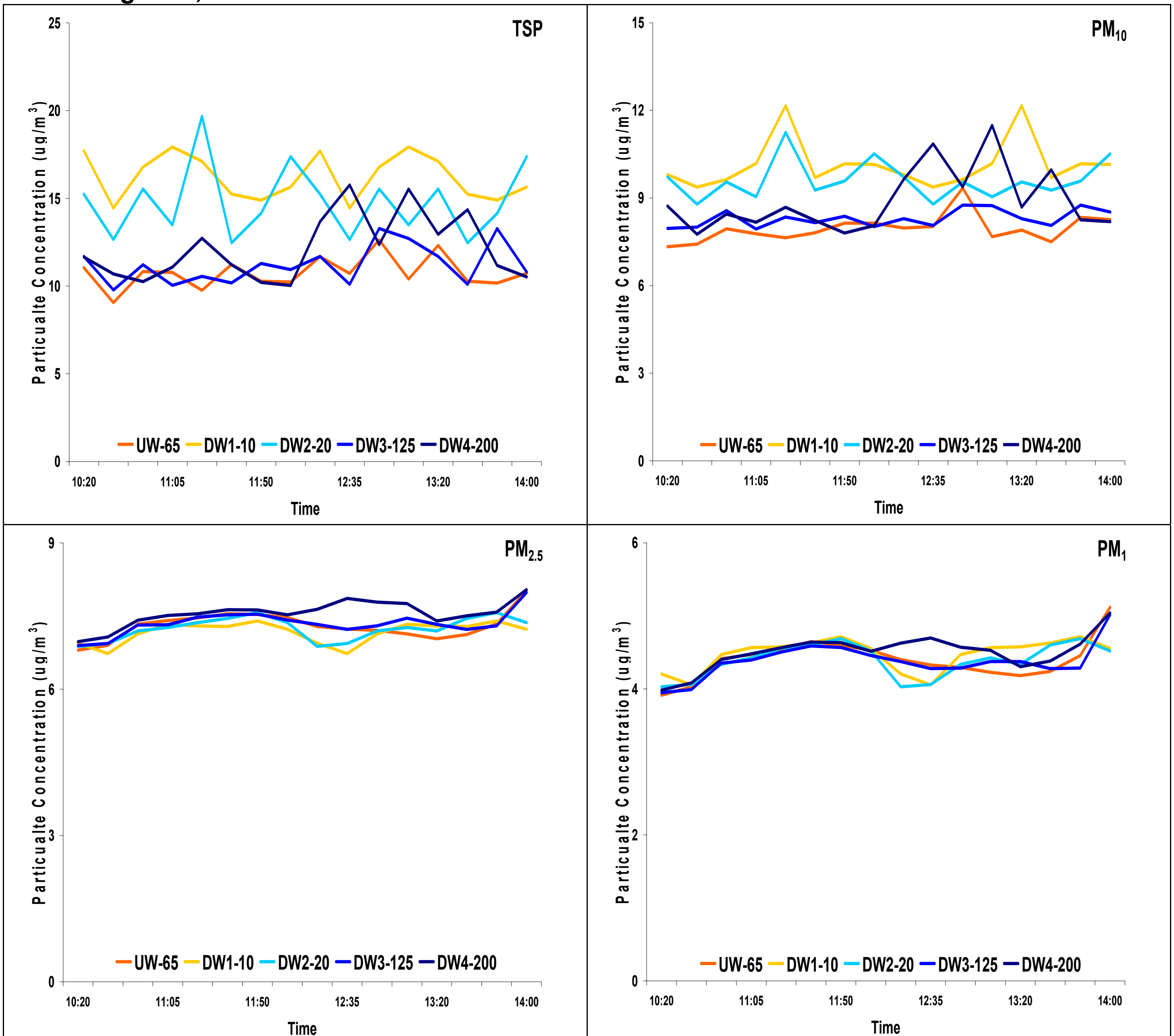
If you enter the above data into an Excel spreadsheet, plot the data, create a trendline and display its slope, y-intercept and R-squared value. Recall that the R-squared value is the square of the correlation coefficient (Excel shows the correlation coefficient as "*R*"). The correlation coefficient gives us a measure of the reliability of the linear relationship between the *x* and *y* values. (Values close to 1 indicate excellent linear reliability.)

APPENDIX E: Monitoring Surveys Graphs and Tables

Tables are included for every sampling period. The column labelled “Distance to Highway 402” gives the distance from the road in metres.

“Particulate Concentration” gives the average concentration in micrograms per cubic metre (μg/m^3) for each size range for the period when all the samplers were running. “Difference DW minus UW” is the downwind concentration minus the upwind concentration in micrograms per cubic metre (μg/m^3).

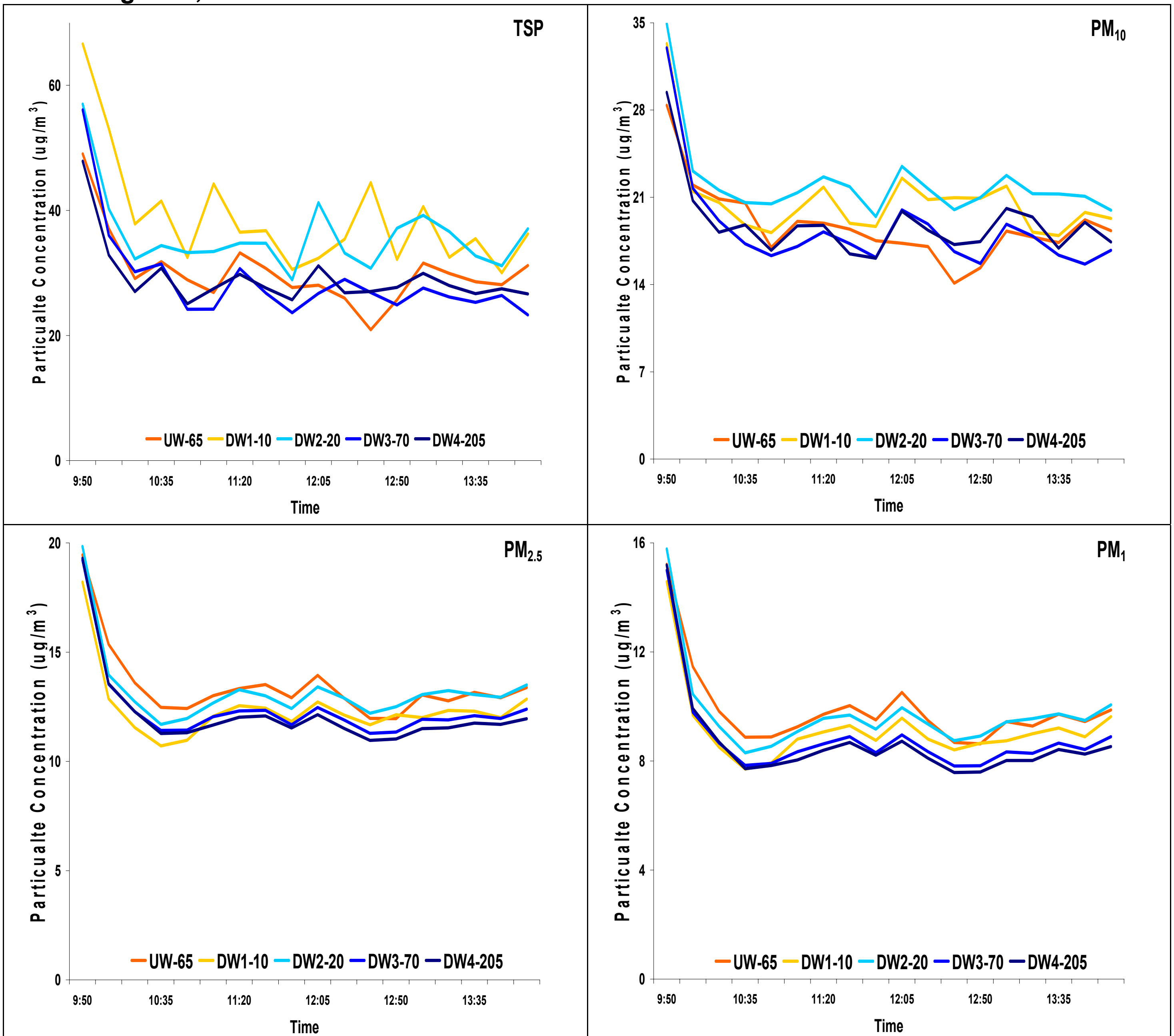
August 5, 2004



August 5, 2004 10:20-14:00 EST

Station	Distance from Highway 402 (metres)	Particulate Concentration (µg/m³)				Difference DW minus UW (µg/m³)			
		TSP	PM_{10}	$PM_{2.5}$	PM_1	TSP	PM_{10}	$PM_{2.5}$	PM_1
UW-65	65	10.8	8	7.3	4.4				
DW1-10	10	16.2	10.1	7.2	4.5	5.4	2.1	-0.1	0.1
DW2-20	20	14.8	9.6	7.2	4.4	4	1.6	-0.1	0
DW3-125	125	11.2	8.3	7.3	4.4	0.4	0.3	0	0
DW4-200	200	12.1	8.9	7.6	4.5	1.3	0.9	0.3	0.1

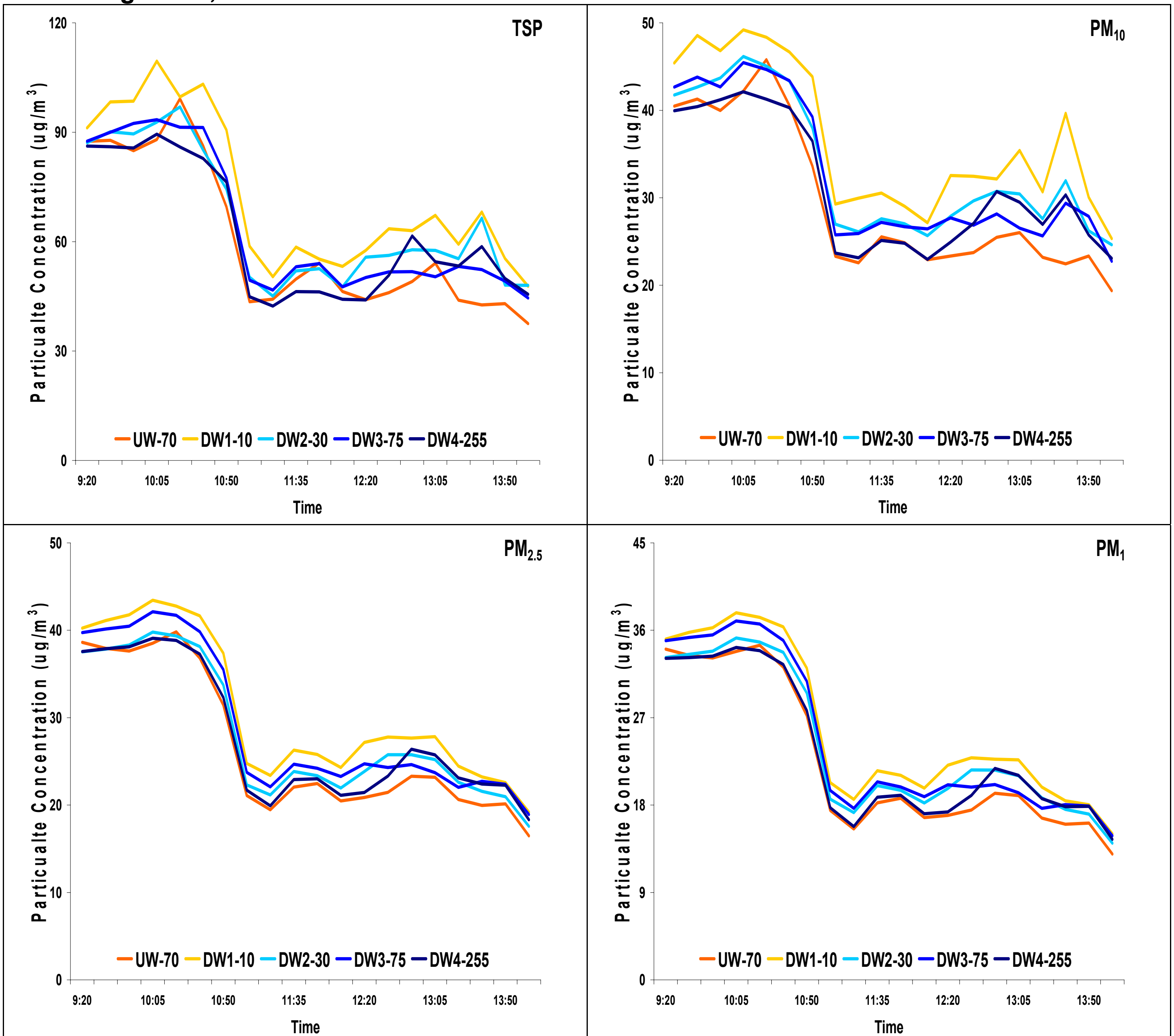
August 9, 2004



August 9, 2004 09:50-14:00 EST

Station	Distance from Highway 402 (metres)	Particulate Concentration (µg/m³)				Difference DW minus UW (µg/m³)			
		TSP	PM_{10}	$PM_{2.5}$	PM_1	TSP	PM_{10}	$PM_{2.5}$	PM_1
UW-65	65	30.3	18.8	13.4	9.9				
DW1-15	15	38.8	20.8	12.4	9.2	8.5	2	-1	-0.7
DW2-20	20	36	22.1	13.2	9.7	5.7	3.3	-0.2	-0.2
DW3-70	70	28.9	18.5	12.4	8.8	-1.4	-0.3	-1	-1.1
DW4-205	205	29.2	18.9	12.2	8.7	-1.1	0.1	-1.2	-1.2

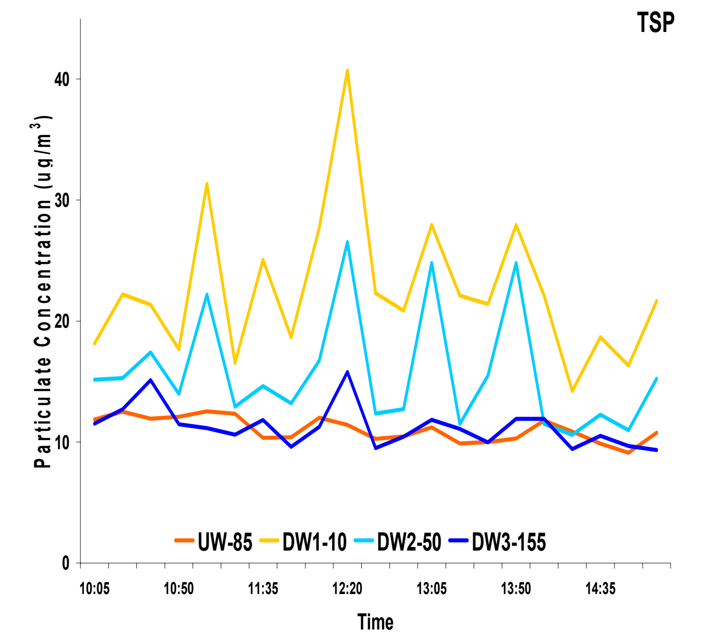
August 26, 2004

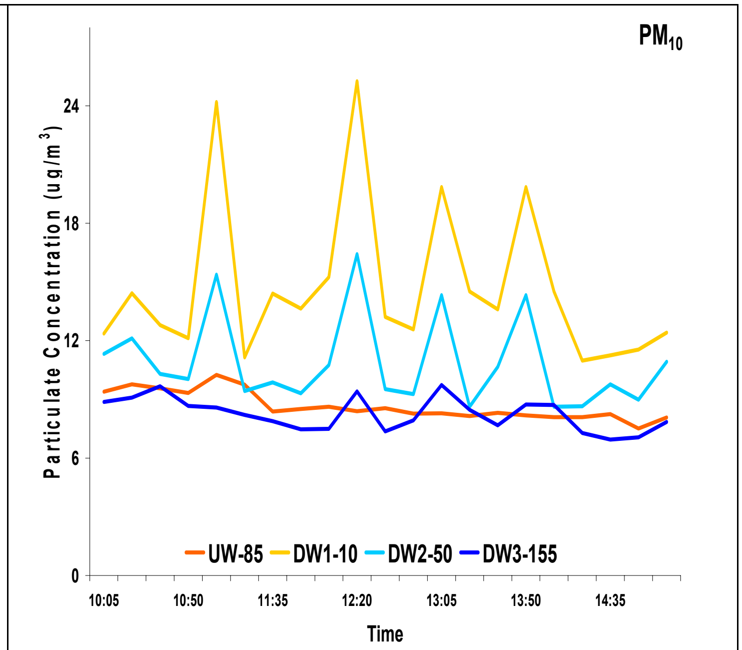


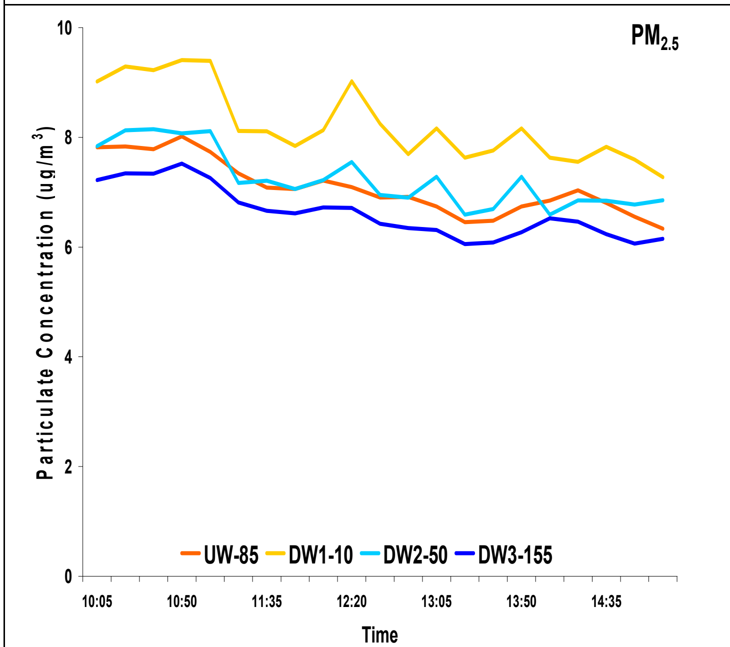
August 26, 2004 09:20-14:00 EST

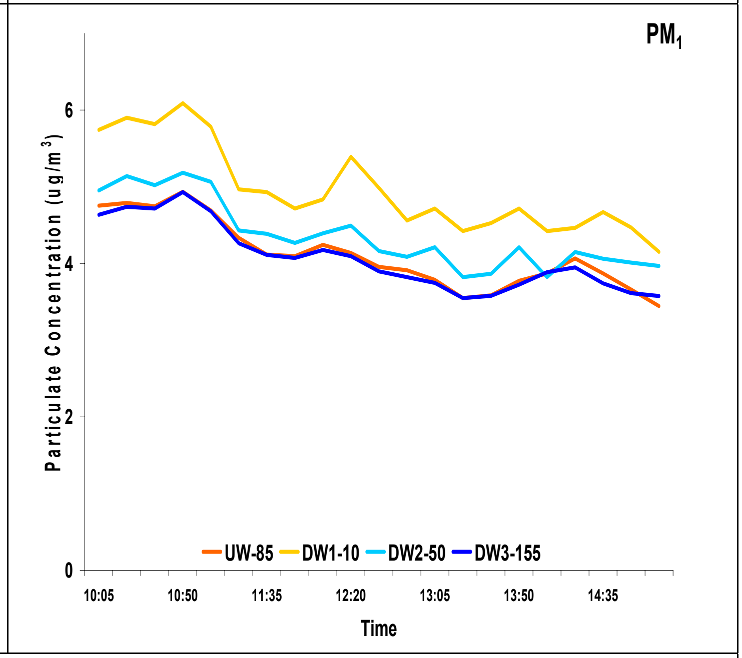
Station	Distance from Highway 402 (metres)	Particulate Concentration ($\mu g/m^3$)				Difference DW minus UW ($\mu g/m^3$)			
		TSP	PM_{10}	$PM_{2.5}$	PM_1	TSP	PM_{10}	$PM_{2.5}$	PM_1
UW-70	70	60.1	29.5	26.6	22.5				
DW1-10	10	72.5	36.7	30.6	25.7	12.4	7.2	4	3.2
DW2-30	30	65.4	33.2	28	23.9	5.3	3.7	1.4	1.4
DW3-75	75	63.9	32.4	29	24.5	3.8	2.9	2.4	2
DW4-255	255	61.7	31	27.6	23.2	1.6	1.5	1	0.7

September 1, 2004





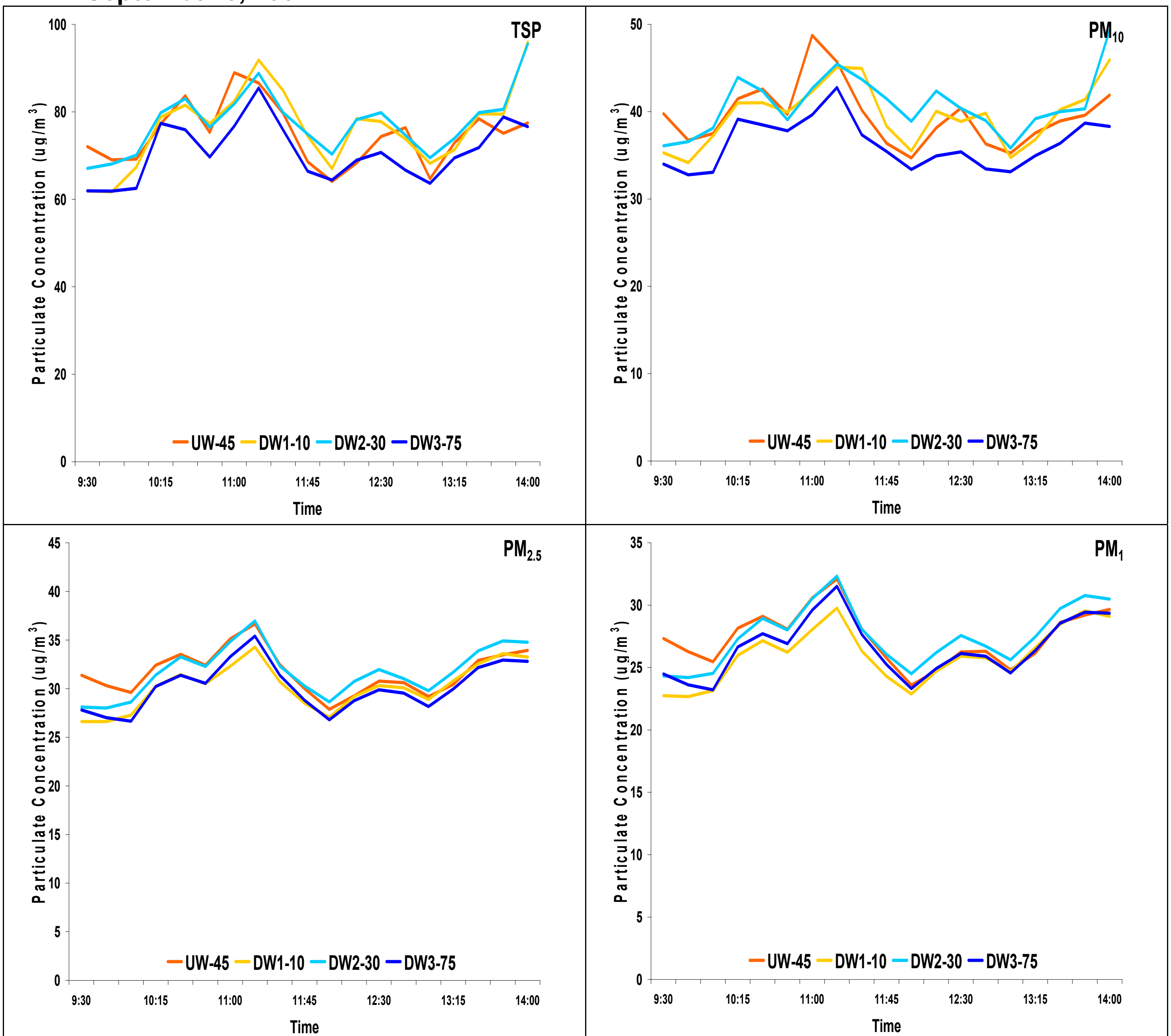




September 1, 2004 10:05-15:00 EST

Station	Distance from Highway 402 (metres)	Particulate Concentration ($\mu g/m^3$)				Difference DW minus UW ($\mu g/m^3$)			
		TSP	PM_{10}	$PM_{2.5}$	PM_1	TSP	PM_{10}	$PM_{2.5}$	PM_1
UW-85	85	11	8.7	7.1	4.1				
DW1-10	10	22.6	14.8	8.2	5	11.6	6.1	1.1	0.9
DW2-50	50	15.7	10.9	7.2	4.4	4.7	2.2	0.1	0.3
DW3-155	155	11.3	8.2	6.6	4.1	0.3	-0.5	-0.5	0

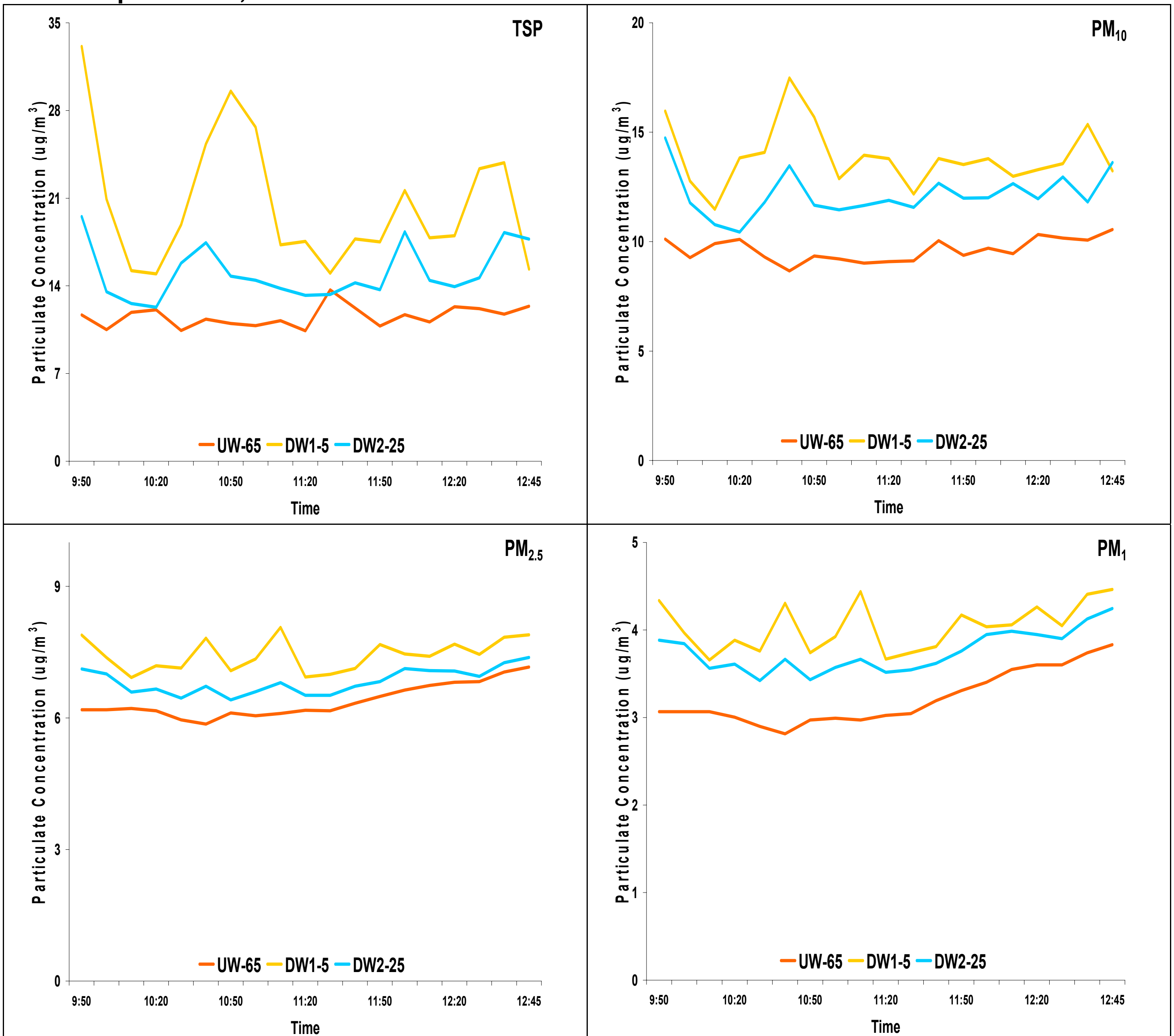
September 3, 2004



September 3, 2004 9:30-14:00 EST

Station	Distance to Road (metres)	Particulate Concentration ($\mu g/m^3$)				Difference DW minus UW ($\mu g/m^3$)			
		TSP	PM_{10}	$PM_{2.5}$	PM_1	TSP	PM_{10}	$PM_{2.5}$	PM_1
UW-45	45	74.8	39.6	31.7	27.4				
DW1-10	10	76.5	39.3	30.2	26	1.7	-0.3	-1.5	-1.4
DW2-30	30	77.5	40.8	31.8	27.5	2.7	1.2	0.1	0.1
DW3-75	75	70.8	36.3	30.2	26.6	-4	-3.3	-1.5	-0.8

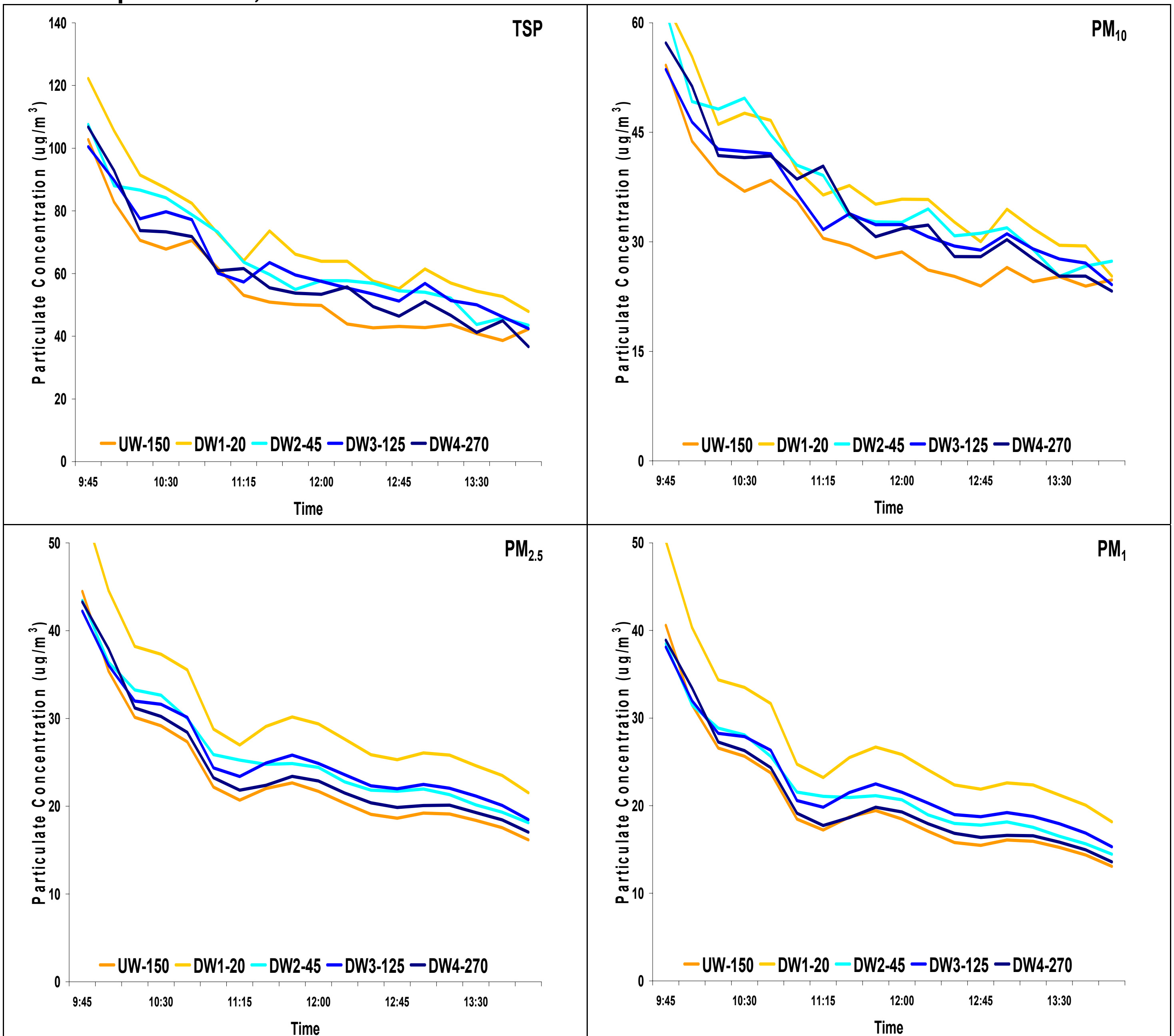
September 8, 2004



September 8, 2004 9:50-12:45 EST

Station	Distance from Highway 402 (metres)	Particulate Concentration ($\mu g/m^3$)				Difference DW minus UW ($\mu g/m^3$)			
		TSP	PM_{10}	$PM_{2.5}$	PM_1	TSP	PM_{10}	$PM_{2.5}$	PM_1
UW-65	65	11.6	9.6	6.4	3.2				
DW1-5	5	20.5	13.9	7.4	4	8.9	4.3	1	0.8
DW2-25	25	15.1	12.2	6.8	3.7	3.5	2.6	0.4	0.5

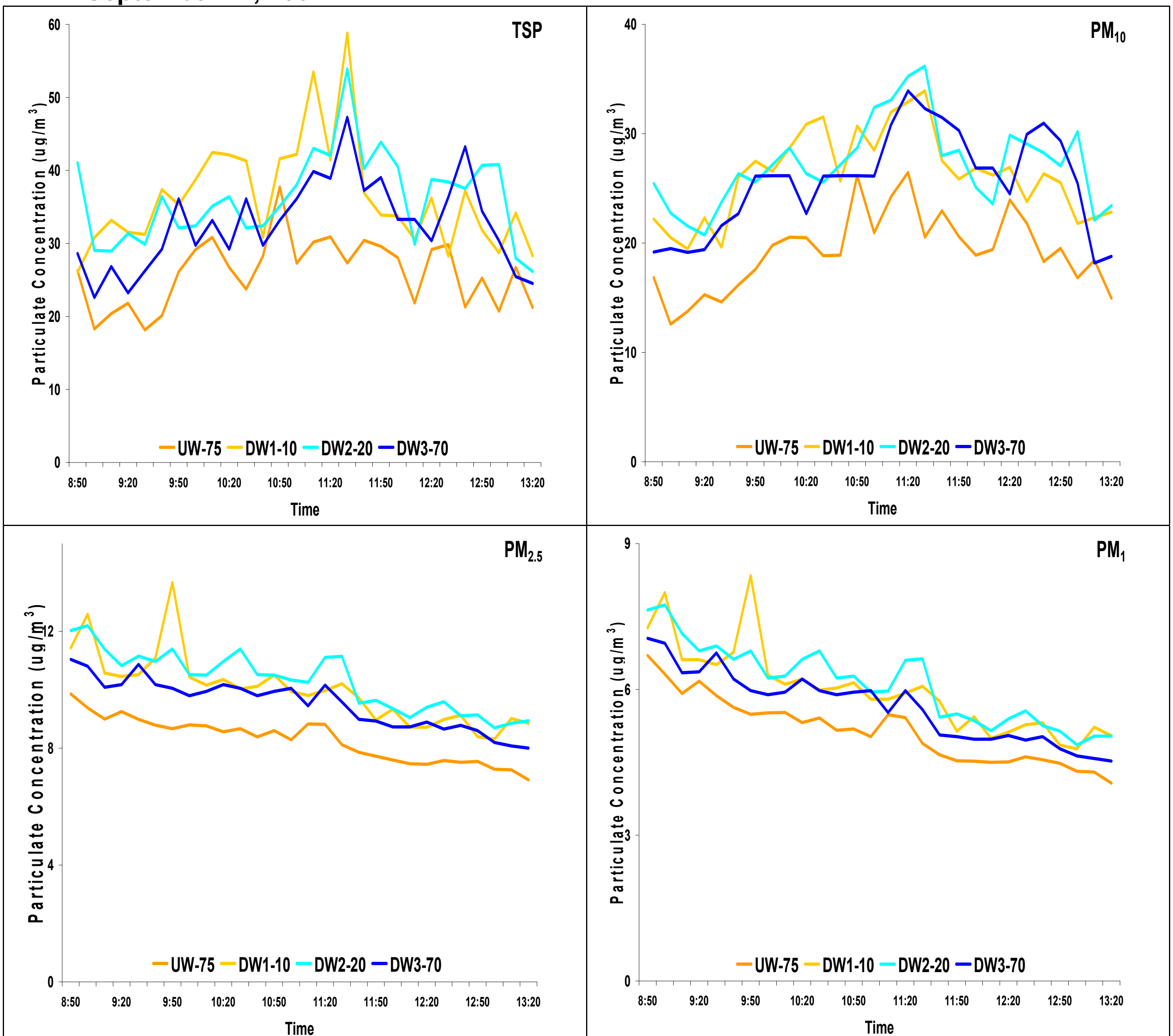
September 13, 2004



September 13, 2004 09:45-14:00 EST

Station	Distance to Road (metres)	Particulate Concentration ($\mu g/m^3$)				Difference DW minus UW ($\mu g/m^3$)			
		TSP	PM_{10}	$PM_{2.5}$	PM_1	TSP	PM_{10}	$PM_{2.5}$	PM_1
UW-150	150	55.4	31.4	23.6	20.2				
DW1-20	20	71.1	38.5	30.8	27.2	15.7	7.1	7.2	7
DW2-45	45	64.6	37.1	26	21.9	9.2	5.7	2.4	1.7
DW3-125	125	62.7	34.6	26	22.5	7.3	3.2	2.4	2.3
DW4-270	270	59.8	34.9	24.5	20.8	4.4	3.5	0.9	0.6

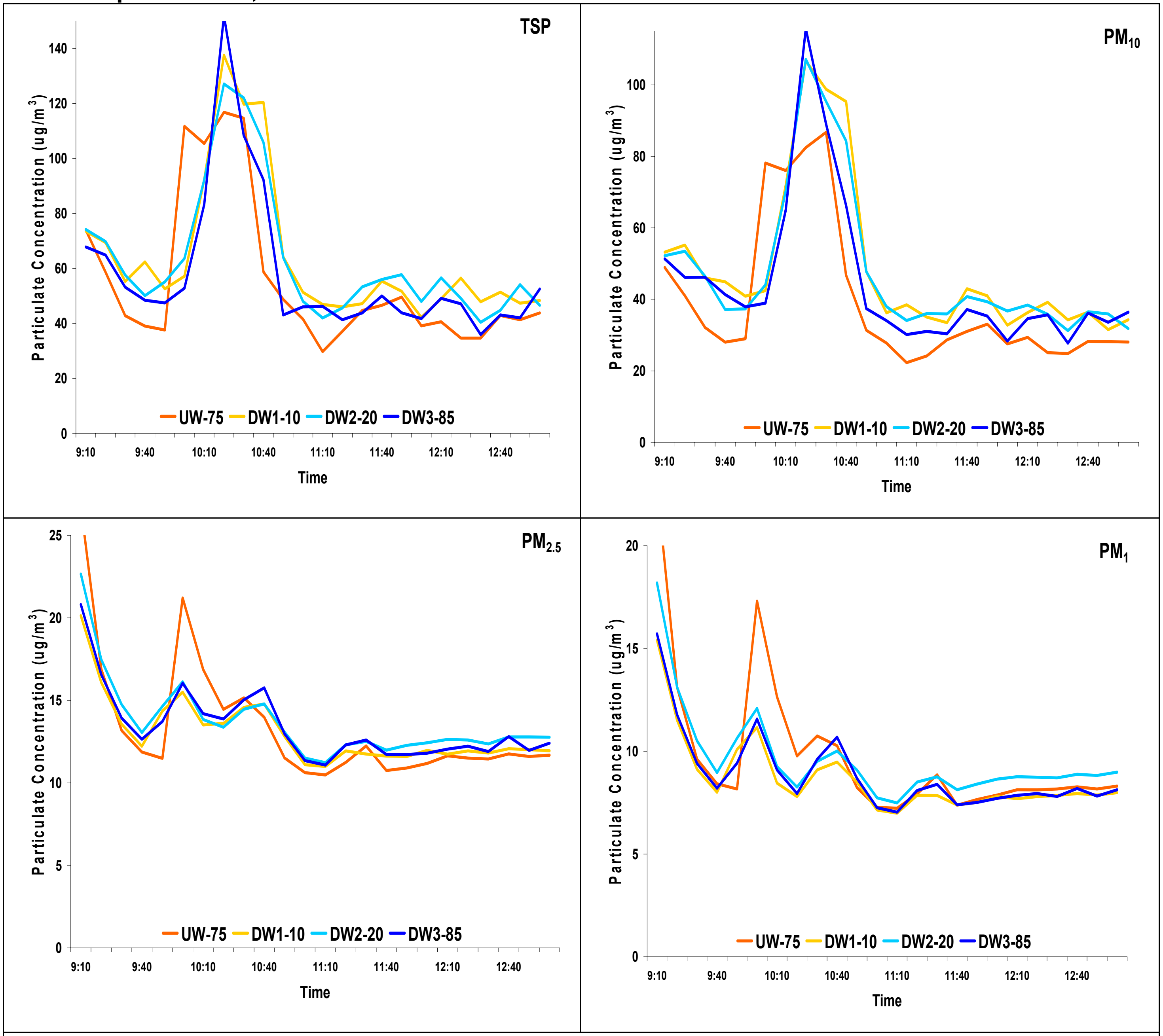
September 21, 2004



September 21, 2004 8:50-13:20 EST

Station	Distance from Highway 402 (metres)	Particulate Concentration (µg/m^3)				Difference DW minus UW (µg/m^3)			
		TSP	PM$_{10}$	PM$_{2.5}$	PM$_1$	TSP	PM$_{10}$	PM$_{2.5}$	PM$_1$
UW-75	75	26	19.3	8.3	5.1				
DW1-10	10	36.4	26.2	10	6	10.4	6.9	1.7	0.9
DW2-20	20	36.2	27.2	10.3	6.1	10.2	7.9	2	1
DW3-70	70	32.6	25.6	9.5	5.6	6.6	6.3	1.2	0.5

September 23, 2004



September 23, 2004 9:10-13:00 EST

Station	Distance from Highway 402 (metres)	Particulate Concentration (μg/m^3)				Difference DW minus UW (μg/m^3)			
		TSP	PM$_{10}$	PM$_{2.5}$	PM$_1$	TSP	PM$_{10}$	PM$_{2.5}$	PM$_1$
UW-75	75	55.6	39.1	13.3	9.8				
DW1-10	10	64.4	48.9	13.1	8.7	8.8	9.8	-0.2	-1.1
DW2-20	20	63.5	47.7	13.7	9.6	7.9	8.6	0.4	-0.2
DW3-85	85	58.4	44.4	13.4	8.9	2.8	5.3	0.1	-0.9

Mobile Traffic Surveys – September 8, 21 and 23, 2004

Mobile Survey - September 8, 2004	Difference (Mobile minus Upwind in ug/m^3)			
	TSP	PM_{10}	$PM_{2.5}$	PM_1
Median	1.1	2.2	2.3	1.9
Downwind Roadside (DW-20)	0.9	2.4	1.7	1.4
10 Metres Downwind (DW-50)	1.3	1.7	1.2	0.9
40 Metres Downwind (DW-100)	-2.1	0.6	1.0	0.9
60 Metres Downwind (DW-150)	-1.1	1.1	0.9	0.8
80 Metres Downwind (DW-200)	-1.2	0.2	1.0	0.9
120 Metres Downwind (DW-250)	-1.0	0.7	1.1	1.0

Mobile Survey - September 21, 2004	Difference (Mobile minus Upwind in ug/m^3)			
	TSP	PM_{10}	$PM_{2.5}$	PM_1
Upwind Roadside (UW-RS)	13.6	9.4	1.5	0.8
Median	13.5	8.6	1.3	0.7
Downwind Roadside (DW-RS)	8.5	8.6	1.5	0.8
10 Metres Downwind (DW-10)	11.0	10.9	1.9	1.1
20 Metres Downwind (DW-20)	10.2	7.8	1.1	0.5
50 Metres Downwind (DW-50)	1.8	0.0	0.0	0.0
100 Metres Downwind (DW-100)	-0.5	0.0	0.1	0.0

Mobile Survey - September 23, 2004	Difference (Mobile minus Upwind in ug/m^3)			
	TSP	PM_{10}	$PM_{2.5}$	PM_1
Upwind Roadside (UW-RS)	19.8	23.4	4.8	2.9
Median	14.6	23.4	4.0	2.1
Downwind Roadside (DW-RS)	4.0	22.0	3.6	1.7
20 Metres Downwind (DW-20)	4.5	13.3	3.2	1.6
50 Metres Downwind (DW-50)	7.7	4.8	2.9	1.5
100 Metres Downwind (DW-100)	8.7	3.1	3.1	1.6
140 Metres Downwind (DW-140)	1.9	3.1	3.1	1.4

APPENDIX F: MODELLING RESULTS

Summary

In 2003 and 2004, monitoring similar to that described in this report was conducted in Windsor. The results are published in a report available on the Ministry web site.[1]

During the evaluation of the findings, Ministry staff decided to model the fine particulate ($PM_{2.5}$) emissions of the traffic to augment the monitoring results. The modelling details and results are described in a separate report.

The same model has been applied to traffic on Highway 402 near the Blue Water Bridge for the area where the monitoring took place. Results of the modelling are presented below. They are displayed as a series of maps which indicate areas of different concentration for a variety of idealized meteorological conditions. Two sets of models are presented: traffic during periods where trucks have backed up from the bridge forming a stop-and-go queue and free-flowing (no delays) traffic in all four highway lanes. Only traffic on Highway 402 is modelled.

Description

Ministry staff used *AERMOD Prime*, a state-of-the-art air-dispersion model developed by the US Environmental Protection Agency and American Meteorological Society. This model was chosen for its versatility, ease of use, and general acceptance in the scientific community.

Moving-vehicle emissions are based upon published values of emission rates and number distributions for the North American traffic fleet. While the figures used here are about two-three years old, they are a good approximation.

Emissions from trucks queues were determined empirically during the Windsor traffic study cited above.

Traffic densities for free-flowing traffic were taken as half the average values used in the Windsor study. Truck densities for queues were based upon average length of the trucks and observed spacing between trucks.

[1] http://www.ene.gov.on.ca/envision/techdocs/index.htm#AIR Preliminary Air Quality Assessment Related to Traffic Congestion at Windsor's Ambassador Bridge, Report 4624e

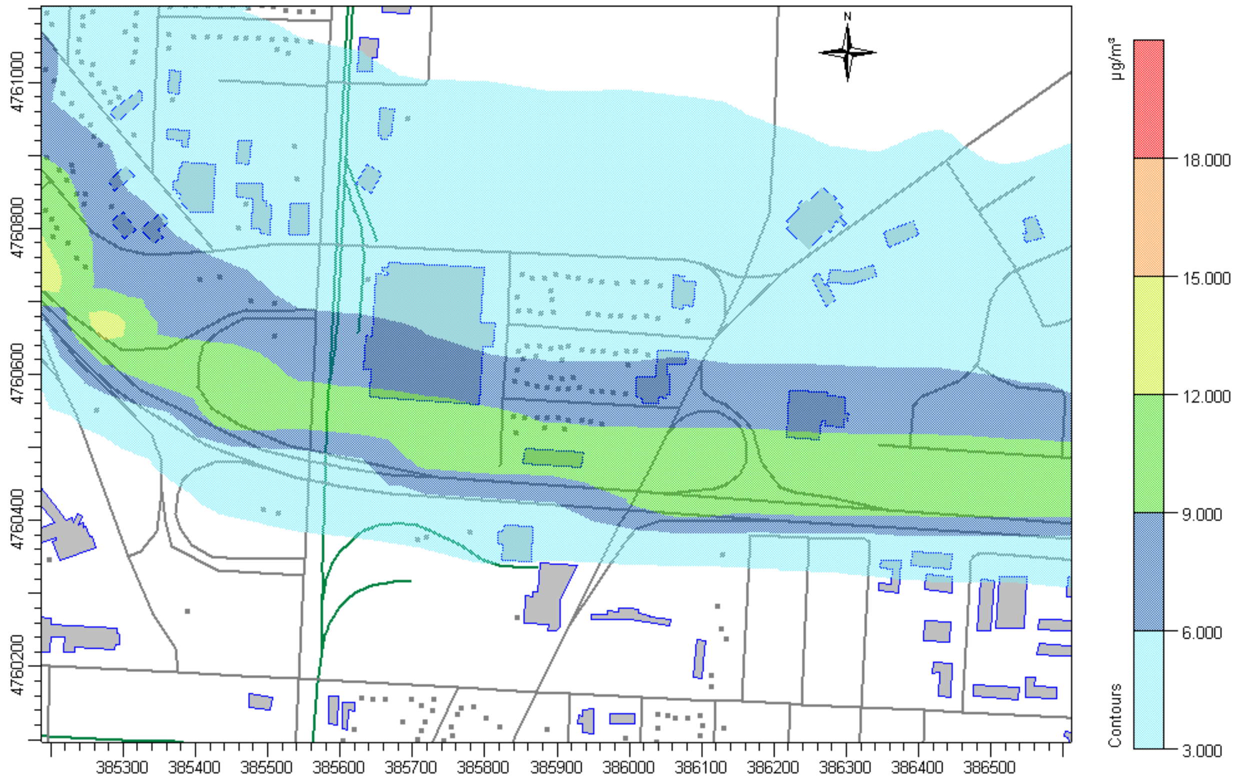


Figure 46: Model Output

Modelling was conducted for three sets of meteorological conditions:

- winds nearly parallel to the road at the monitoring site,
- winds perpendicular to the road, and
- the dominant wind direction for the Sarnia area.

While all of these values are approximate, they provide a reasonable estimate of the values that would be encountered. Since the purpose of this study is to illustrate the effects of the truck queue under different circumstances, the input data is more than adequate.

Explanation of Diagrams

Figure 45 displays an output map from one of the model runs. The grey lines represent roads, the green lines are railways; the grey dots are small buildings and the larger rectangles correspond to larger buildings. The numbers on the bottom and left side are Universal Transverse Mercator (UTM)[3] coordinates of the area. They are expressed in metres so the diagram displays an area approximately one kilometre north to south and 1.4 kilometres east to west.

[3] UTM coordinates are an alternative to latitude and longitude used in geographic information systems. The units are expressed in metres. There is more than one set of these coordinates. The Ministry uses the NAD 83 Datum.

The different coloured areas represent locations where the model calculated different concentration levels. For example, the green area represents particulate concentrations between 9 μg/m^3 and 12 μg/m$^{3.}$ Uncoloured areas have calculated levels lower than 3 μg/m^3. In some cases, calculated levels were too low to register on this scale. To illustrate these results a second scale was also used. These results are colour-coded differently to decrease the chance of confusion of the two scales.

Results

The results are displayed in the maps below. They represent three different wind directions and different meteorological conditions for these directions. All are based on three-hour simulations. Truck queues are assumed to be present during each of these days.

The first sets represent winds that are approximately perpendicular to the road.

The second sets represent winds that are approximately parallel to the road.

The third sets represent typical winds in the Sarnia area. This set is broken into two groups, one for low winds and one for higher winds.

Within each set, there are three different cases based upon different atmospheric stabilities. Stability is a measure of the strength of the forces that cause turbulence in the atmosphere.

The first is a stable condition. This occurs when there is little no heating to cause convection. There is also little or no wind, as mechanical turbulence will still tend to mix the air especially near the ground. Anything released into the atmosphere will tend remain near the release point, dispersing only slowly.

In neutral conditions, the atmospheric conditions neither favour convection nor oppose it. Mixing will occur primarily due to wind turbulence. Pollution will disperse more quickly in these conditions than in stable conditions.

In convective (unstable) conditions, the atmosphere is heated from below and so vertical mixing will occur much like that seen in boiling water. This occurs in addition to any effects due to wind forces. These conditions tend to disperse pollution much more quickly.

In cases where the model predicted significant particulate concentrations, the traffic was also modelled without the truck queue to underline the queue's contribution to downwind particulate concentrations.

Perpendicular Winds

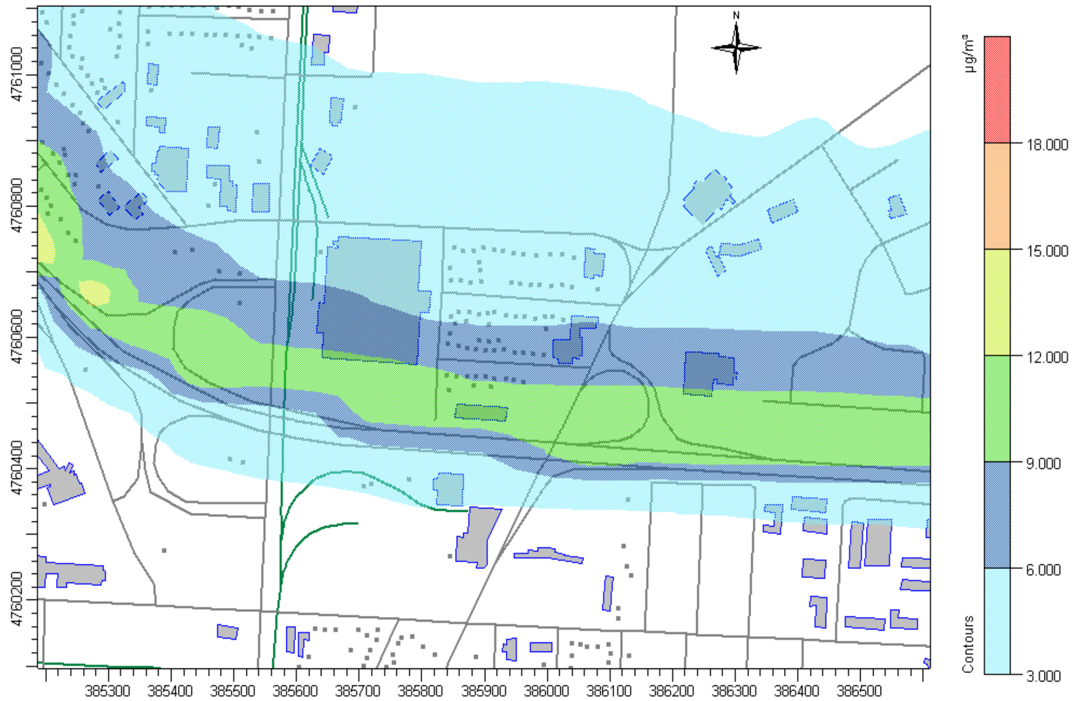


Figure 47: Stable Conditions, Truck Delays

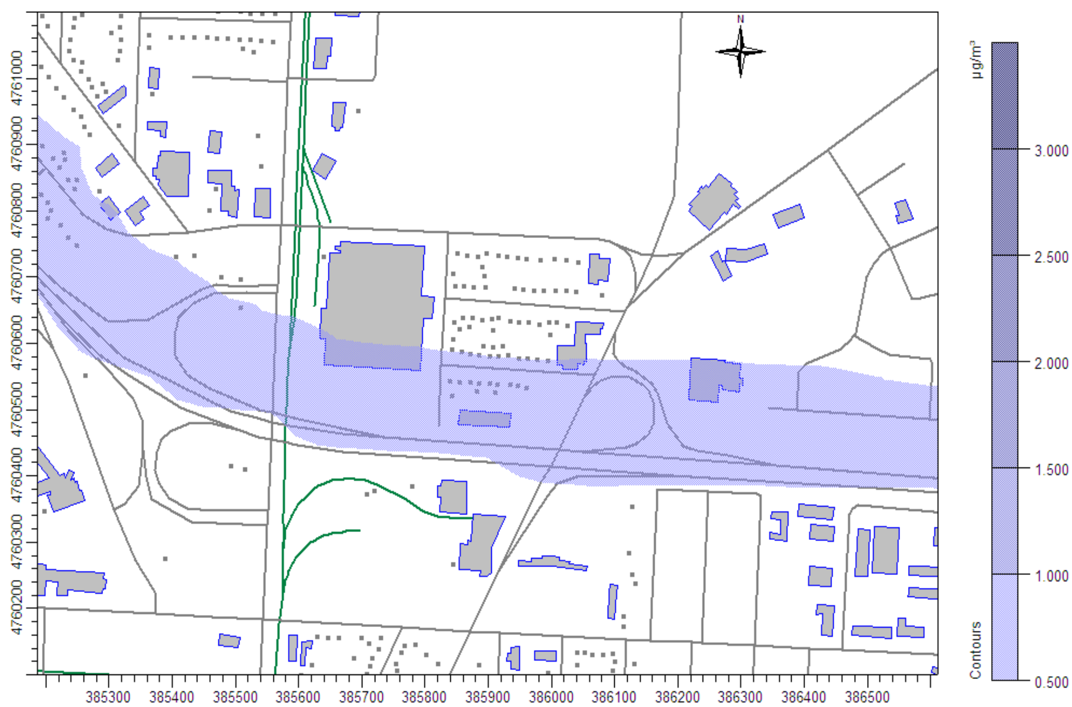


Figure 48: Stable Conditions, Free Flowing Traffic

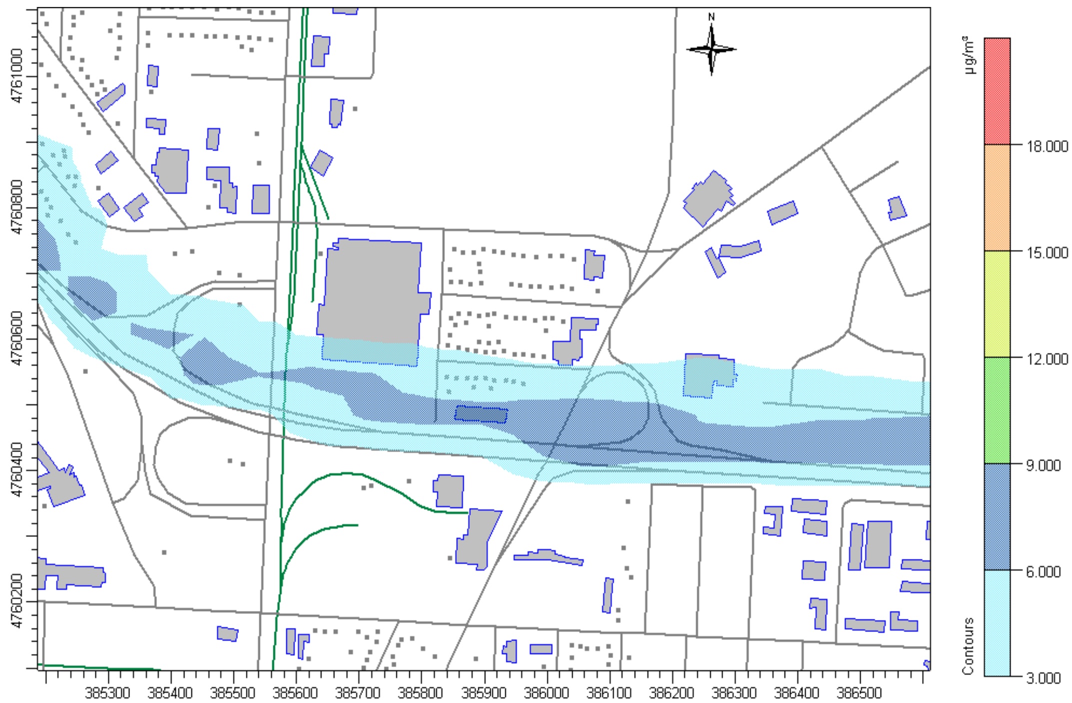


Figure 49: Neutral Conditions, Truck Delays

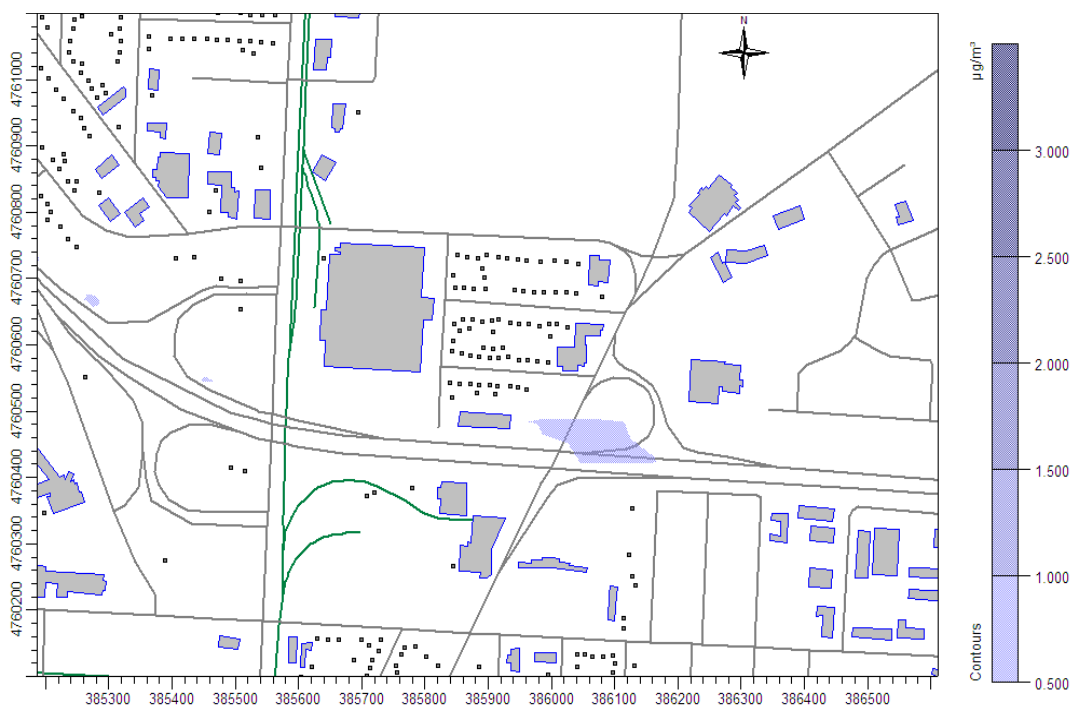


Figure 50: Neutral Conditions, Free Flowing Traffic

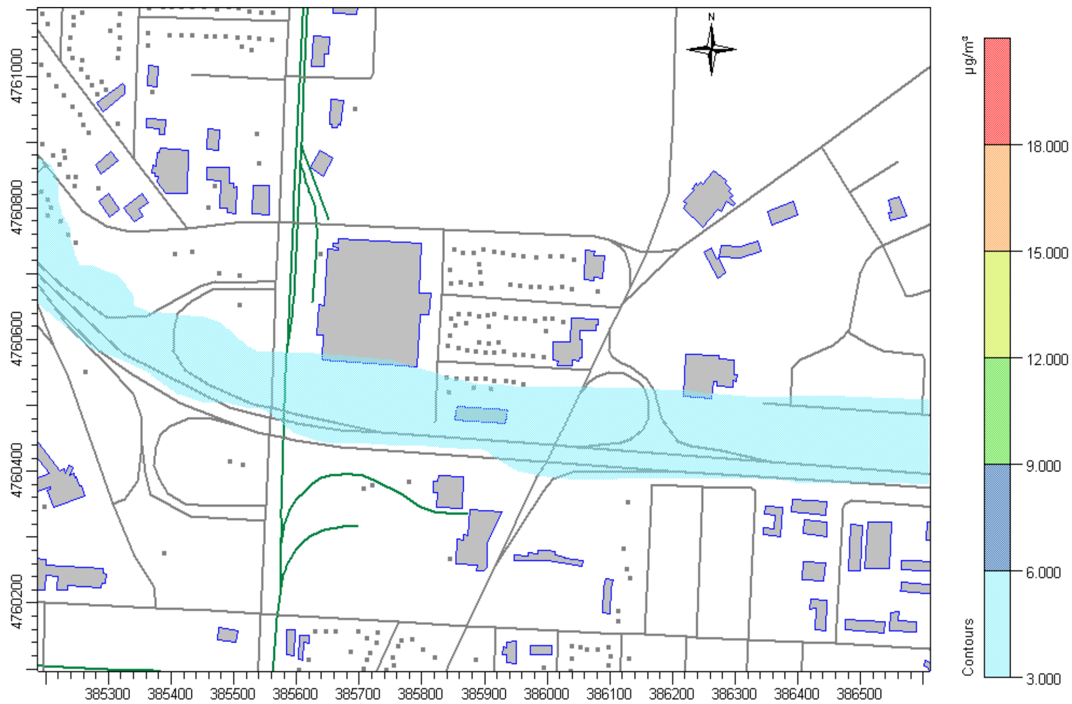


Figure 51: Convective Conditions, Truck Delays

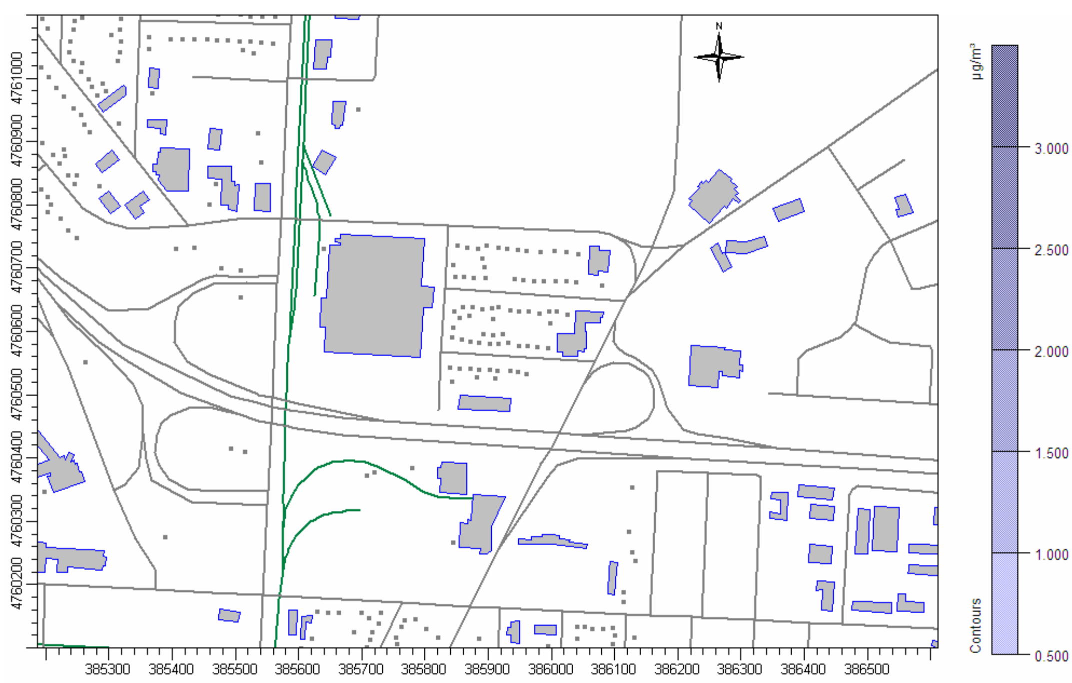


Figure 52: Convective Conditions, Free Flowing Traffic

Parallel Winds

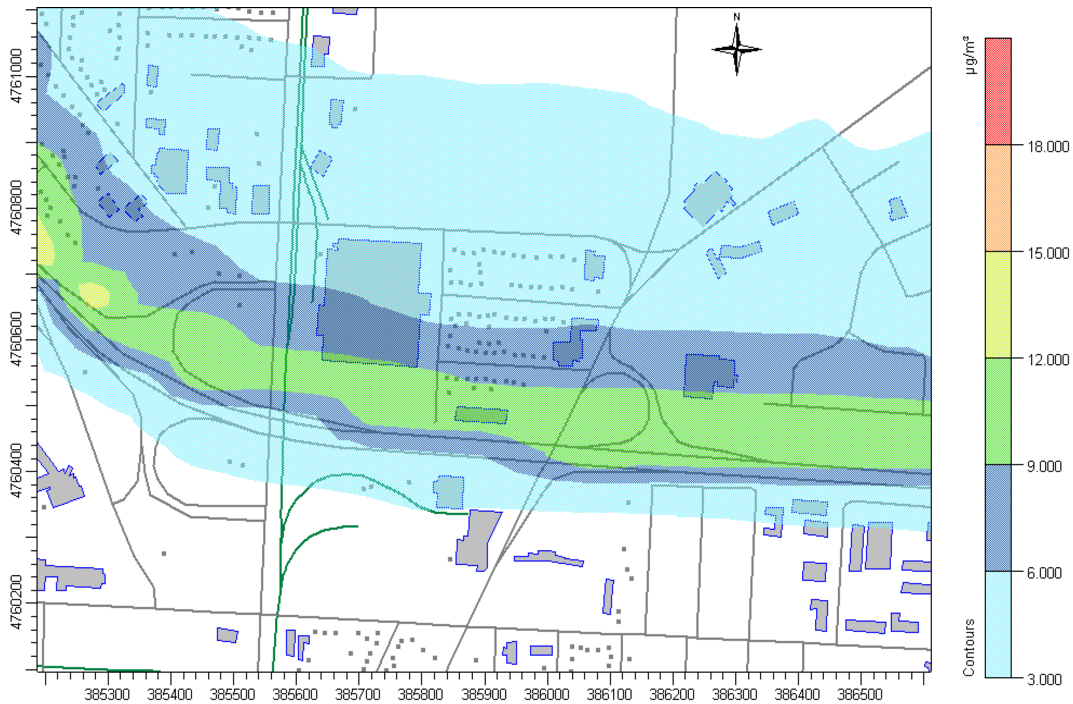


Figure 53: Stable Conditions, Truck Delays

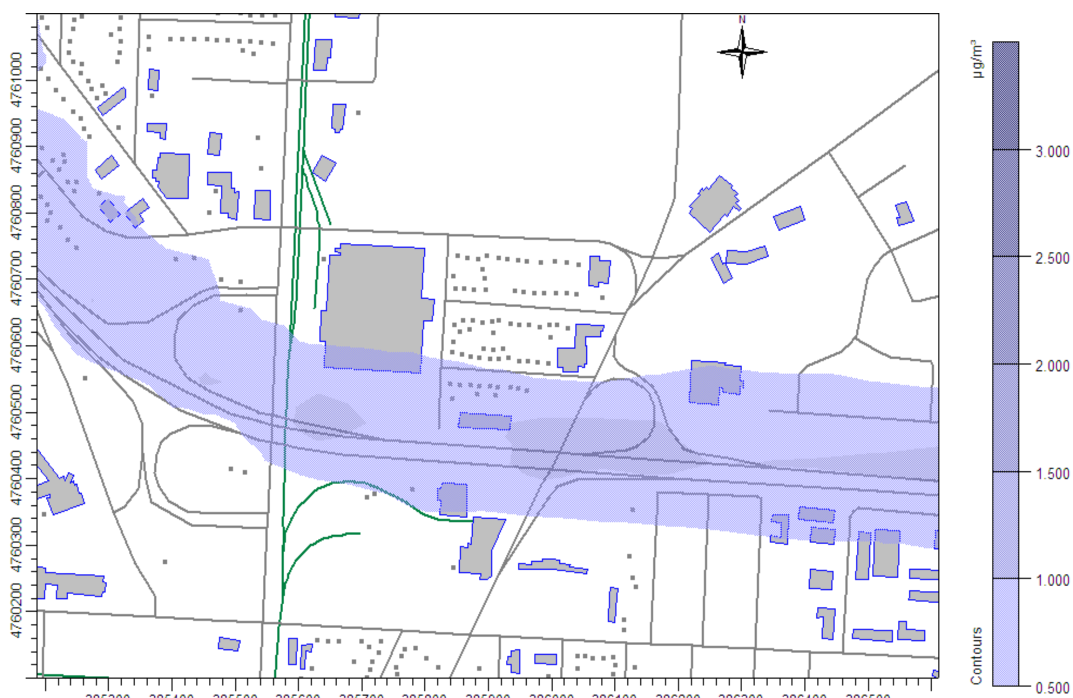


Figure 54: Stable Conditions, Free Flowing Traffic

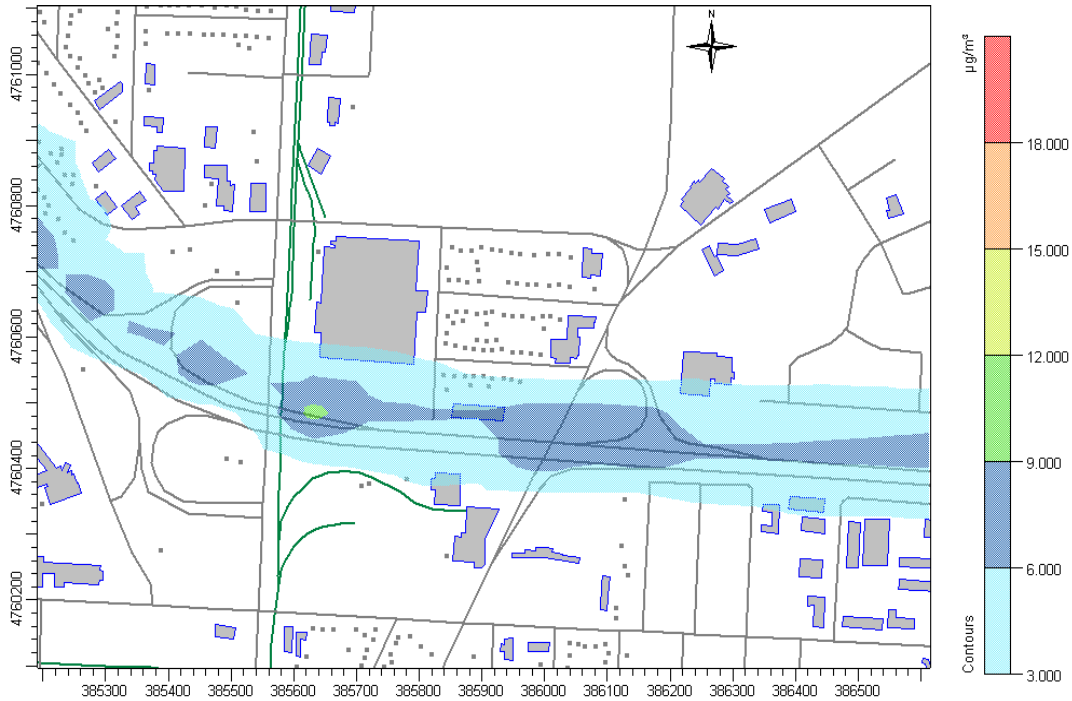


Figure 55: Neutral Conditions, Truck Delays

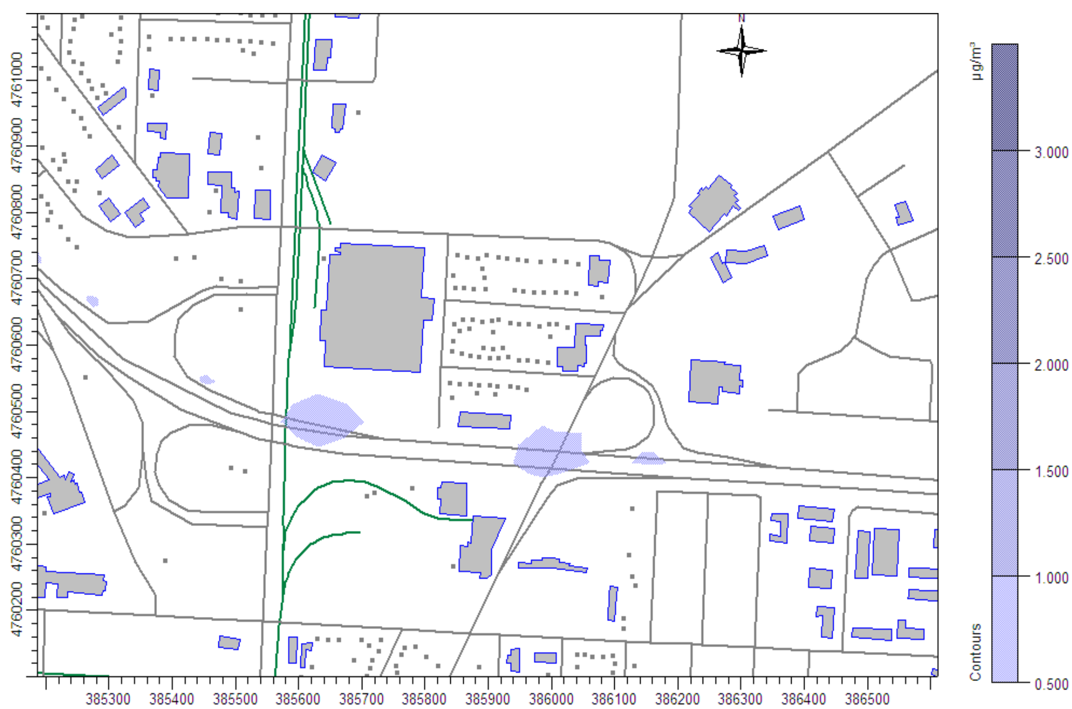


Figure 56: Neutral Conditions, Free Flowing Traffic

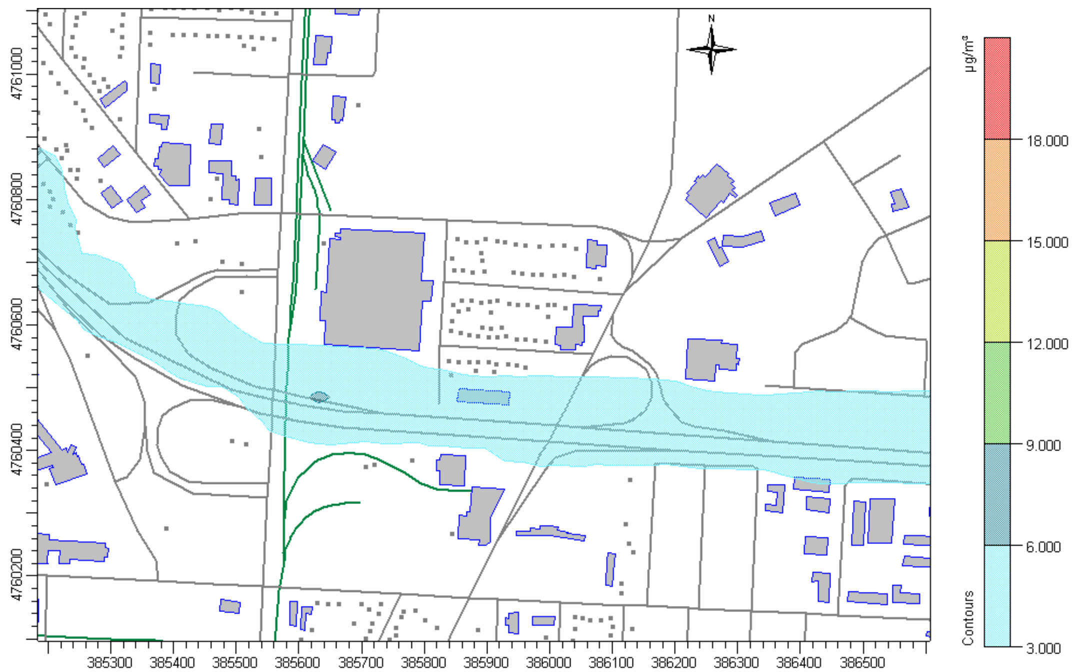


Figure 57: Convective Conditions, Truck Delays

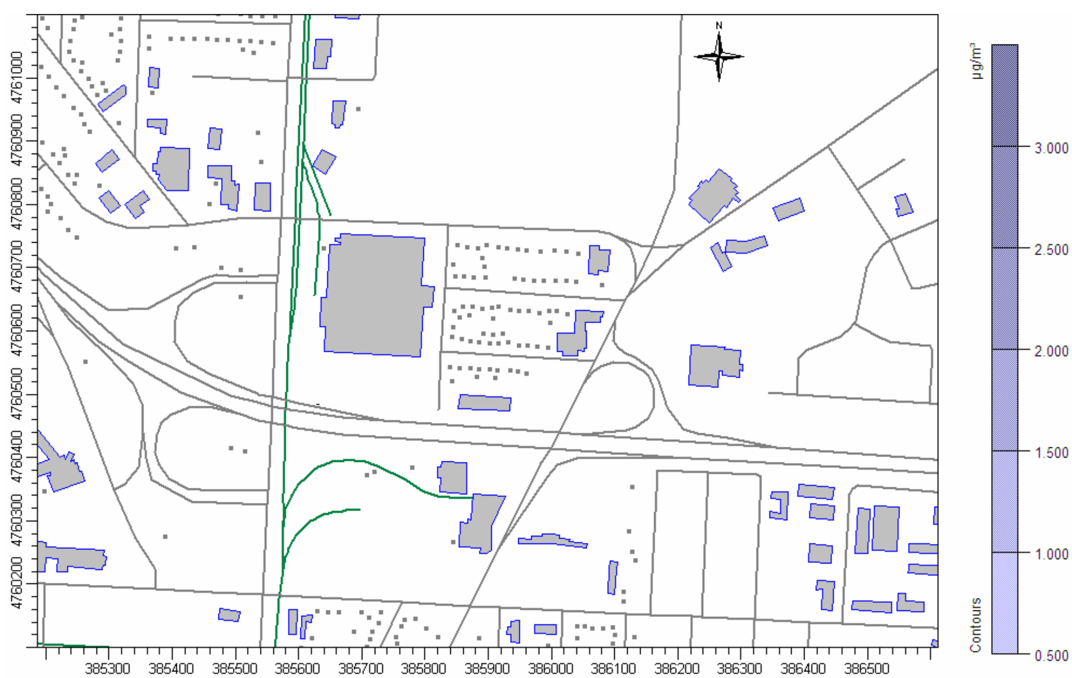


Figure 58: Convective Conditions, Free Flowing Traffic

Typical Sarnia Direction - Strong Winds

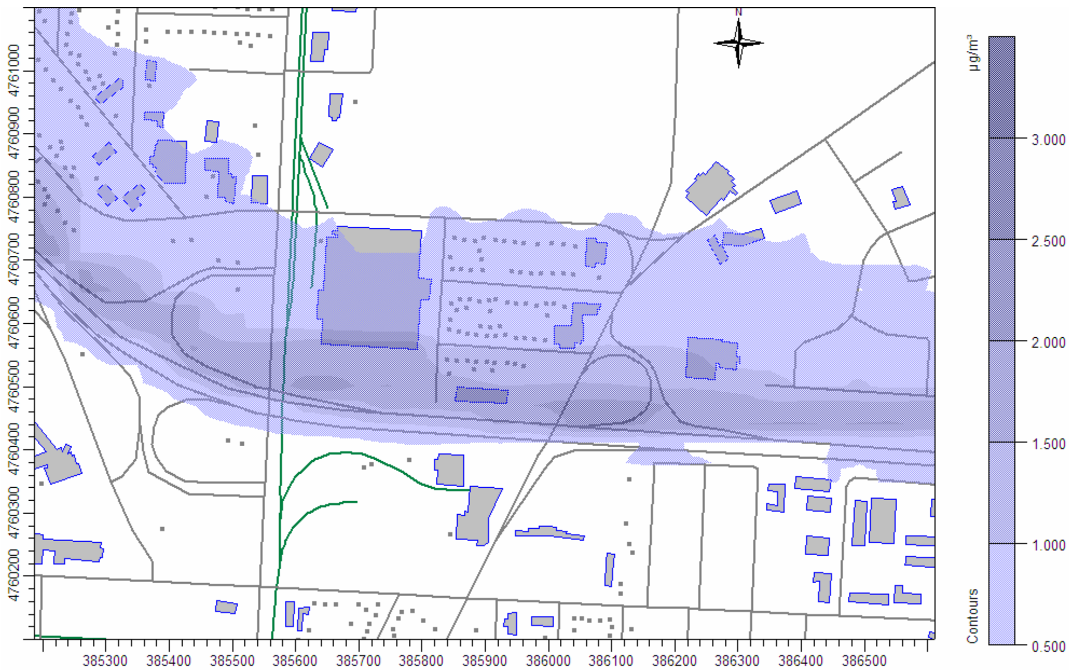


Figure 59: Stable Conditions, Truck Delays

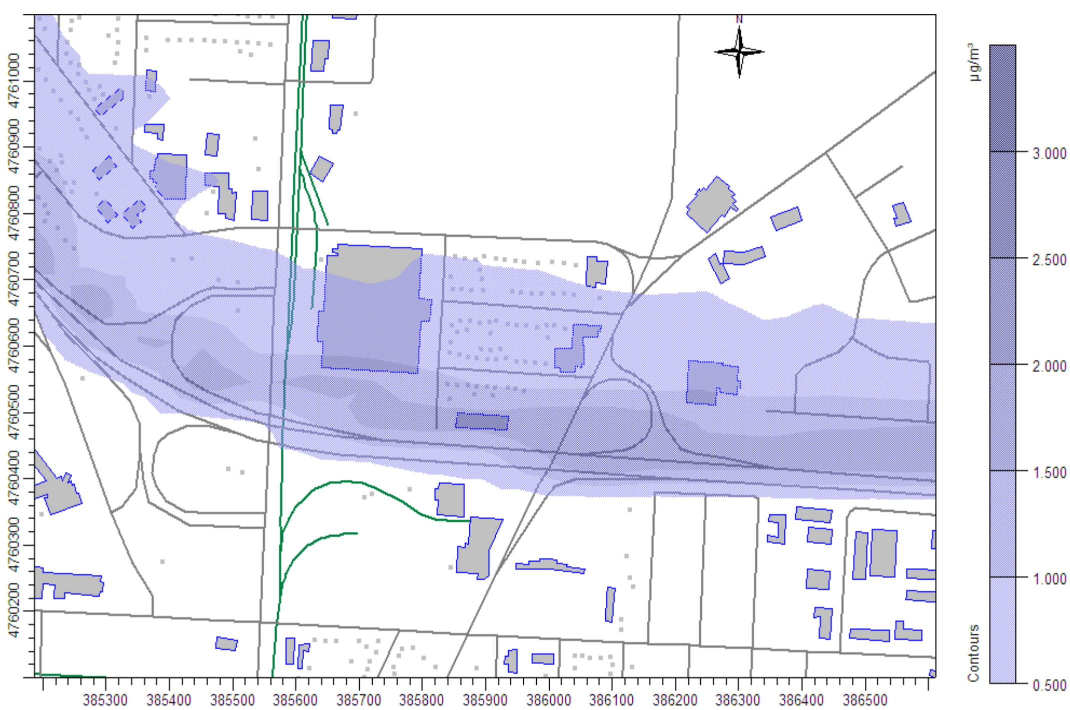


Figure 60: Neutral Conditions, Truck Delays

Figure 61: Convective Conditions, Truck Delays

Figure 62: Stable, Neutral and Convective Conditions, Free Flowing Traffic

Typical Sarnia Direction - Light Winds

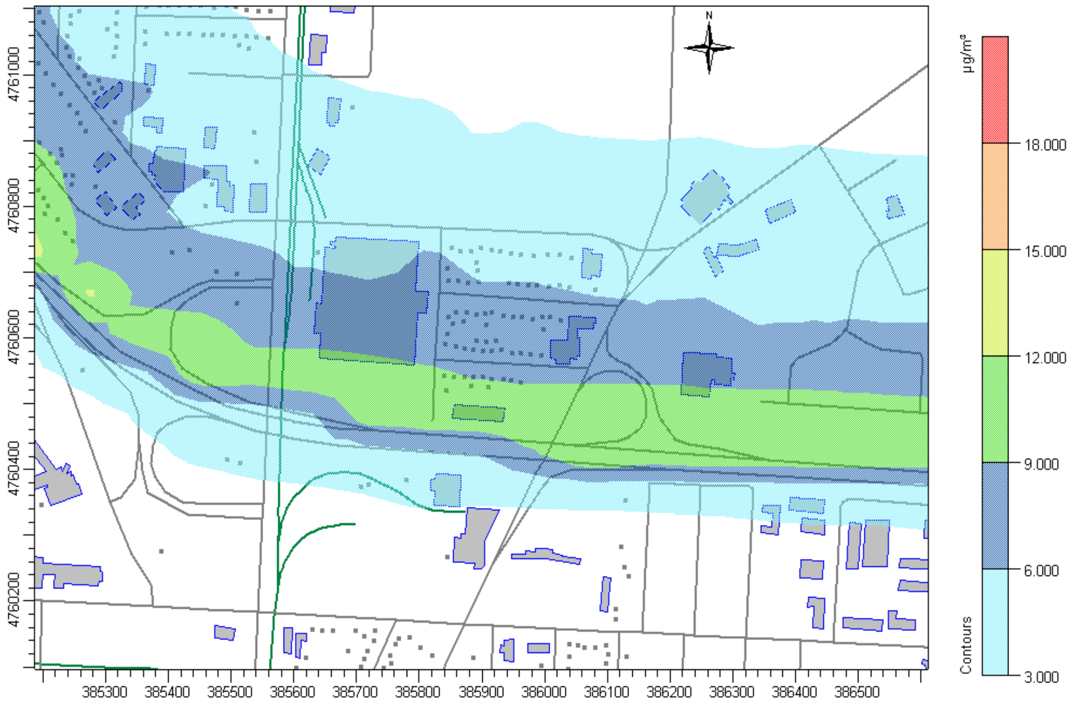


Figure 63: Stable Conditions, Truck Delays

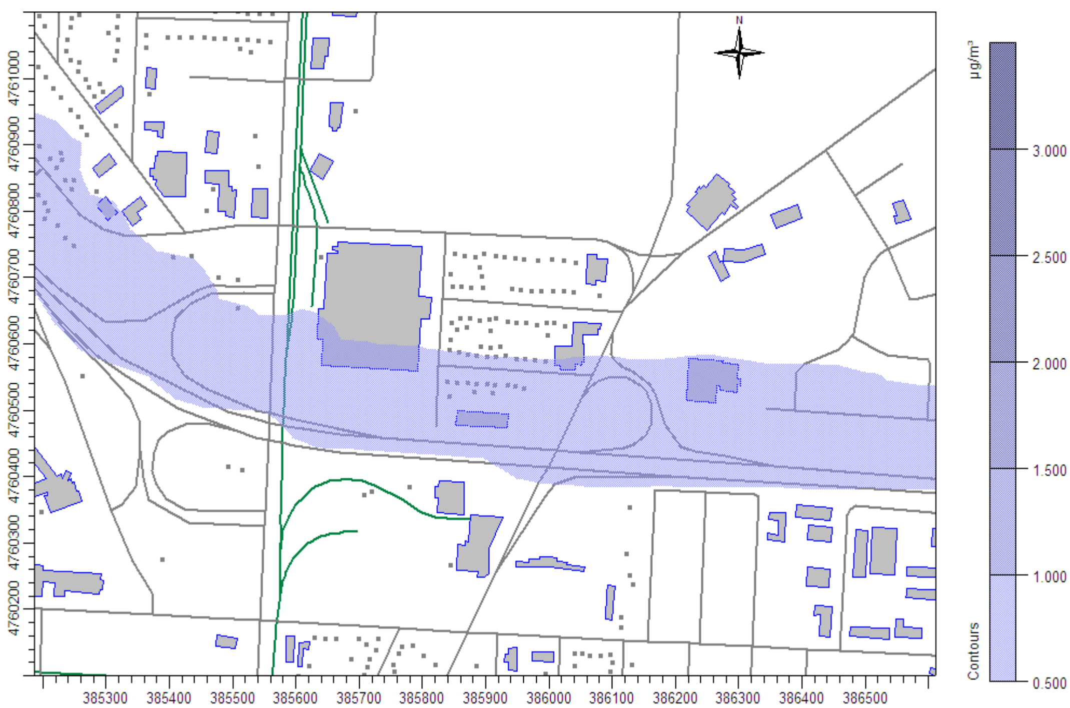


Figure 64: Stable Conditions, Free Flowing Traffic

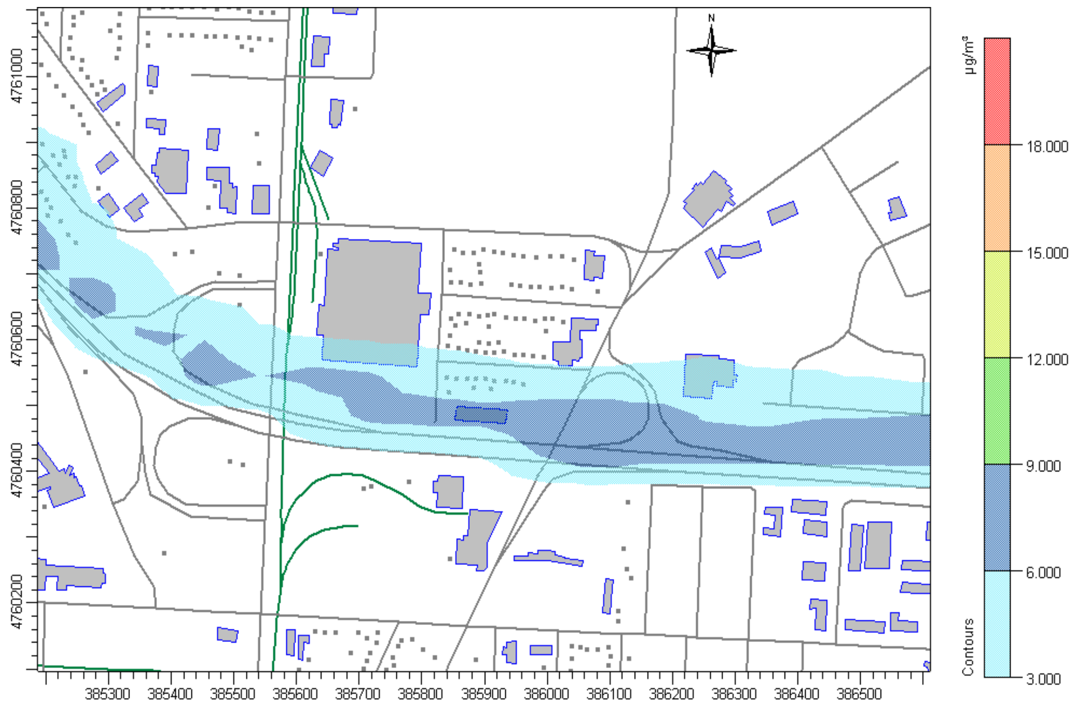


Figure 65: Neutral Conditions, Truck Delays

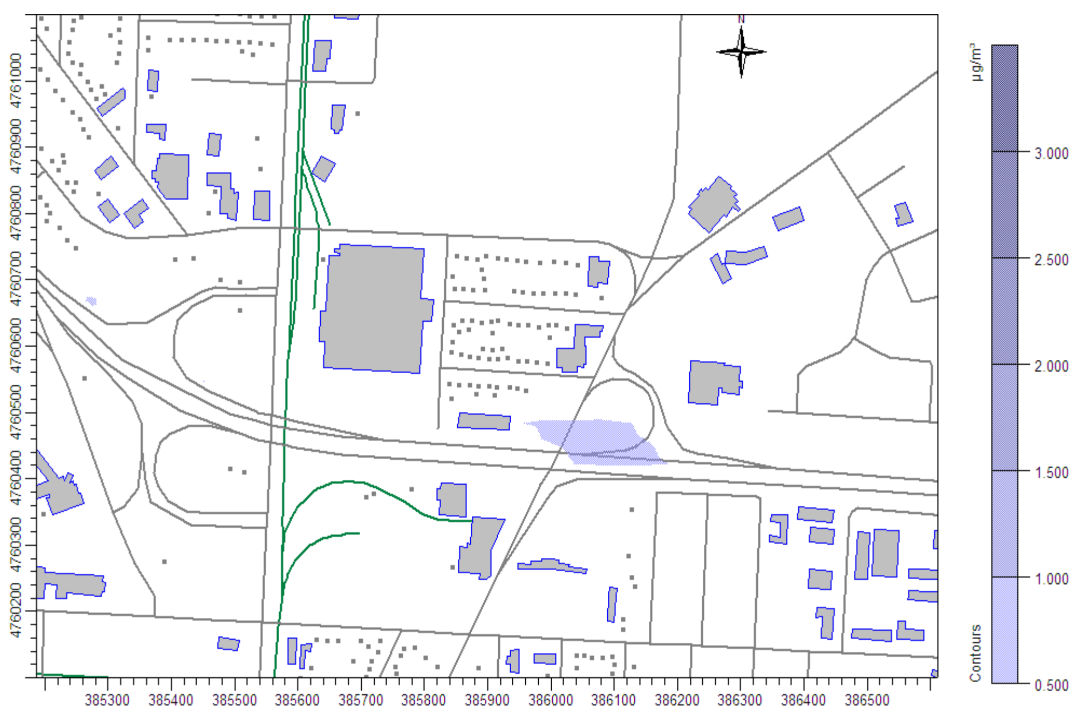


Figure 66: Neutral Conditions, Free Flowing Traffic

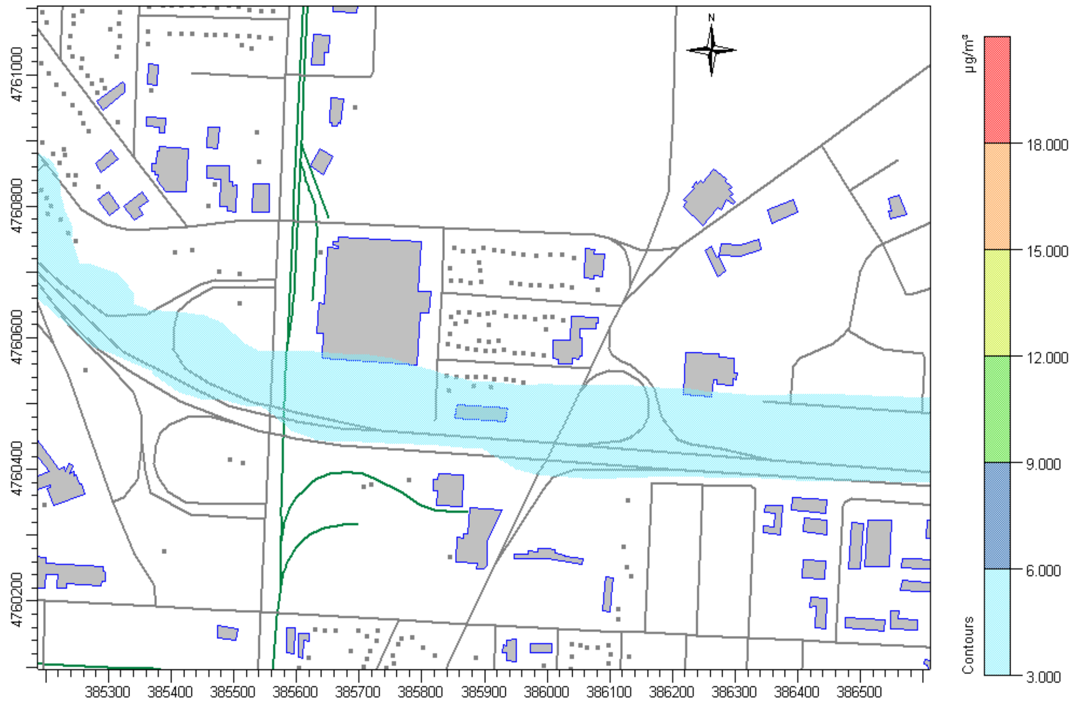


Figure 67: Convective Conditions, Truck Delays

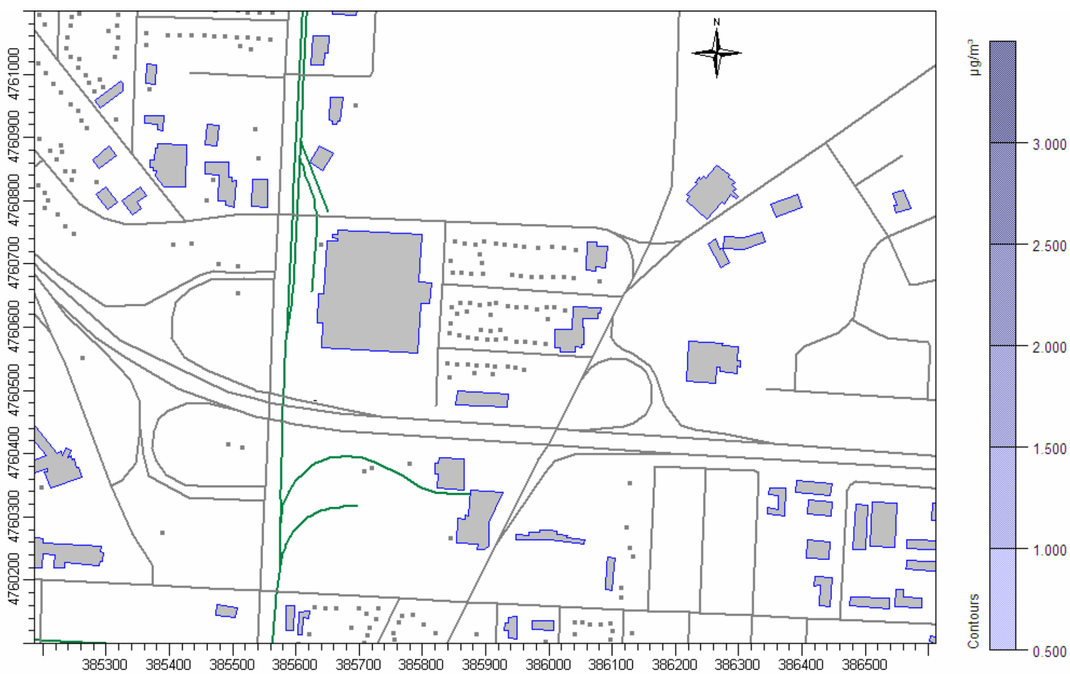


Figure 68: Convective Conditions, Free Flowing Traffic

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