FHWA and EPA

National Near-Road Study

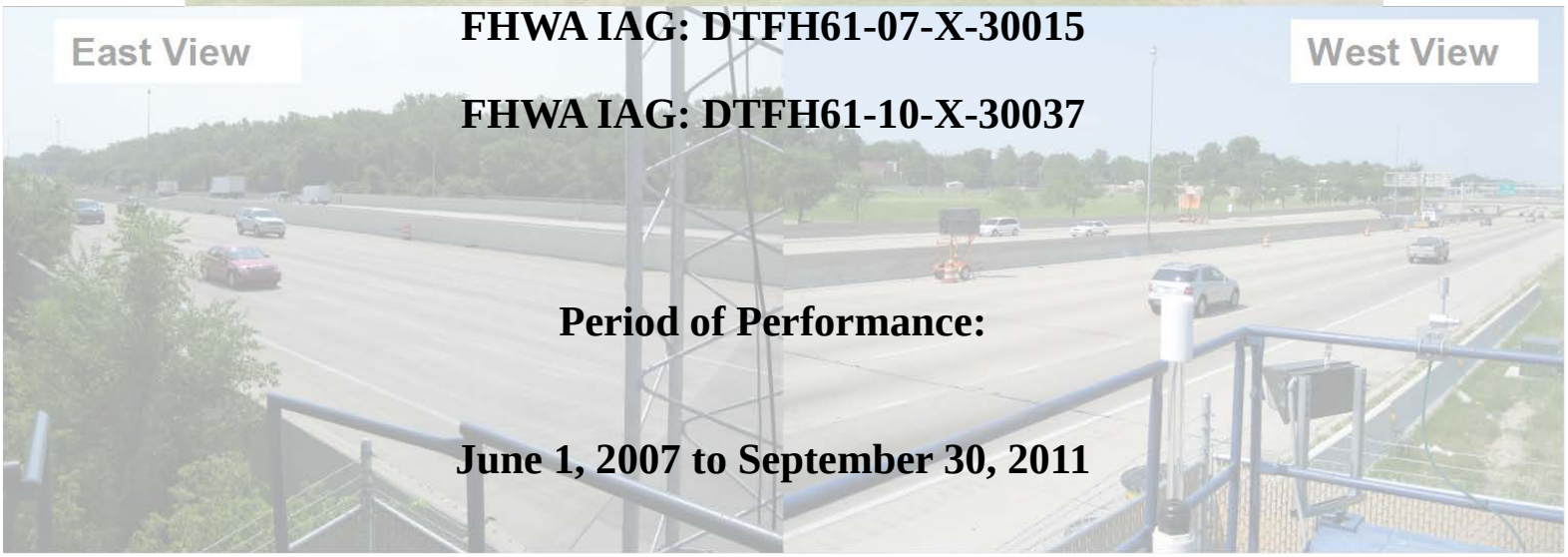
Detroit

EPA IAG: RW-69-922499

EPA IAG: RW-69-923285

FHWA IAG: DTFH61-07-X-30015

FHWA IAG: DTFH61-10-X-30037



Period of Performance:

June 1, 2007 to September 30, 2011

Technical Report Documentation Page

1. Report No. DTFH61-07-X-30015	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle FHWA and EPA National Near-Road Study, Detroit, MI		5. Report Date May 2013 6. Performing Organization Code: EPA IAG: RW-69-922499	
7. Author(s) Sue Kimbrough, EPA. Richard C. Shores, EPA. Donald A. Whitaker, EPA		8. Performing Organization Report No.	
9. Peforming Organization Name and Address Daniel A. Vallero U.S. Environmental Protection Agency, MD E-205-02 109 TW Alexander Dr. Research Triangle Park, NC 27711		10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFH61-07-X-30015	
12. Sponsoring Agency Name and Address Office of Natural Environment Federal Highway Administration 1200 New Jersey Ave., SE Washington DC 20590		13. Type of Report and Period Covered Near Road Pollutant Concentration Monitoring. June 1, 2007 to September 30, 2011 14. Sponsoring Agency Code HEPN-1	
15. Supplementary Notes The research was conducted by U.S. Environmental Protection Agency (EPA) and overseen by a Near Road Team consisting of many representatives of Federal Highway Administration and EPA. A more detailed list can be found in Box 16.			
16. Abstract: This report provides a summary of a field study conducted in Detroit, MI from September 2010 thru mid-June 2011. The objective of this research study has been to determine Mobile Source Air Toxic (MSAT) concentrations and variations in concentrations as a function of distance from the highway and to establish relationships between MSAT concentrations as related to highway traffic flows including traffic count, vehicle types and speeds, meteorological conditions such as wind speed and wind direction; and other pollutants primarily emitted from motor vehicles. EPA/FHWA Near Road Team Daniel L. Costa, National Program Director, Air Climate and Energy, David D. Kryak, EPA Gayle S.W. Hagler, EPA, Douglas McKinney, EPA, Carlos Nunez, EPA William Mitchell, EPA, Richard W. Baldauf, EPA Eben Thoma, EPA, Carry W. Croghan, EPA Alan Vette, EPA. Victoria Martinez, IAG Project Officer, FHWA, Karen Perritt, FHWA.			
17. Key Words Near Road Air Pollution Monitoring, pollutant concentrations, monitoring, Mobile Source Air Toxics (MSAT).			
18. Distribution Statement No restrictions. This document is available to the public electronically through the Federal Highway Administration Office of Natural Environment, Washington DC, 20590			
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 152	22. Price

This report in part meets the reporting requirements as delineated in the terms and conditions of EPA IAG: RW-69-922499 and EPA IAG RW-69-923285.

Project Officer: Daniel A. Vallero

U.S. Environmental Protection Agency
MD E-205-02
109 TW Alexander Dr.
Research Triangle Park, NC 27711

vallero.daniel@epa.gov
(v) 919-541-3306

Technical Contacts:

Sue Kimbrough	**kimbrough.sue@epa.gov** **(v) 919-541-2612**	**U.S. Environmental Protection Agency** **MD-E343-02** **109 TW Alexander Dr.** **Research Triangle Park, NC 27711**
Richard C. Shores	**shores.richard@epa.gov** **(v) 919-541-4983**	**U.S. Environmental Protection Agency** **MD-E343-02** **109 TW Alexander Dr.** **Research Triangle Park, NC 27711**
Donald A. Whitaker	**whitaker.donald@epa.gov** **(v) 919-541-1571**	**U.S. Environmental Protection Agency** **MD-E205-04** **109 TW Alexander Dr.** **Research Triangle Park, NC 27711**

EPA/FHWA Near Road Team	
Daniel L. Costa, National Program Director, Air Climate and Energy	
David D. Kryak, EPA	Gayle S.W. Hagler, EPA
Douglas McKinney, EPA	Mike Hays, EPA
Carlos Nunez, EPA	William Mitchell, EPA
Richard W. Baldauf, EPA	Eben Thoma, EPA
Carry W. Croghan, EPA	Alan Vette, EPA
Victoria Martinez, IAG Project Officer, FHWA	
Karen Perritt, FHWA	Kevin Black, FHWA

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

Executive Summary

Part I: Study Overview

In 2002, the Sierra Club legally challenged the U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) and the Nevada Department of Transportation's (NDOT) National Environmental Policy Act (NEPA) environmental document related to the proposed widening of U.S. 95 in Las Vegas, Nevada. FHWA entered into a Settlement Agreement with Nevada DOT and the Sierra Club, wherein the FHWA agreed to undertake a research effort to characterize the impact and behavior of particulate matter with aerodynamic diameter less than 2.5 microns ($PM_{2.5}$) and MSATs near highways.[1]

The FHWA and U.S. Environmental Protection Agency (U.S. EPA) determined that it would be in the best interest of both organizations to implement this project in a collaborative manner, allowing a more effective utilization of staffing and resources. The first study was conducted in the city of Las Vegas, Nevada in the vicinity of I-15. The site location was just south of the I-15 and Russell Road interchange and just north of the I-15 and I-215 interchange. This was completed in mid-December, 2009. Detroit was the second study city. A site was selected for Detroit in collaboration with FHWA, Michigan DOT, Southeast Michigan Council of Government and EPA. The site selected for Detroit was along I-96, east of Telegraph Road (US 24) (Figure 1).

The objective of the study conducted under this Protocol was to determine MSAT concentrations and variations in concentrations as a function of distance from the highway and to establish relationships between MSAT concentrations as related to highway traffic flows including traffic count, vehicle types, and speed; meteorological conditions such as wind speed and wind direction; and other air pollutants emitted from motor vehicles such as carbon monoxide (CO) and oxides of nitrogen (NO_X).[2] This report focuses on carbon monoxide (CO), nitrogen oxide (NO), nitrogen dioxide (NO_2), oxides of nitrogen (NO_X), black carbon (BC), particulate matter less than 10 microns (PM_{10}), $PM_{2.5}$, PM Coarse, and MSAT (1-3, butadiene, benzene, acrolein, formaldehyde, acetaldehyde) measurements (Table 1).

FHWA's "detailed monitoring protocol" outlined a uniform approach to conduct this study, as well as future related studies, for evaluating mobile source contributions to air toxic compounds and $PM_{2.5}$ and their dispersion patterns[2]. This protocol was peer reviewed by other federal agencies (EPA and DOE), State environmental and transportation agencies, the Sierra Club, and academic institutions. A more detailed examination of the monitoring protocol indicates that for each city, continuous monitoring and integrated sample collection was required at four monitoring sites located at distances ranging from roadside to 300 meters (m). In addition, wind speed and wind direction was required at each site. Moreover, monitoring for the complete suite of meteorological parameters was required at the monitoring station positioned 50 to 150 m from the roadway (100 meter downwind).

Part II: Site Selection

The site selection process consisted of a series of seven steps (1) determine site selection criteria[2]; (2) develop list of candidate sites and supporting information; (3) apply site selection filter ("coarse" and "fine"), (4) site visit; (5) select candidate site(s) via team discussion; (6) obtain site access permission(s); and (7) implement site logistics. This process resulted in the selection of a location along I-96, just east of Telegraph Road (US 24).[3]

Of the eighteen sites evaluated, the I-96 site was considered the "optimal" site of all the monitoring sites considered[3]. This site had the most advantages and fewest disadvantages of all the monitoring sites considered in meeting the project objectives.

This site had high AADT (165,300 AADT for 2006), no noise walls, meteorological and traffic data availability, manageable site logistics including right-of-way (ROW) access, and favorable wind direction[4]. Of the disadvantages, this site did not permit a perpendicular transect and it is in an urban industrialized area that may contain potentially confounding nearby sources.

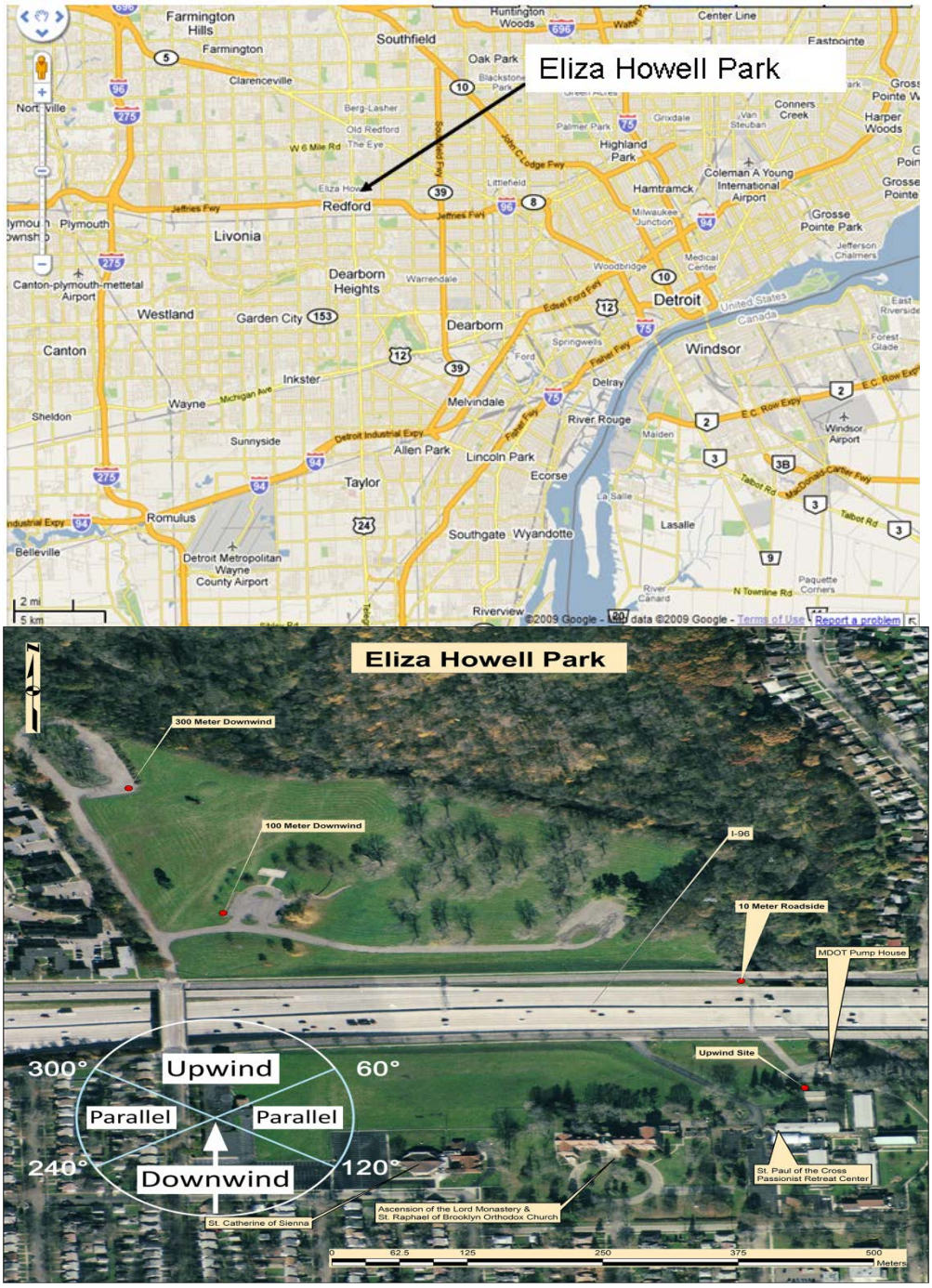


Figure 1. Map of Detroit Monitoring Sites and Wind Sectors.

Part III: Analytical Instruments and Methods

The analytical methods implemented during this study followed EPA standard methods and Federal Reference Methods for performing ambient air measurements when applicable.

The following table summarizes the measurements taken at each monitoring site.

Table 1. Summary of Measurements Conducted at Each Monitoring Site.

Measurements	10 Meter Roadside	100 Meter Downwind	300 Meter Downwind	100 Meter Upwind
TO-11A Cartridge sampling	X	X	X	X
TO-15 Canister sampling	X	X	X	X
Continuous gas monitoring (CO, NO_x)	X	X	X	X
Continuous black carbon monitoring (Aethalometer)	X	X	X	X
Continuous fine particle (TEOM)	X	X	X	X
Integrated $PM_{2.5}$ (FRM)	X	X	X	X
Wind speed/wind direction	X	X	X	X
Meteorological monitoring (temp, RH, etc.)		X		
Sound Meter	X	X		
Video Camera	X			X
Traffic Sensors (Wavetronix)	X			X

The video was also used to validate traffic count information from the radar units.

Most analyzers deployed for this study performed well with the exception of the TEOMs. While an instrument upgrade was performed in the field by technical staff from the equipment manufacturer in late November 2009 and early December 2009 in Las Vegas, Nevada, these upgrades improved instrument performance and stability, but issues remained. Instrument performance remained an issue throughout the Detroit study.

Part IV: Data Management, Analysis and Validation

Figure 2 provides a conceptual flow diagram of the data management process utilized in this study. Additional details on this process, as well as data analysis and validation procedures are provided in the Quality Assurance Project Plan (QAPP) developed for this study.

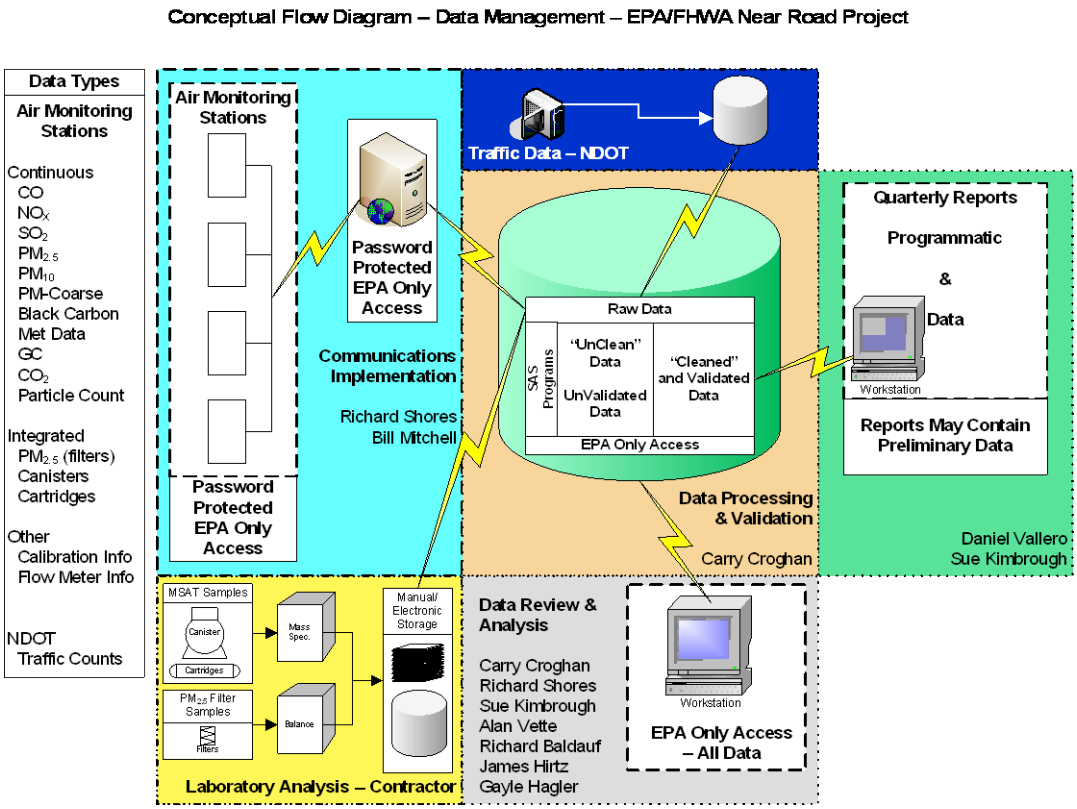


Figure 2. Flow Diagram - Data Management

Part V: Results and Discussion

During this study gigabytes of data were collected—including data from continuous monitors such as the CO, NO_X, BC and TEOM (PM_{10}, $PM_{2.5}$, PM Coarse) analyzers, etc.; integrated sample data; traffic data and video data. Results (i.e., data and graphs) presented herein were selected based on the original objectives of the study: "…to determine MSAT concentrations and variations in concentrations as a function of distance from the highway and to establish relationships between MSAT concentrations as related to highway traffic flows including traffic count, vehicle types, and speed; and meteorological conditions such as wind speed and wind direction; and other pollutants primarily emitted from motor vehicles such as CO, NO, NO_2, NO_X and BC."[2]

Traffic Activity.

Traffic activity for this location exhibited the typical bi-modal distribution as shown in Figure 3. It should be noted that construction activity on the M-39, an adjacent connecting freeway, may have influenced traffic patterns during a portion of this study. The field team noted that construction did take place on the M-39 during the late-winter/early-spring of 2011.

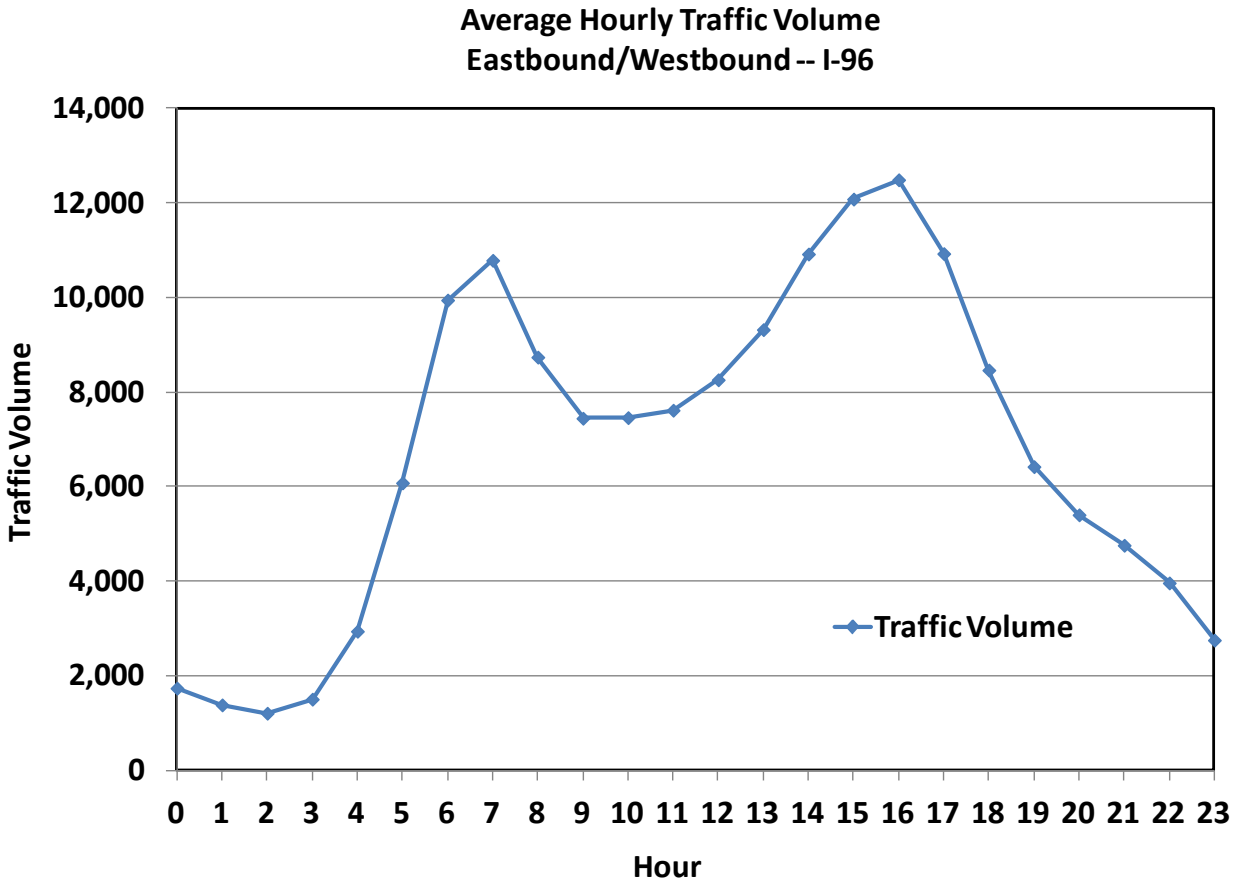


Figure 3. Average Hourly Traffic Volume at I-96 Site from Sept. 29, 2010 through June 20, 2011.

Meteorology.

Figure 4 a. shows wind direction and speeds by time of day. Figure 4 b. shows percent of time the wind is from each sectors by month, observed during the course of the study. As can be seen from the wind roses, there were strong northwesterly winds during the morning commute hours. One implication is that the study sites may have been influenced by nearby sources such as traffic from US-24, Telegraph Road, a 6-lane divided highway approximately 440 meters west of Station 2 and 380 meters west of Station 3. An additional nearby source of air pollutants was the apartment complex immediately adjacent (west of Station 2 and 3). The source of emissions at the apartment complex was most probably cold-start emissions from passenger vehicles.

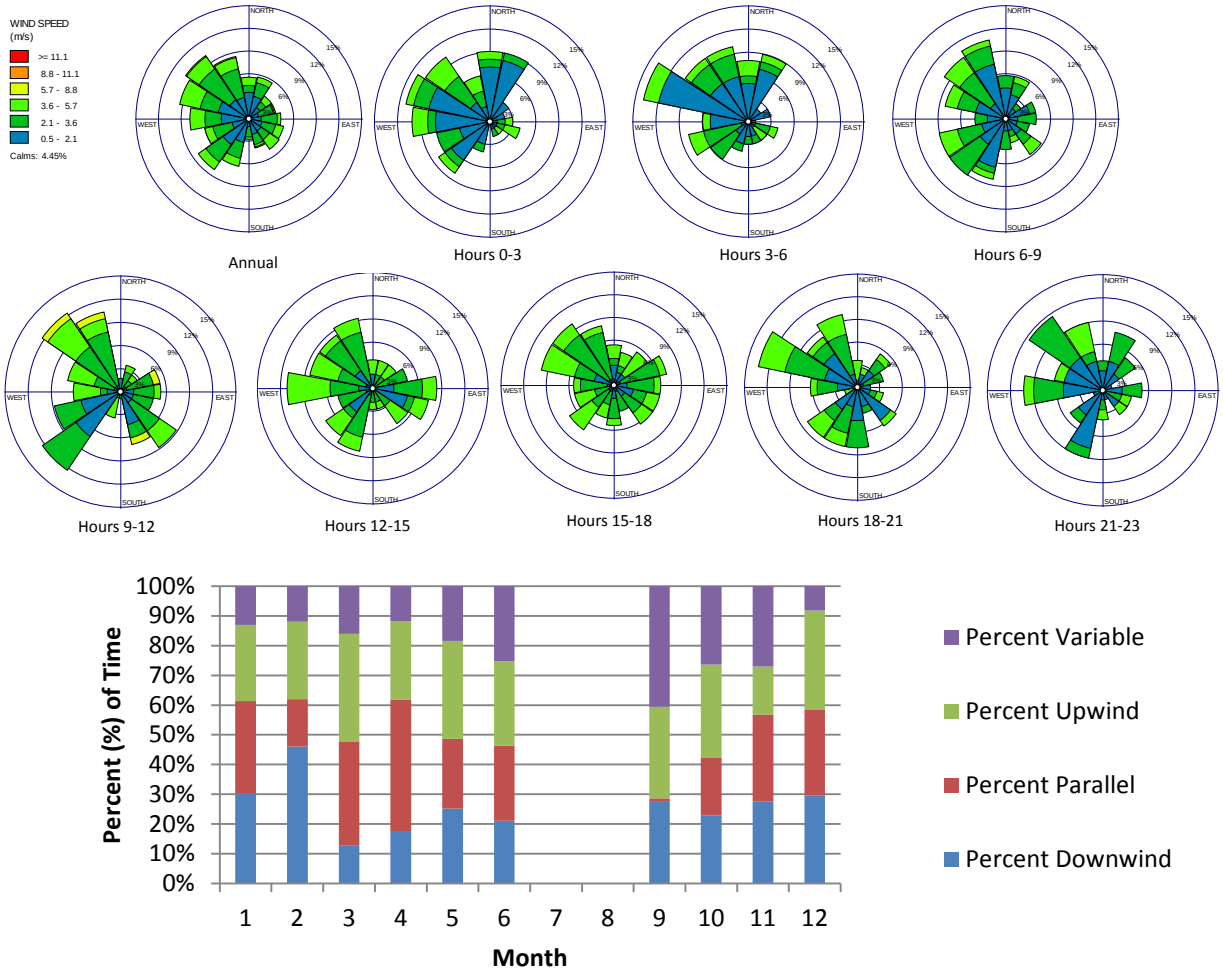


Figure 4 a. Wind Roses from the 100 m Station North of I-96 by time of day and Figure 4 b. Wind Direction in Percent, September 2010 through June 2011

Air Quality – Continuous Analyzers.

Figure 5 shows the spatial gradient for NO, NO_2, and NO_X for the study period. The spatial gradient is similar to the spatial gradient for the Las Vegas study. As shown by the figure the mean values for Station 3 are slightly higher than Station 2. This may be the result of air pollutant influences from nearby sources.

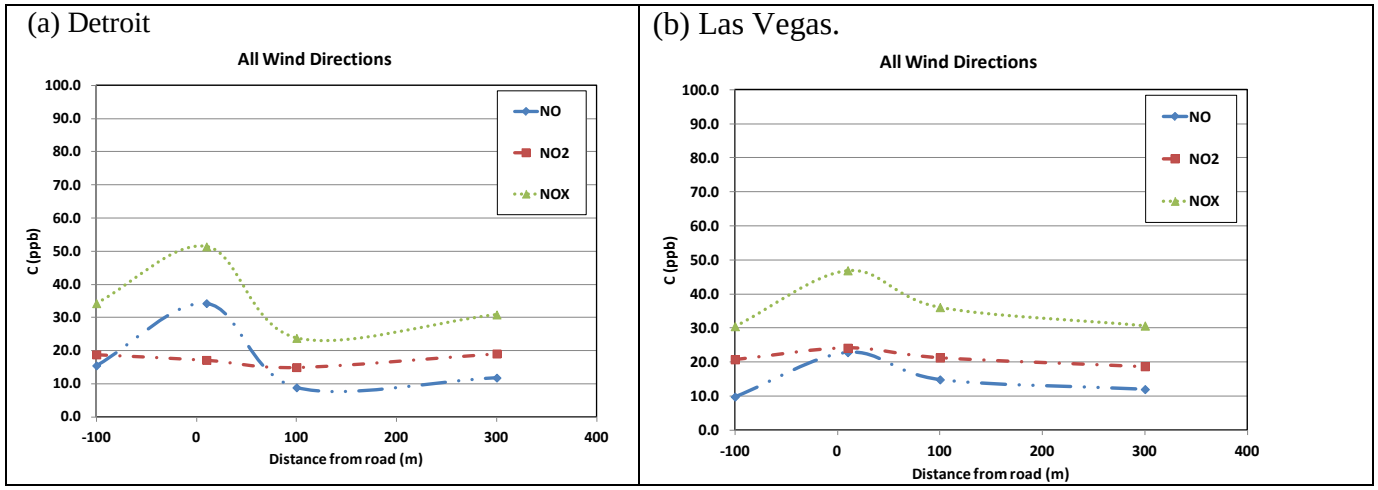


Figure 4 Average concentrations of NO, NO_2 and NO_x measured at all four monitoring stations indicating long-term trends in concentration gradients for each pollutant (a) Detroit. (b) Las Vegas – (source FHWA and EPA National Near-Road Study Las Vegas Final Report).

Figure 5 note: The lines connecting the points are provided as a visual aid to the reader and do not imply statistically significant differences in concentrations.

Figure 6 shows a polar plot for NO_2 for all stations and all wind directions. The radial dimension is an indicator of wind speed (m/sec). Further away from the center of the plot, the higher the wind speed.

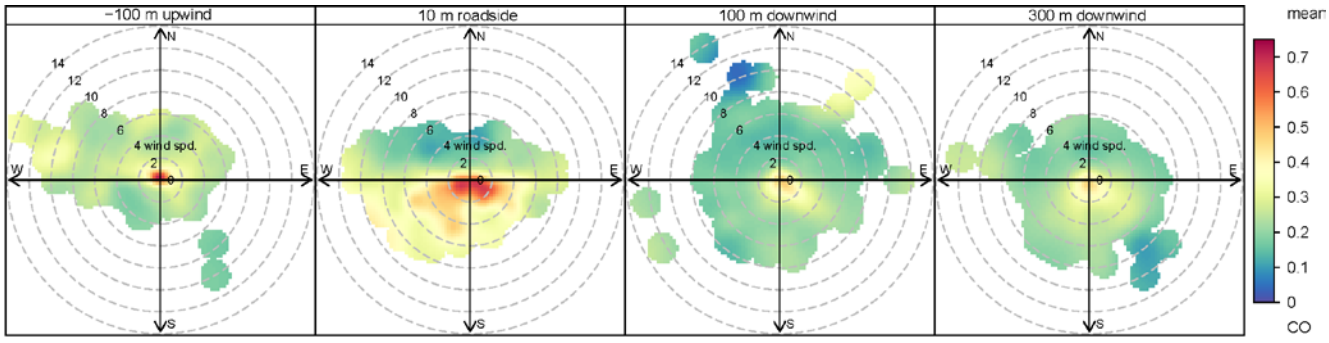


Figure 5 Polar plot for NO_2 for all stations, all wind directions.

Note that higher average NO, NO_2 and NO_X concentrations and generally steeper gradients were observed during conditions when the winds are from the roadway as opposed to all wind directions (Figure 6). This may also be observed in CO concentration plots, Figure 7 and Figure 8. As shown by these figures (Figures 8, and 9) the mean values for Station 3 are slightly higher than Station 2. This may be the result of air pollutant influences from nearby sources.

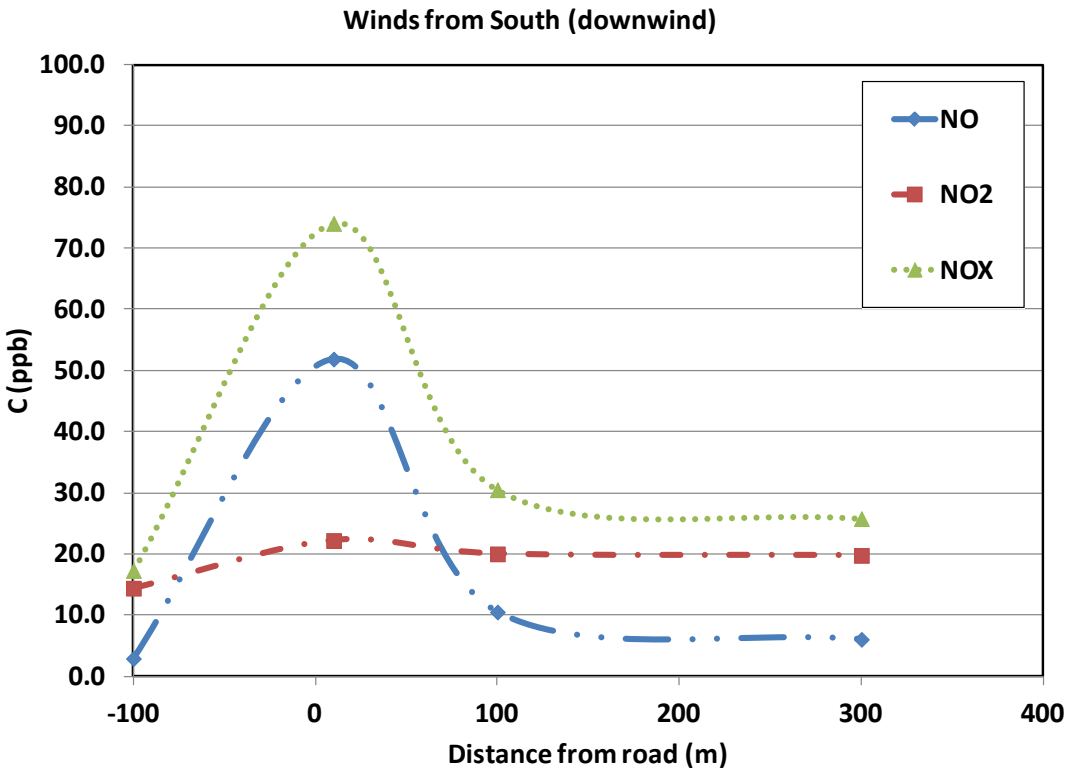


Figure 6 Average concentrations of NO, NO_2, and NO_x measured at all four monitoring stations indicating long-term trends in concentration gradients for each pollutant—winds from south.

Figure 7 note: The lines connecting the points are provided as a visual aid to the reader and do not imply statistically significant differences in concentrations.

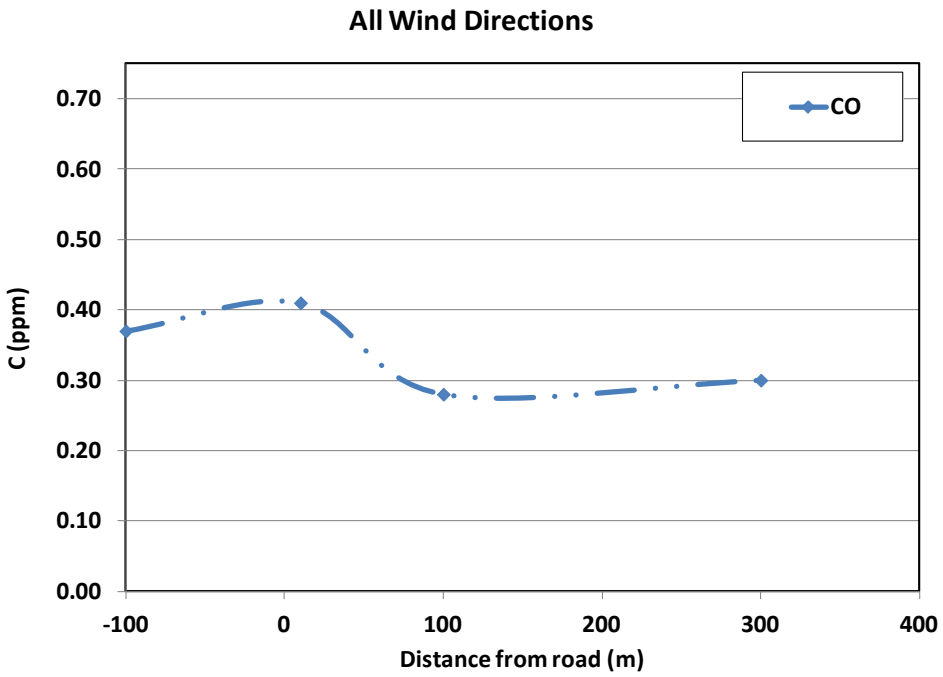


Figure 7 Average CO concentrations – winds from all wind directions.

Figure 8 note: The lines connecting the points are provided as a visual aid to the reader and do not imply statistically significant differences in concentrations.

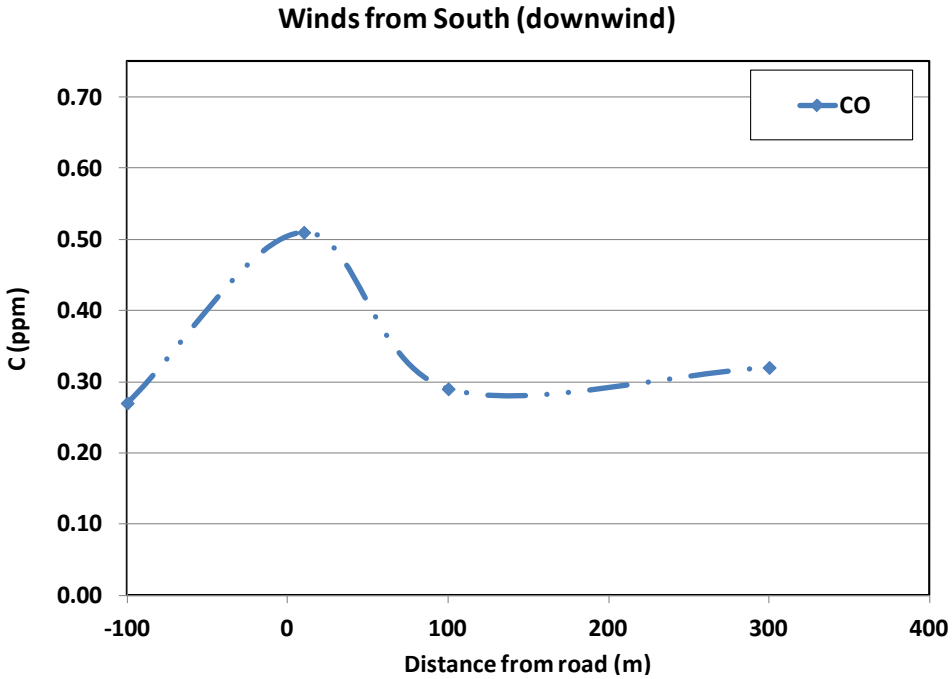


Figure 8. Average CO Concentrations -- winds from south.

Figure 9 note: The lines connecting the points are provided as a visual aid to the reader and do not imply statisticially significant differences in concentrations.

Air Quality – Integrated Samples -- VOC

Table 2 shows the number of observations, mean and 95% confidence intervals for the VOC data (TO-15 method).

Table 2. VOC -- averages for all wind directions (09/29/2010-06/15/2011)

Site name	Distance from Road	N (Obs.)	Mean (ppb)	95% CI (ppb)
Acrolein				
4	100 m upwind	32	0.72	0.55 – 0.89
1	10 m roadside	37	0.69	0.56 – 0.82
2	100 m downwind	21	0.68	0.54 – 0.81
3	300 m downwind	34	0.63	0.51 – 0.74
1,3-Butadiene				
4	100 m upwind	31	0.13	0.08 – 0.18
1	10 m roadside	37	0.19	0.14 – 0.24
2	100 m downwind	21	0.13	0.07 – 0.18
3	300 m downwind	34	0.12	0.07 – 0.16
Benzene				
4	100 m upwind	32	0.36	0.27 – 0.44
1	10 m roadside	37	0.46	0.36 – 0.55
2	100 m downwind	21	0.29	0.19 – 0.40
3	300 m downwind	34	0.32	0.24 – 0.40

NOTE: Data are for valid samples only.

Data Caveats– Integrated Samples -- VOC

All sample results are presented with no blank or recovery correction. This was deemed unnecessary as the field blank values were either zero, below the method detection limit, or not statistically significant. While acrolein data is reported for the TO-15 method, caution should be used when assessing the data.

Air Quality – Integrated Samples -- Carbonyl

Table 3 shows the number of observations, mean and 95% confidence intervals for the carbonyl data (TO-11a method).

Table 3. Carbonyl -- averages for all wind directions (09/29/2010-06/15/2011)

Site name	Distance from Road	N (Obs.)	Mean (ppb)	95% CI (ppb)
Acrolein				
4	100 m upwind	32	3.83	1.02 – 6.64
1	10 m roadside	34	4.08	1.43 – 6.74
2	100 m downwind	30	1.21	0.17 – 2.25
3	300 m downwind	36	1.12	0.34 – 1.90
Acetaldehyde				
4	100 m upwind	32	2.16	1.38 - 2.94
1	10 m roadside	34	2.67	1.10 - 4.23
2	100 m downwind	30	2.05	1.24 - 2.87
3	300 m downwind	36	1.68	0.90 - 2.45
Formaldehyde				
4	100 m upwind	32	3.14	1.93 - 4.35
1	10 m roadside	34	3.27	2.02 - 4.53
2	100 m downwind	30	2.60	1.30 - 3.89
3	300 m downwind	36	3.13	1.94 - 4.32

NOTE: Data are for valid samples only.

Data Caveats– Integrated Samples – Carbonyl

All sample results are presented with no blank or recovery correction. This was deemed unnecessary as the field blank values were either zero, below the method detection limit, or not statistically significant. While acrolein data is reported for the TO-11a method, caution should be used when assessing the data.

Data Caveats– Integrated Samples – Acrolein

Acrolein results are presented for both TO-15 (VOCs) and TO-11a (carbonyls) methods and the results should be used with caution. Method TO-15 utilizes passivated stainless steel canisters under vacuum to be filled at a constant rate to near ambient pressure for a specified time period. The air collected in the canisters undergoes laboratory analysis using a GC/MS. Method TO-11a

utilizes cartridges containing DNPH coated media. These cartridges are connected to a sampler that draws ambient air at a constant rate for a specified time period. These cartridges undergo laboratory analysis using High-Performance Liquid Chromatography (HPLC)

Both methods are considered problematic as both methods have issues with the measurement of acrolein. The TO-15 method is considered problematic due to the "growth" of acrolein inside cleaned canisters. Acrolein concentrations inside cleaned canisters containing zero humidified air have been shown to increase over time due to unknown reasons. The TO-11a method is considered inaccurate due to the retention instability on the DNPH coated absorbent and low acrolein capture efficiency.

Moreover, caution should be used when comparing Las Vegas acrolein measurements to Detroit acrolein measurements. Acrolein values for Las Vegas were reported using TO-11a, while acrolein values for Detroit are reported using TO-11a and TO-15. We observed "growth" of acrolein in canisters during the Las Vegas study and for this reason we had very low confidence in the data and did not report acrolein results using TO-15. We did not observe "growth" of acrolein in canisters during the Detroit study.

EPA is continuing to research acrolein measurement methods, specifically focusing on the TO-15 method. This research is currently identified as a priority in EPA ORD's research action plan.

Air Quality – Integrated Samples – $PM_{2.5}$

A summary of $PM_{2.5}$ averages and confidence intervals are shown in Table 4. Figure 9 shows box-whisker plots $PM_{2.5}$ integrated filter samples.

Table 4. $PM_{2.5}$ Filters -- averages for all wind directions (09/29/2010-06/15/2011)

Site name	Distance from Road	N (Obs.)	Mean ($\mu g/m^3$)	95% CI ($\mu g/m^3$)
Station 4	-100 m (upwind)	17	11.46	8.14 - 14.78
Station 1	10 m roadside	19	12.87	8.84 - 16.90
Station 2	100 m downwind	16	12.12	8.53 - 15.71
Station 3	300 m downwind	18	10.40	7.10 - 13.69

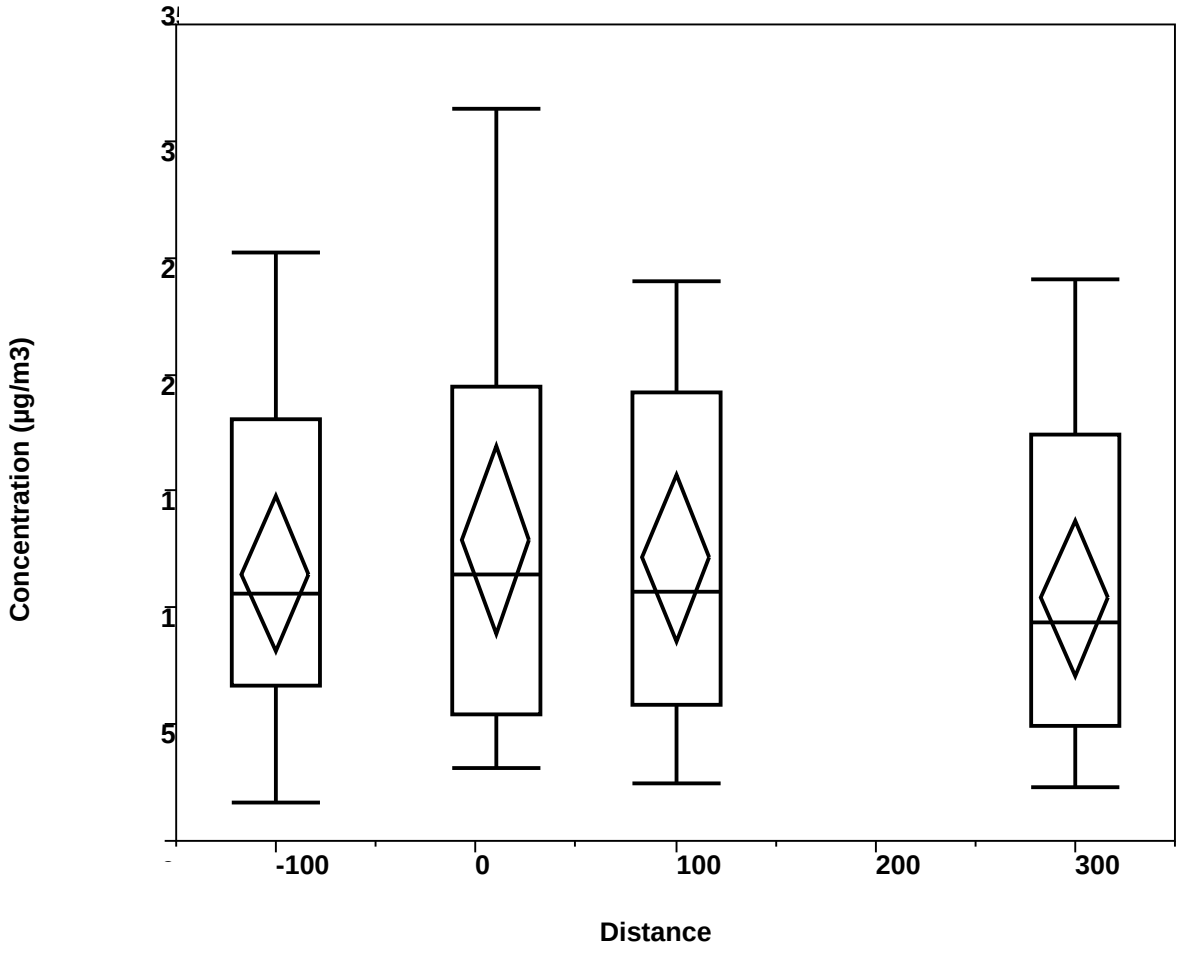


Figure 9 Box-Whisker Plot for $PM_{2.5}$ for all stations, all sample times, all wind directions.

Part VI: Summary

This report provides a summary of a field study conducted in Detroit, MI from September 29, 2010 thru June 20, 2011. The objective of this research study has been to determine MSAT concentrations and variations in concentrations as a function of distance from the highway and to establish relationships between MSAT concentrations as related to highway traffic flows including traffic count, vehicle types and speeds, meteorological conditions such as wind speed and wind direction; and other pollutants primarily emitted from motor vehicles such as CO, NO, NO_2, NO_X, BC, PM_{10}, $PM_{2.5}$, PM Coarse, and MSATs. These detailed results support the following preliminary conclusions:

- Concentration gradients are observed for gaseous pollutants and black carbon associated with distance from roadway.
- Effect of wind speed appears to be a factor with regards to concentration gradient (e.g., dilution effect).
- Non I-96 sources may be larger contributors than previously expected (Figure 7 and Figure 8), for example:
  - ✓ Impact of near-by apartment complex at 300 meter downwind site (e.g., cold-start CO emissions).
  - ✓ Telegraph Road (300 meter downwind site).

Preliminary results of this study provide indications that highway vehicle emissions impact near-road air quality. Known highway vehicle pollutants such as CO, NO, NO_2, NO_X and BC have elevated concentrations in a near-road environment and decrease as one moves away from the road. Additional analysis of the data is needed to more accurately quantify the effect of wind speed as well as other near-road effects.

Part VII: Lessons Learned

Costs, timeliness and other operational factors are just some of the site implementation variables that may be difficult to control. These implementation variables include site access and permissions, electrical connectivity, security, communications, site operators and equipment. Costs may be estimated but there may be unforeseen factors that influence the outcome of the

costs. An example was the performance of an analytical instrument utilized in the study. This instrument had both design and manufacturing issues that only became apparent after the instruments were deployed. The remedy for this situation was that the manufacturer performed an "in the field upgrade". Projects of this nature present myriad challenges both from a programmatic and technical perspective.

Access to sites owned by private citizens can be challenging. Adjacent property owners may understand the necessity of improving the state-of-the-science, benefiting the community at-large and have a desire to be a "good" citizen, but existing lease and financial issues are a deterrent to participation. In addition, liability, insurance compensation, hassle factor(s), and other real and perceived issues present obstacles to site access.

Electrical and communications companies have numerous requirements for obtaining their services. This process requires interactions with utility companies as well as local (i.e., county or city) inspections departments.

Part VIII: Uncertainties

Study Design. This study focused on a single location (freeway) in one city. Additional locations are needed to fully assess air pollutant concentration gradients from different roadway types; different traffic patterns; geographic locations; meteorological conditions, etc.

Methods. The analytical methods implemented during this study followed EPA standard methods and Federal Reference Methods for performing ambient air measurements. Refinements to methods can and do occur over the course of time due to improved technologies and measurement techniques, however the most current technologies and techniques were implemented for this study.

Data. Uncertainties in the data may be considered in two parts: overall data integrity, individual measurements. Electronic data streaming was utilized whenever possible to lessen the chance of human error (i.e., transcription error) and ensure overall data integrity. When hardcopy data sheets, notes, chain-of-custody forms were utilized; an EPA staff member reviewed the hardcopy and verified the data. Quality assurance of the data (i.e., individual measurements) is an on-

going process and often occurs during more specific data analysis. Given that this project generated gigabytes of data, thorough quality assurance of the data is an on-going activity.

Part IX: Conclusions

The FHWA and EPA collaborated on a research effort to characterize the impact and behavior of particulate matter with aerodynamic diameter less than 2.5 microns ($PM_{2.5}$), MSATs near highways and other pollutants primarily emitted from motor vehicles such as CO, NO, NO_2, NO_X and BC. Additional data analysis will be required over the coming months to adequately assess the significance and implications of the results of this study.

FHWA and EPA

National Near-Road Study

1 Introduction

In 2002, the Sierra Club legally challenged the U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) and the Nevada Department of Transportation's (NDOT) National Environmental Policy Act (NEPA) environmental document related to the proposed widening of U.S. 95 in Las Vegas, Nevada, including the assessment of impacts of mobile source air toxics (MSATs) from the proposed project. FHWA entered into a Settlement Agreement with Nevada DOT and the Sierra Club, wherein the FHWA agreed to undertake a research effort to characterize the impact and behavior of particulate matter with aerodynamic diameter less than 2.5 microns ($PM_{2.5}$) and MSATs near highways.[1] The FHWA Administrator contacted all 50 states requesting that the States participate in this research study. Two States volunteered: Nevada and Michigan.

The FHWA and U.S. Environmental Protection Agency (U.S. EPA) determined that it would be in the best interest of both organizations to implement this project in a collaborative manner, allowing a more effective utilization of staffing and resources.

2 Background

The objective of the study was to determine MSAT concentrations and variations in concentrations as a function of distance from the highway and to establish relationships between MSAT concentrations as related to highway traffic flows including traffic count, vehicle types, and speed; and meteorological conditions such as wind speed and wind direction.[2]

Studies have demonstrated that spatial gradients of several traffic-emitted air pollutants (e.g. NO_x, CO, elemental or black carbon, ultrafine and coarse particles, and mobile source air toxics) decrease with distance from the road, generally returning to levels comparable to concentrations upwind of the road within a few hundred meters downwind[5,6]. Some studies show that fine particulate matter ($PM_{2.5}$) is only moderately impacted by traffic with greater contributions of ultrafine and coarse particles[5,6]. The extent of the spatial impacts of traffic related air pollutants is related to factors including the type of roadway, traffic volume and intensity, and meteorology[5,6,7,8]. The areal extent of traffic generated particles, especially ultrafine particles, has been shown to vary diurnally and seasonally with the greatest spatial extent of the roadway plume occurring at night and during winter[9,10]. The composition of PM near roads is also impacted by traffic emissions with greater quantities of a number of metals including copper, iron, and antimony[11,12]. While most studies have focused on the criteria air pollutants PM, CO and NOx, less information exists concerning the spatial distribution of mobile source air toxics (MSATs) near-roadways[1,7,13].

This report describes the methods and initial results from research conducted to evaluate mobile source contributions to criteria, air toxics and $PM_{2.5}$ pollutant concentrations, and their dispersion patterns near a highway in Detroit, Michigan.[2]

3 Study Design

The objective of the research study is to determine pollutant concentrations and the variation of pollutant concentrations as a function of distance from the highway (Figure 10). Additional important considerations of the study includes establishing relationships between pollutant concentrations as related to highway traffic characteristics including traffic count, vehicle types and speeds, and meteorological conditions such as wind speed and wind direction. This study provided detailed concentration data and distributions of motor vehicle emitted pollutants including regulated gases, air toxics, and particulate matter.[4]

3.1 Detailed Monitoring Protocol

FHWA's "detailed monitoring protocol" outlines a uniform approach to conduct all studies for evaluating mobile source contributions to air toxic compounds and $PM_{2.5}$ and their dispersion patterns[2]. A more detailed examination of the monitoring protocol indicates that for each city, continuous monitoring and integrated sample collection was required at four monitoring sites (Figure 10). In addition, wind speed and wind direction was required at each site. Moreover, monitoring for the complete suite of meteorological parameters was required at the monitoring station positioned 50 to 150 m from the roadway (100 meter downwind). Table 1 summarizes the measurements taken at each monitoring site and Table 5 summarizes measurement parameters, sampling approach, and instruments.

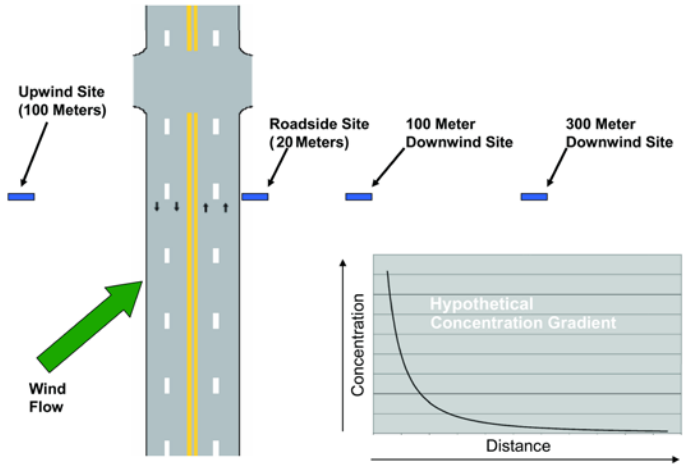


Figure 10. Illustration of Monitoring Site Locations.

Table 5. Summary of Protocol Measurement Parameters, Sampling Approach and Instruments.

Measurement Parameter	Sampling Approach	Instrument Data				
		Make/Model	Accuracy	Precision	Detection Limit	Sample Type and Frequency
Carbon Monoxide (CO)	nondispersive infrared	EC 9830T	± 5% 0-1000ppb	0.5% of reading	25 ppb	Continuous (5 minute)
Oxides of nitrogen (NO_x)	chemiluminescence	EC 9841B	< 1%	0.5 ppb	0.5 ppb	
Black Carbon (BC)	Aethalometer	Magee – Aethalometer, Models AE16 and AE20	1:1 comparison w/ EC on filters	Repeatability: 1 part in 10,000	0.1 µg/m^3 w 1 min res.	
$PM_{2.5}$	$PM_{2.5}$ FRM method	FRM BGI PQ200				24-hour integrated 1-in-12 day schedule 1 sample each day at each road-side location
$PM_{2.5}$	TEOM	Thermo TEOM – 1405DF	±0.75%	±2.0 µg/m³ (1-hour ave), ±1.0 µg/m³ (24-hour ave)	0.1 µg/m³	Continuous (5 minute)
PM_{10}						
PM Coarse						
Acetaldehyde	USEPA Method TO-11A	Atec 2200 Cartridge Sampler	± 2 %	± 2 %	N/A	1-hour integrated 1-in-12 day schedule 9 samples each day at each road-side location
Formaldehyde						
Acrolein	USEPA Method TO-15	Entech 1800 Canister Sampler	± 2 %	± 2 %	N/A	
Benzene						
1,3-Butadiene						
Wind Speed	sonic anemometer	RM Young Model 81000	±0.05 m/s	std. dev. 0.05 m/s at 12 m/s	0.01 m/s	Continuous (5 minute)
Wind Direction			± 5°	± 10°	0.1°	
Air Temperature	temperature probe	Vaisala HMP45D	±0.2°C at 20° C	0.1 ° C	0.1 ° C	
% Relative Humidity	relative humidity sensor	Vaisala HMP45A	±2%RH from 0…90% RH)	1% RH	1% RH	

Measurement Parameter	Sampling Approach	Instrument Data				
		Make/Model	Accuracy	Precision	Detection Limit	Sample Type and Frequency
Rain Gauge	rain bucket	Ecotech Rain Gauge	+/- 5% at 25-50 mm/hour	± 1mm	± 1mm	
Solar Radiation	solar radiation	MetOne 394 Pyranometer	±5% from 0…2800 watts meter^2	±1% constancy from -20°C to +40°C	9 mV/kwatt meter-2, approx	
Sound	microphone	Extech 407764	±1.5dB (under reference conditions)	0.1dB	0.1dB	
Video	video	Axix 223M Vivotek SD7151	N/A			Continuous (15 minutes)
Vehicle Count	radar	Radar (Wavetronix)				
Vehicle Speed						
Vehicle Type						

1. Accuracy and precision in terms of ultrafine particle concentration is difficult to determine in the field due the lack of particle concentration standards. However, particle counters are routinely verified in the field for accuracy in flow rate. Precision was estimated in this study by collocating UFP samplers prior to use of instruments in the field.

3.2 Study Design Enhancements

Enhancements to the study protocol included SO2 monitors at located at Site 2 (100 meter downwind) and Site 4 (100 meter upwind). Video was also used to validate traffic count information.

3.3 Site Location

The site selection process resulted in the selection of a location along I-96, approximately 800 meters (m) east of Telegraph Road (US 24) in the vicinity of Eliza Howell Park in Detroit, Michigan[3]. Three of the four monitoring stations were placed approximately 10 m, 100 m and 300 m downwind of I-96. The fourth monitoring station was located approximately 100 m upwind of I-96. At this location, I-96 has an east-west orientation. Prevailing winds at this location are generally west and southwest. This assessment was based on meteorological data from the National Climatic Data Center for the Detroit-Wayne County International Airport.

This site was considered the optimal site of all the candidate monitoring sites[3]. This site has high AADT (165,300 AADT for 2006), no noise walls, meteorological and traffic data availability, manageable site logistics including ROW access, and favorable wind direction[3]. This location is shown in **Figure 1**.

4 Site Selection Methodology and Site Selection Criteria

4.1 Methods

Site selection methodology has been described previously in (Kimbrough, et al. 2008 and Kimbrough et al. 2011).

In brief, site selection and implementation consisted of seven steps (1) determining site selection criteria–previously established by FHWA and documented in the Monitoring Protocol [2]; (2) develop list of candidate sites and supporting information; (3) apply site selection filter ("coarse" and "fine"), (4) site visit; (5) select candidate site(s) via team discussion; (6) obtain site access permission(s); and (7) implement site logistics.

4.2 Candidate Site Listing

The purpose of any site selection process is to gather and analyze sufficient data that would lead one to draw informed conclusions regarding the selection of the most appropriate site for the monitoring that will be performed in Detroit, Michigan.

Site selection in Detroit, MI shared several methods common to those employed in Las Vegas, NV [4] and described in (Kimbrough, et al. 2008 and Kimbrough et al. 2011)[3,4]. The site selection process provided sufficient data to inform the selection of the most appropriate site for the pollutant measurements to be performed in Detroit, MI.

A list of possible sites was developed using the monitoring protocol's site selection criteria (Table 6). The data used to formulate the recommendations were based on data developed by the Michigan Department of Transportation (MDOT) with input from Michigan Department of Environmental Quality (MDEQ) and Southeast Michigan Council of Government (SEMCOG). In addition, geographic information system (GIS) data, tools and techniques and on-site visits by project team members were used to develop supporting information regarding each potential site. The Michigan Department of Transportation (MDOT) provided annual average daily traffic (AADT) counts. Other types of spatial data (e.g., street network) were downloaded from the Michigan GIS web site as well as other relevant web sites. The National Climatic Data Center

Table 6. All Sites Considered for Detroit Site Selection.

Site ID	Site	AADT	Meteorology	Roadway to Site Characteristics		Nearby Sources	Downwind Sampling	Comments
				Elevation	Direction			
A	I-696 (Illitch Property)	157,800	W, SW	At Grade	North	N	S	Property is privately owned some of the land is leased by the City of Farmington Hills for soccer fields
B	I-696	157,800	W, SW	Slightly Below Grade	North	N	S	On boundary of two commercial properties, some vegetation obstructions
C	I-696 (Farmington Hills High School)	167,500	W, SW	Below Grade	Northeast	N	S	Steep, heavily vegetated embankment, school grounds have many out-buildings
D	M-39 (Garden View Estates)	151,200	SW, S	At Grade	East	CM; R	R; C	P33 housing project funded U.S. Department of Housing and Urban Development, HOPE VI f. Nothing built on site; area completely fenced-in
E	I-96 (Eliza Howell Park)	165,300	SW, S	Above Grade	North	R	S; R	Steep embankment from service drive to east side of park, broken gate into park
F	I-75 (Avondale High School)	142,182	W, SW	Below Grade	East	R	R; V	Steep, heavily vegetated embankment, power poles at strategic locations
G	I-275 (Schoolcraft Community College)	197,700	W, SW	Below Grade	West	CM; R	R; C	Site is located on the windward side of roadway, vegetated embankment, ramp
H	M-10 (Fairbanks Elementary School)	117,034	SW, S	Below Grade	Northeast	CM; R	R; C; UT	No unobstructed locatiion to place 250-300m monitor, AADT below 135,000
I	I-75 (Amelia Earhart Middle School)	105,500	SW, S	Below Grade	Northwest	CM; R	R; C; UT	Heavily used service drive, AADT below 135, 000
J	I-275/I-96	193,700	SW, S	At Grade	Northeast	CM; R	R; C; S	Commercial Property in Livonia east of I-275/I-96 and north of 7 Mile Road I275/I96-7MI RD

Nearby Sources N = None; UT = Urban Traffic; CM = Commercial; R = Residential

Downwind Sampling R = Residential; C = Complex (mixed commercial) ; S = Semi-open fields; V = Vegetation

4.3 Application of Coarse Site Selection Filter

Joint-agency team meetings were held which resulted in the reduction of the number of sites from a list of 10 to approximately three sites [14,15]. A review of the full table of candidate sites was conducted during these team meetings and sites that obviously did not meet minimum site criteria requirements (Table 6) were eliminated. The site selection criteria were applied as a set of "filters" and most candidate sites were eliminated during this process. For example, the first filter eliminated sites with low AADT (i.e., < 150,000) or the placement of a 300 meter downwind (250 – 350 meter) site would not be possible. Additional important criteria, while not explicitly stated in the monitoring protocol, include restricted downwind sampling, presence of confounding air pollutant sources and site access (administrative and physical) [4].

4.4 Ground Truthing

During the first site visit to Detroit in June 2008, all sites were visited as shown in Table 6, Supplemental Information. Several promising sites had to be eliminated due to impending construction activity. Two additional sites were considered unsuitable due to the inability to site the 300 meter downwind monitor (250-300 meter) monitor in an unobstructed location and a heavily used service drive, respectively. Two sites had AADT below 135,000. Five of the remaining sites did not represent Detroit's urban landscape. Another site was located on the windward side of the roadway and had to be eliminated. In addition, this site as well as another site was eliminated due to vegetated embankments. MDOT, Michigan DEQ and SEMCOG staff helped to obtain local meteorological and roadway information during the site visit that would have been otherwise unavailable [14,15].

4.5 Geospatial Tools

Geospatial tools used to support this site selection process included Environmental Systems Research Institute's (ESRI) ArcGIS and GoogleEarth Pro. Relevant data layers were developed (Table 7) and maps were created based on these data layers and site selection criteria. The advantages and disadvantages of each site were "weighed". From this process, one site was selected for measuring MSAT compounds.

Table 7. Data Inputs for Detroit Site Selection Process.

Data Input	Source	Comments
Spatial Data		
AADT	Michigan DOT SEMCOG	http://www.michigan.gov/mdot/0,1607,7-151-9622_11033-22141--,00.html http://www.semcog.org/Data/Apps/trafficcounts.cfm?mcd=8999
Topology	Michigan DOT	Site visits by Michigan DOT personnel.
	EPA/FHWA Personnel	Site visits by EPA/FHWA Personnel.
Potentially confounding air pollutant sources	EPA/FHWA Personnel	Site visits by EPA/FHWA Personnel.
Street Data	Michigan GIS	http://www.mcgi.state.mi.us/mgdl/
Points of Interest		
Administrative Boundaries		
Schools		
Aerial Imagery	GlobeXplorer	ImageConnect Service (ArcGIS)
	Google Earth	http://earth.google.com/
Non-spatial Data		
Selection Criteria	Settlement Agreement	http://www.fhwa.dot.gov/environment/airtoxicmsat/setagree.pdf
	Monitoring Protocol	http://www.fhwa.dot.gov/environment/airtoxicmsat/FinalDMPJune.pdf
Geometric Design, Geographic Location	Aerial Photos – Digital Globe	Aerial images downloaded using ArcGIS tools.
Availability of Traffic Volume Data	Michigan DOT	Conference calls, site visit by EPA/FHWA Personnel.
Meteorology	National Climatic Data Center	http://cdo.ncdc.noaa.gov/CDO/cdo
Downwind Sampling	EPA/FHWA Personnel	Site visits by EPA/FHWA Personnel.

ArcGIS 9.2 [16] was used to create the maps used in the site selection process. Spatial data were downloaded from relevant web sites. Table 7 shows the sources of data used for this site selection process. It should be noted that the use of maps for the site selection process is only a tool in the site selection process. It is very important in this process to perform site visits,

establish contacts with state/local transportation agencies and environmental agencies. Typically, these groups will be able to provide up-to-date information as to site conditions that may ultimately influence site selection decisions.

4.6 Site Selection — Results and Discussion

Following the application of the selection criteria[3,4], the candidate sites were further prioritized during a series of team discussions between U.S. EPA, U.S. FHWA, Michigan DOT, and SEMCOG staff. The pros and cons of each site were discussed. Initially, Site E was not considered a viable site as there was going to be an extensive wastewater construction project at that location. This construction project was cancelled due to budget issues. Site E was reconsidered and selected for site development. Site E met or exceeded the AADT requirements (> 150,000), did not have noise barriers, did have acceptable downwind sampling and acceptable meteorology (**Figure 1**, Figure 11, and Figure 13).

Proper siting of downwind sampling locations was an important criterion for this project. Any location where proper siting of downwind sampling sites was restricted due to topology, existing structures, meteorology, etc., excluded otherwise suitable sites for consideration and inclusion in this study.

As shown in Figure 12 the wind direction for Site E did have acceptable meteorological conditions. Since Detroit is an urbanized industrial city, influences from nearby sources are a factor.

It should be noted that construction activity on the M-39, an adjacent connecting freeway, may have influenced traffic patterns during a portion of this study. The field team noted that construction did take place on the M-39 during the late-winter/early-spring of 2011. In addition, a bridge replacement project took place adjacent to the sites during the late spring/summer of 2011. This bridge replacement project involved Schoolcraft Road, a service street on either side of I-96. The sites most impacted by the bridge replacement project included Site 1 (10 m roadside) and Site 4 (100 m upwind).

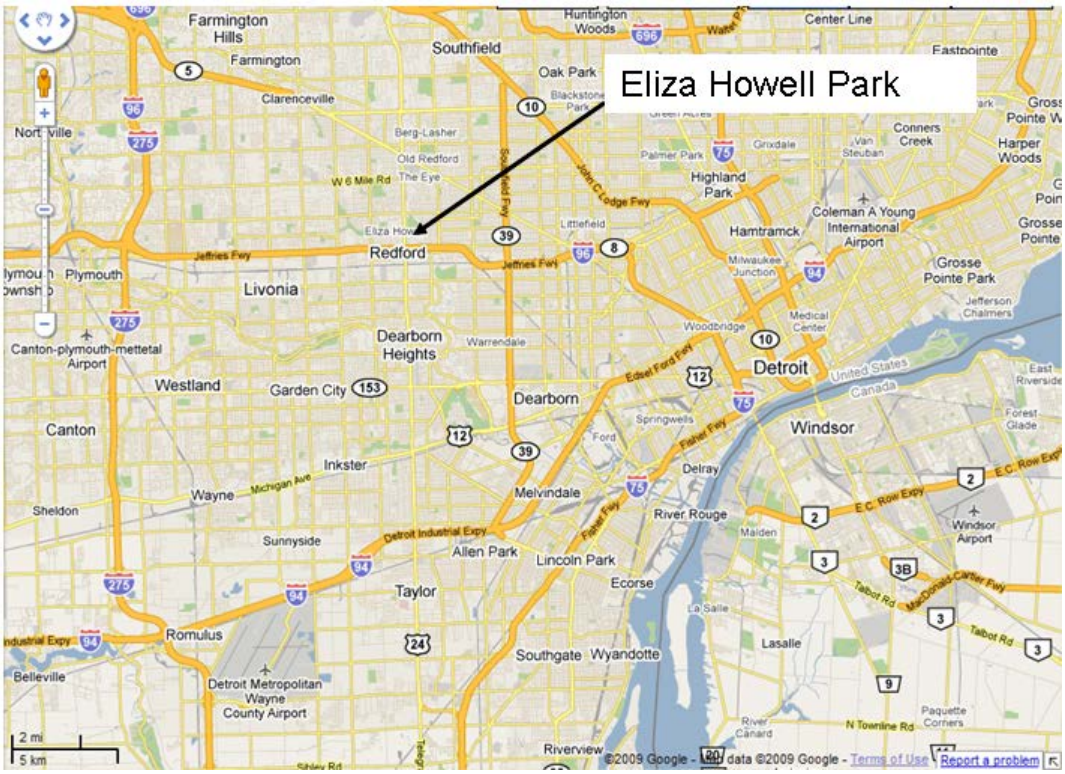


Figure 11. Overview map of Detroit.

Meteorological data from the National Climatic Data Center for the Detroit-Wayne County International Airport indicate that the wind flow is generally from the west and southwest (Figure 13).

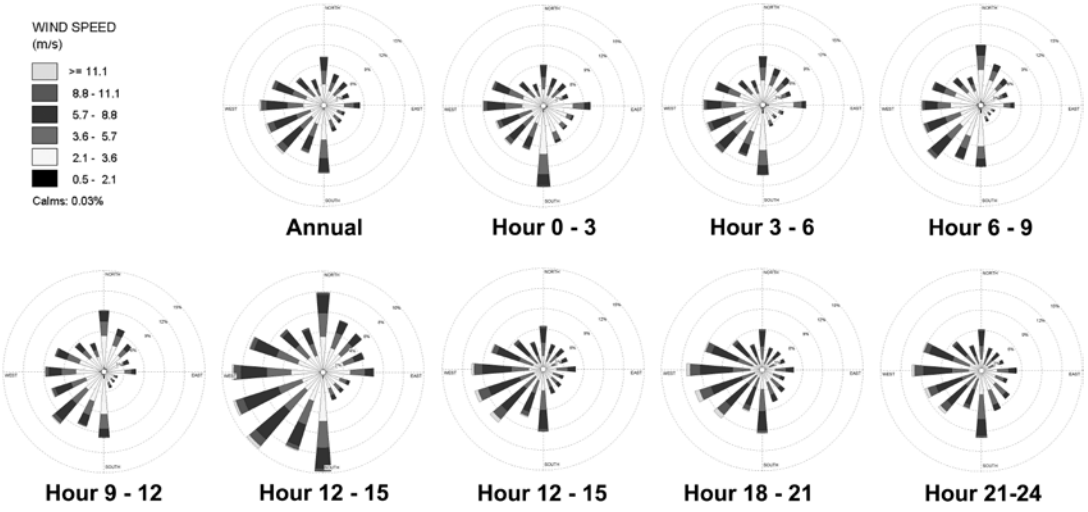


Figure 12. Wind roses for Detroit Area.

Figure 13. Photos of Site E.

The project participants recognized that no perfect air monitoring site was possible; trade-offs were a factor of the Detroit study and would be a factor with almost any other environmental study conducted within any other city. It was a question of balancing benefits with risks and costs. The selection was further complicated by external constraints and drivers. The principal constraint was the legal mandates of the Settlement Agreement, especially the data that must be derived pursuant to the monitoring protocol. Few, if any, design decisions can be made exclusively from a single perspective. These decisions can be visualized as attractions within a force field. If the factors are evenly distributed and weighted, the diagram might appear as that in Figure 14a and b. But, as a given differential force increases, that factor will progressively

drive the decision. In the present case study, the decision is most directly influenced by legal requirements, but which also needs to be scientifically credible and economically feasible (Figure 14a).

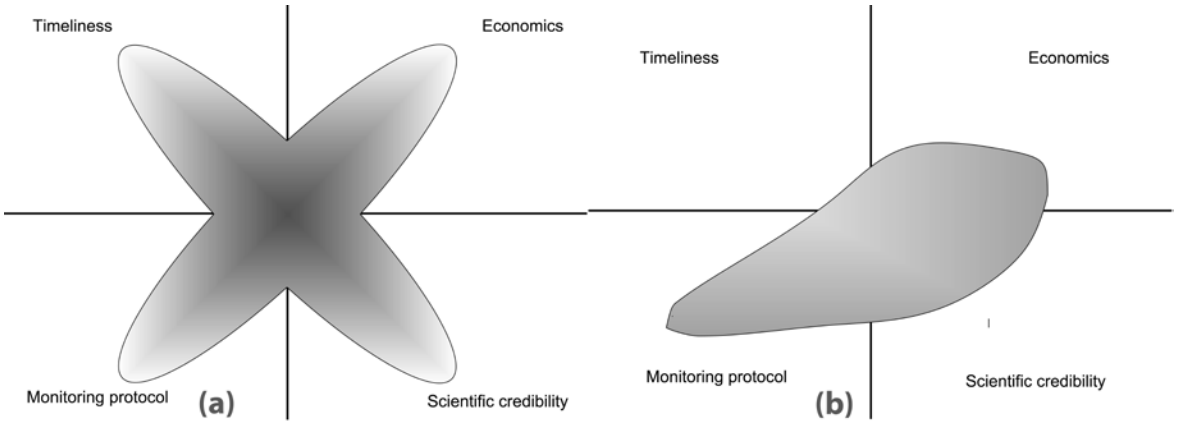


Figure 14a. Decision Force Field – Equal Weight Factors. (b). Decision Force Field – Unequal Weight Factors. Source: Adapted from D. Vallero and C. Brasier. (2008). *Sustainable Design: The Science of Sustainability and Green Engineering.* John Wiley & Sons, Inc. Hoboken, NJ.

As shown in Figure 14a, a number of factors have nearly equal weight in a design decision, Figure 14b indicates a decision that is most strongly influenced by legal constraints and drivers. For example, the stronger the influence of a factor (e.g. high AADT, the greater the decision will be drawn to that perspective. If the monitoring protocol is somewhat ambiguous, a number of alternatives are available, costs are flexible, and scientific credibility is minimally impacted, the design has a relatively large degree of latitude and elasticity. Note that all factors drive the decision, but that the monitoring protocol and other legal instruments have the greatest influence on the decision.

There is also the question of the best use of resources for this project. For example, a site could be chosen that would call for additional monitoring (and concomitantly additional resources) to overcome certain physical constraints (i.e., above/below grade, noise barriers). Or, a site could be chosen that has some other issue such as low AADT or where traffic monitoring equipment would have to be installed.

Site E had high AADT (206,000 AADT for 2006), no noise barriers, meteorological and traffic data availability, manageable site logistics including right-of-way access, "clean geometric design", and favorable wind direction. Clean geometric design was defined as a facility that did not impede the effective data collection of MSATs and $PM_{2.5}$ [2]. For example, a clean geometric design would be a site that did not include multiple on/off ramps, interchanges, or other complicating facility characteristics. Of the disadvantages, Site E did not afford a perpendicular transect for all shelters. Moreover, Detroit is an industrialized urban area which means that nearby sources are part of the urban landscape. The wind blows predominately from the west-southwest quadrant. The wind roses shown in Figure 12 have been developed from meteorological data downloaded from the National Climatic Data Center, Years 1977 – 2007.

4.7 Site Logistics

Site logistics included but was not limited to, obtaining site access permissions, gaining access to electrical power, communications connectivity, county/city permits, arranging for security fencing, etc. Site logistics, while not explicitly included in the monitoring protocol, was mission critical. Any location where site logistics, was restricted or prohibited either due to administrative or physical issues, was highly problematic and eliminated a site from further development. Obtaining site access permissions, obtaining the proper electrical feed, communications connectivity and being able to establish security fencing was vital to the project.

Electrical and communications connectivity is also challenging. Utility companies have a multitude of requirements for obtaining their services. This is a very involved process that requires interactions with utility companies as well as local (i.e., county or city) inspections departments. Implementation of site logistics may require more time than is needed to obtain ambient air measurements for a given project.

4.8 Site Selection Summary/Conclusions

Site E was the site of choice with the most advantages and fewest disadvantages compared to other monitoring sites that have been considered. Site E had high AADT (206,000 AADT for 2006), no noise barriers, meteorological and traffic data availability, manageable site logistics including ROW access, and favorable wind direction.

Meetings, teleconferences, site visits, written reports, etc. are key activities to any site selection process. These activities ensure that all interested parties are aware of the selection process. Moreover, this ensures that the pros and cons of each site are thoroughly considered and discussed and trade-offs among the various sites are weighed. Throughout this process, trade-offs will and do occur. For example, an ideal site for the air quality modelers (e.g., complex terrain) is not necessarily an ideal site from the perspective of the field researchers (e.g., less complex terrain, site access, etc.). For this project, a group consensus was reached, culminating in a written report for FHWA and U.S. EPA management.

5 Analytical Instruments and Methods

5.1 Data Logging and Time Synchronization

All continuous analyzer data were recorded using an Ecotech 9400TP data logger. These loggers were programmed to record continuous data (averages) at 5-minute intervals. Moreover, these data loggers were time synchronized to National Institute of Standards and Technology (NIST) time by accessing the NIST internet web site hourly and adjusting the data loggers' internal time clock accordingly.

5.2 WinAQMS and WinCollect Software

Ecotech WinAQMS server software was loaded onto the data loggers to handle communications between the continuous analyzers and the data loggers[17]. Ecotech WinCollect software was loaded onto a Windows XP workstation at the EPA Facility in RTP, NC to monitor and determine instrument status and performance, perform remote calibrations, determine data validity and download data from the remote field site to the Near-Road database[18]. This data was loaded into a SAS database for further quality assurance (QA) and data analysis.

5.3 Traffic Activity

EPA assumed a more active role in Detroit due to lessons learned in Las Vegas. Moreover, EPA utilized next generation radar devices; one looking at east bound traffic, a second device looking at west bound traffic along I-96. EPA installed a Wavetronix SmartSensorHD unit at the 10 meter roadside site; the second unit was located on the upwind side (south) of the freeway. Each unit pointed across the freeway and data was collected and stored onto an EPA computer.

Historically, traffic data is reported as an annual average daily traffic (AADT). Historically, these values are not measured 24-7, 365 days per year. Traffic data is collected for 1-2 weeks during the year for a highway segment; monthly and seasonal factors are applied to calculate AADT. The importance of this historical information relative to our project is that the project has highly time-resolved data for analysis of roadside concentration measurements.

Figure 15 shows average hourly traffic speed and volume at the I-96 site.

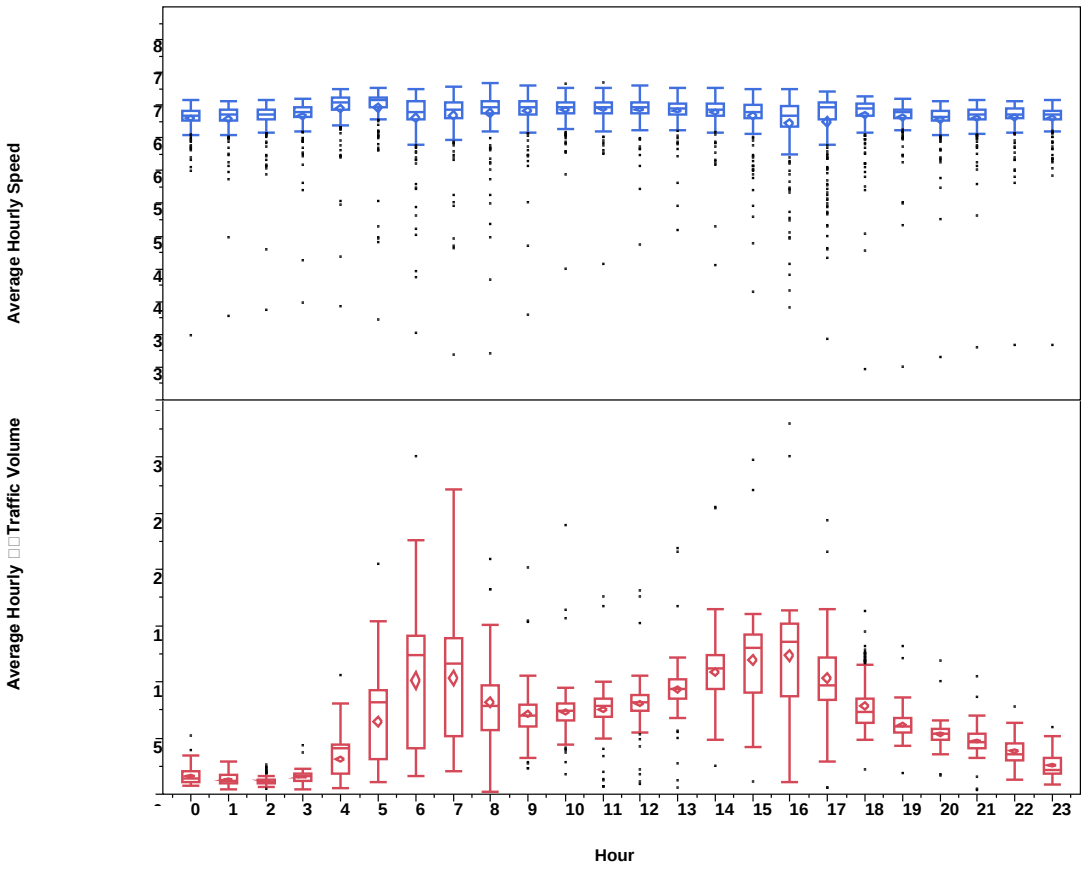


Figure 15. Hourly Average Traffic Volume and Average Speed -- I-96.

5.4 Meteorology

Meteorological monitoring characterized ambient conditions during the day and included measurements for: wind speed, wind direction, ambient temperature, relative humidity, solar radiation, and precipitation. Wind speed and wind direction were characterized by sonic anemometers (R.M. Young Model 81000 Ultrasonic Anemometers). Temperature and relative humidity were characterized by Vaisala HMP45D and Vaisala HMP45A probes, respectively. Barometric pressure was measured by Vaisala PTB210 probe. Solar radiation was measured by a MetOne 394 Pyranometer and precipitation was measured by a rain bucket (Ecotech Rainmaster 1000).

5.5 Continuous Analyzers

5.5.1 Gaseous Pollutants

Gas analyzers (Table 1, Table 8) meeting U.S. Environmental Protection Agency Federal Reference Method (FRM) or equivalent method criteria collected measurements of CO, NO, NO_2, NO_X, at 100 meters upwind, 10 meter roadside, 100 meters downwind and 300 meters downwind from the freeway. The sample height in all cases was at approximately 3 meters above the ground. Data was logged continuously for 5-minute averaging periods over the course of the study period (Table 9). Multi-point calibrations occurred at the beginning of the study while zero and span checks were run every night over the course of the study period.

5.5.2 Black Carbon

Black carbon (BC) was measured continuously at each station using dual-wavelength rackmount Aethalometers (Table 1, Table 8) at 100 meters upwind, 10 Meter Roadside, 100 meters downwind and 300 meters downwind from the freeway. The sample height in all cases was at approximately 3 meters above the ground. Data was logged continuously for 5-minute averaging periods over the course of the study period (Table 9).

The Aethalometer continuously measures BC at five minute intervals by pulling air through a small spot on the sample filter and detecting incremental changes in light attenuation at a specific wavelength. Once the sample spot is loaded to a certain limit, the instrument automatically pauses, rotates the filter tape through to a new clean spot, and begins sampling again; this

translates to a ten minute gap in the data approximately twice per day in the Detroit data set. The main wavelength of light used to detect BC is 880 nm, in the red region of the visible spectrum. In addition, this instrument also detects light attenuation at 370 nm and is a qualitative indicator of additional particulate organics which may absorb light at near-ultraviolet wavelengths.

Black carbon values are calculated by the below equation,

$$BC = \Delta ATN * A / SG * Q * \Delta t \quad (1)$$

where, BC is the concentration of black carbon in the sample (units of ng/m^{-3}), ΔATN is the change in optical attenuation due to light absorbing particles accumulating on a filter, A is the spot area of filter, Q is the flow rate of air through filter, Δt is the change in time, SG is specific attenuation cross-section for the aerosol black carbon deposit on this filter (16.6 m^2/g). SG is an empirical value that was defined by the manufacturer as the ratio of the mass of elemental carbon (measured using a thermal-optical process) and the detected light absorption of the same sample on a filter.

BC data was automatically logged by two methods during the Detroit monitoring period – logging its full set of data fields (17 columns of data) at five minute intervals to a text file using Hyper Terminal and directly logging only the BC concentration estimated from the instrument's analog output to the station database. The analog data was used during the course of the monitoring study to observe the instrument's performance, however the digital data logged to the text file was used as the primary data for analysis, per manufacturer's recommendations.

Further details are in Appendix 12.

5.5.3 Particulate

Particulate analyzers (Table 1, Table 8) meeting U.S. Environmental Protection Agency Federal Reference Method (FRM) or equivalent method criteria collected measurements of PM-Coarse (particles that have an aerodynamic diameter ranging from 2.5 to 10μm) , PM_{10} and $PM_{2.5}$, at 100 meters upwind, 10 meter roadside, 100 meters downwind and 300 meters downwind from the freeway. Aethalometers and continuous particle counters (Table 1and Table 8) measured black carbon and particle counts at 100 meters upwind, 10 meter roadside, 100 meters downwind and

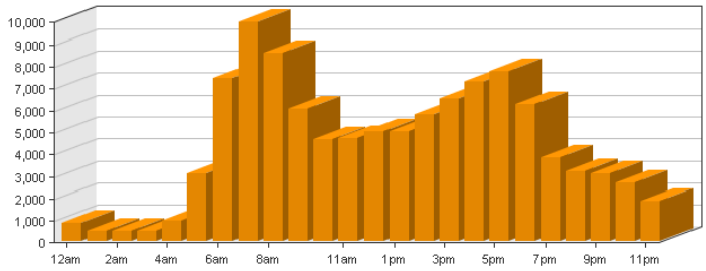
300 meters downwind from the freeway. The sample height was at approximately 3 meters above the ground. Data was logged continuously for 5-minute averaging periods over the course of the study period (Table 9).

Continuous PM-Coarse, PM_{10} and $PM_{2.5}$ measurements were collected by four Thermo Electron Tapered Element Oscillating Microbalances (TEOM) Model 1405-DF at a flow rate of 16.7 liters/minute (L/min) (1.0 m3/hour). The data were recorded as 5-minute averages (Table 9).

5.5.4 Integrated Samples – VOC, Carbonyl, Particulate

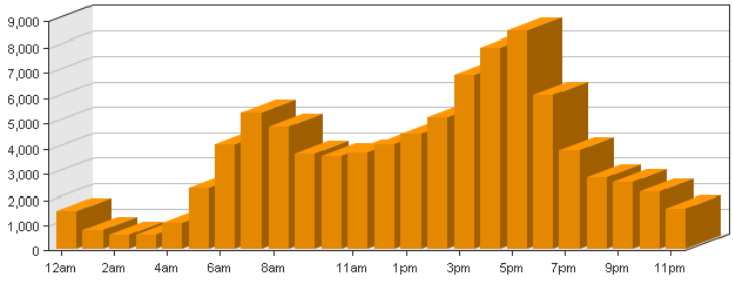
Specific MSATs of interest for this study included: 1,3-butadiene, benzene, acrolein, formaldehyde and acetaldehyde. MSAT samples were collected using U.S. Environmental Protection Agency standard methods: 1) TO-15 and 2) TO-11A. The integrated sampling schedule implemented in Detroit was significantly modified from the Monitoring Protocol. The integrated sampling campaign in Detroit focused on peak periods of traffic (commute times). The figures on the next page show average hourly traffic volumes. These hourly volumes show peak commute times for both east bound and west traffic on I-96 in the vicinity of Eliza Howell Park. From these peak commute times sample times were selected for the MSAT sampling (7 – 8 am and 5 – 6 pm). Samples were collected on a quarterly basis with 5 sample days during the quarter and 2 samples being collected at each station on each sample day during the sample period. This sample strategy followed the 1-in-3 day ambient air quality monitoring schedule that corresponded to the schedule posted on EPA's web site[19] and followed by State/local air agencies for ambient air quality monitoring. The EPA $PM_{2.5}$ federal reference method (FRM) was used for the collection of $PM_{2.5}$ integrated samples.

Quarterly basis was defined as four 3-month periods. The sample periods overlapped from one quarter to the next quarter. The sample periods were scheduled to minimize operating costs and maximize sample distribution across quarters with respect to seasonal data collection. Moreover, blanks and duplicates will be incorporated into the sampling regime.



Hour	Count	Hour	Count	Hour	Count
12 am - 1 am	867	8 am - 9 am	8,574	4 pm - 5 pm	7,255
1 am - 2 am	492	9 am - 10 am	6,060	5 pm - 6 pm	7,750
2 am - 3 am	485	10 am - 11 am	4,629	6 pm - 7 pm	6,229
3 am - 4 am	481	11 am - 12 pm	4,708	7 pm - 8 pm	3,833
4 am - 5 am	933	12 pm - 1 pm	5,016	8 pm - 9 pm	3,179
5 am - 6 am	3,058	1 pm - 2 pm	5,011	9 pm - 10 pm	3,098
6 am - 7 am	7,419	2 pm - 3 pm	5,775	10 pm - 11 pm	2,644
7 am - 8 am	9,959	3 pm - 4 pm	6,516	11 pm - 12 am	1,856

I-96 East Bound at Telegraph Road



Hour	Count	Hour	Count	Hour	Count
12 am - 1 am	1,535	8 am - 9 am	4,845	4 pm - 5 pm	7,939
1 am - 2 am	781	9 am - 10 am	3,751	5 pm - 6 pm	8,590
2 am - 3 am	602	10 am - 11 am	3,671	6 pm - 7 pm	6,074
3 am - 4 am	570	11 am - 12 pm	3,782	7 pm - 8 pm	3,896
4 am - 5 am	1,030	12 pm - 1 pm	4,149	8 pm - 9 pm	2,802
5 am - 6 am	2,390	1 pm - 2 pm	4,548	9 pm - 10 pm	2,635
6 am - 7 am	4,128	2 pm - 3 pm	5,185	10 pm - 11 pm	2,243
7 am - 8 am	5,395	3 pm - 4 pm	6,874	11 pm - 12 am	1,605

I-96 West Bound at Telegraph Road

Integrated Samples	Collection Time
1	7:00 – 8:00 AM
2	5:00 – 6:00 PM

The following calendar shows this sampling scheme. Days shown in yellow are sampling days corresponding to 1-in-3 sampling schedule.

3rd Quarter																						
Jul-10								Aug-10								Sep-10						
				1	2	3		1	2	3	4	5	6	7				1	2	3	4	
4	5	6	7	8	9	10		8	9	10	11	12	13	14		5	6	7	8	9	10	11
11	12	13	14	15	16	17		15	16	17	18	19	20	21		12	13	14	15	16	17	18
18	19	20	21	22	23	24		22	23	24	25	26	27	28		19	20	21	22	23	24	25
25	26	27	28	29	30	31		29	30	31						26	27	28	29	30		
4th Quarter																						
Oct-10								Nov-10								Dec-10						
					1	2			1	2	3	4	5	6				1	2	3	4	
3	4	5	6	7	8	9		7	8	9	10	11	12	13		5	6	7	8	9	10	11
10	11	12	13	14	15	16		14	15	16	17	18	19	20		12	13	14	15	16	17	18
17	18	19	20	21	22	23		21	22	23	24	25	26	27		19	20	21	22	23	24	25
24	25	26	27	28	29	30		28	29	30						26	27	28	29	30	31	
31																						

1st Quarter																						
Jan-11								Feb-11								Mar-11						
						1				1	2	3	4	5			1	2	3	4	5	
2	3	4	5	6	7	8		6	7	8	9	10	11	12		6	7	8	9	10	11	12
9	10	11	12	13	14	15		13	14	15	16	17	18	19		13	14	15	16	17	18	19
16	17	18	19	20	21	22		20	21	22	23	24	25	26		20	21	22	23	24	25	26
23	24	25	26	27	28	29		27	28							27	28	29	30	31		
30	31																					

2nd Quarter																			
Apr-11								May-11							Jun-11							
					1	2	1	2	3	4	5	6	7				1	2	3	4
3	4	5	6	7	8	9	8	9	10	11	12	13	14	5	6	7	8	9	10	11
10	11	12	13	14	15	16	15	16	17	18	19	20	21	12	13	14	15	16	17	18
17	18	19	20	21	22	23	22	23	24	25	26	27	28	19	20	21	22	23	24	25
24	25	26	27	28	29	30	29	30	31					26	27	28	29	30	31	
31																				

5.5.4.1 EPA Compendium Method TO-15 – Canister – VOC

Collection of canister samples by the TO-15 method calls for the atmosphere to be sampled by the introduction of air into a specially-prepared stainless steel canister. An Entech Model 1816 programmable multi-canister automated sampler was used to accurately regulate the filling of the sample canisters with air. Evacuated SUMMA passivated 6 liter (L) canisters were filled to near ambient pressure. A nominal flow rate of 75 milliliter/minute (mL/min) was maintained over a 1-h sampling period for a total sampled volume of approximately 4.5 L. Evacuated canisters received from the laboratory and ready for sampling were placed on the Entech sampling system by attaching each canister's valve to individual sampling ports. The initial pressure was measured for each canister to insure that every canister falls within an acceptable pressure range (<0.5 psia). Any canisters above the acceptable range were replaced with one that met the initial pressure criteria (0.5 psia). With the canisters attached, each port was leak checked to insure that fittings had been properly tightened and the samples would not leak prior to and after collection. Sample labels printed with the individual sample codes were affixed to the canister tags for sample identification. The sampler was programmed for the scheduled sampling times and flow rates. Timers and solenoids within the Entech sampler were activated and deactivated allowing sample collection based on the entered sampling program. After the air samples were collected, the canister valves were closed and the canister prepared for shipment to the laboratory for analysis. Sample collection information such as initial and final pressures, initial and final times,

canister id number, etc. were either hand recorded on a data collection form for subsequent entry in the electronic data form or entered directly into the electronic data form. Chain-of-custody (COC) sheets were generated and the samples were shipped to the laboratory. Upon receipt at the laboratory, the canister sample label was compared against the datasheet and the COC sheet. Any discrepancies were resolved at that time. The samples were stored until the laboratory analysis of the canisters was completed.

5.5.4.2 EPA Compendium Method TO-11A – Cartridges – Carbonyl

The EPA Compendium TO-11A DNPH carbonyl method was implemented in Detroit for the collection and analysis of air samples for formaldehyde and acetaldehyde. DNPH sampling cartridges are commercially available for this method and were purchased and provided for field sampling. Air samples for carbonyls on DNPH cartridges were collected using an ATEC 8010 automated sampler manufactured by Atmospheric Technology (ATEC). This was the same instrument used for the DNSH cartridge sampling. The instrument is a microprocessor controlled sampler that can be programmed to draw ambient air at a constant rate through various types of sampling cartridges for designated time periods. The sampler consists of two units (channels) each having 10 active sampling ports and one non-active port. Channel 1 (ports 1-10) was used for the DNPH samplers and Channel 2 (ports 11- 20) was used for the DNSH samplers. DNPH samples were collected at a flow rate of 1.00 lpm for a one hour time period.

DNPH cartridges were attached to the ATEC's Teflon sampling lines and labeled with the sample collection code. A leak check of each cartridge was performed using the leak check feature of the Atec sampler. This ensured that the cartridges were installed properly. A light blocking sleeve was installed around each cartridge to reduce artifacts due to light sensitivity. The sampler was programmed with the flow, start time and end time for each cartridge channel. During sampling, solenoid valves associated with each cartridge was activated/deactivated based on the programmed sampling schedule. Upon completion of sampling, the cartridges were removed, capped, secured for shipment, and returned via overnight delivery to the EPA RTP facility. Sample collection information such as initial and final flow rates, initial and final times, canister id number, etc. were either hand recorded on a data collection form for subsequent entry in the electronic data form or entered directly into the electronic data form. COC sheets were

generated and the samples shipped to the laboratory. While awaiting shipping, samples were stored in an on-site refrigerator. A cooler with frozen blue ice packs was used to ship the cartridges.

5.5.4.3 Particulate

A BGI PQ 200A $PM_{2.5}$ federal reference method (FRM) sampler was used for the collection of $PM_{2.5}$ integrated samples. Cassettes loaded with pre-weighed 46.2 mm Teflon filters were prepared at the EPA RTP facility by EPA staff and shipped to the Detroit field staff. Filter IDs were linked to unique sample codes generated and printed by data collection spreadsheets. Samples were collected over a 24-h period beginning at midnight of the sampling day. Flow rates and pressures were recorded by the sampler. At completion, the filter was removed and flow rates and pressures were transcribed onto the data collection spreadsheets. The filter cassettes were removed, packed for shipment, and returned by overnight delivery to EPA RTP.

Table 8. Summary of Measurement Parameters, Sampling Approach, Instruments, and DQI Goals for Project.

Measurement Parameter	Sampling Approach	Instrument Data				DQI Goals		
		Make/Model	Accuracy	Precision	Detection Limit	Accuracy	Precision	Completeness
Gas Analyzers								
Carbon Monoxide	(NDIR FRM CO analyzer)	EC 9830T	± 5% 0-1000ppb	0.5% of reading	25 ppb	20%	95 % CI +/- 20 %	80%
Oxides of nitrogen	Chemiluminescence	EC 9841B	< 1%	0.5 ppb	0.5 ppb	20%	95 % CI +/- 20 %	80%
Particulate Samplers								
Black Carbon	(Aethalometer)	Magee - Aethalometer	1:1 comparison w/ EC on filters	Repeatability: 1 part in 10,000	0.1 µg/m^3 w 1 min res.	+/- 0.035 µm^3	+/- 0.035 µm^3	80%
$PM_{2.5}$	($PM_{2.5}$ FRM method)	FRM BGI PQ200				20%	95 % CI +/- 20 %	90%
$PM_{2.5}$	(TEOM)	Thermo TEOM – 1405DF	±0.75%	±2.0 µg/m³ (1-hour ave), ±1.0 µg/m³ (24-hour ave)	0.1 µg/m³	20%	95 % CI +/- 20 %	80%
PM_{10}								
PM Coarse								
Air Toxics								
Acetaldehyde	USEPA Method TO-11A	Atec 2200 Cartridge Sampler	± 2 %	± 2 %	N/A	25%	10% for flow rate 20% for HPLC	80%
Formaldehyde						25%	10% for flow rate 20% for HPLC	80%
Acrolein	USEPA Method TO-15	Entech 1800 Canister Sampler	± 2 %	± 2 %	N/A	25%	10% for flow rate 20% for GC/MS	80%
Benzene						25%	10% for flow rate 20% for GC/MS	80%
1,3-Butadiene						25%	10% for flow rate 20% for GC/MS	80%
Meteorological Instruments								
Wind Speed	Sonic anemometer	RM Young Model 81000	±0.05 m/s	std. dev. 0.05 m/s at 12 m/s	0.01 m/s	20%	95 % CI +/- 20 %	90%
Wind Direction			± 5°	± 10°	0.1°	20%	95 % CI +/- 20 %	90%
Air Temperature	Temperature probe	Vaisala HMP45D	±0.2°C at 20° C	0.1 ° C	0.1 ° C	20%	95 % CI +/- 20 %	90%

Measurement Parameter	Sampling Approach	Instrument Data				DQI Goals		
		Make/Model	Accuracy	Precision	Detection Limit	Accuracy	Precision	Completeness
% Relative Humidity	Relative humidity sensor	Vaisala HMP45A	±2%RH from 0…90% RH)	1% RH	1% RH	20%	95 % CI +/- 20 %	90%
Barometric Pressure	Barometric Pressure	Vaisala PTB210	± 0.15 hPa at 20° C	± 0.05 hPa	± 0.05 hPa	20%	95 % CI +/- 20 %	90%
Rain Gauge	Rain bucket	Ecotech Rain Gauge	+/- 5% at 25-50 mm/hour	± 1mm	± 1mm	20%	95 % CI +/- 20 %	90%
Solar Radiation	solar radiation	MetOne 394 Pyranometer	±5% from 0…2800 watts meter^2	±1% constancy from -20°C to +40°C	9 mV/kwatt meter-2, approx	20%	95 % CI +/- 20 %	90%
Other								
Sound	Microphone	Extech 407764	±1.5dB (under reference conditions)	0.1dB	0.1dB	20%	95 % CI +/- 20 %	80%
Video	Video	Axix 223M Vivotek SD7151						
Vehicle Count	Radar	Wavetronix SS-125				20%	95 % CI +/- 20 %	80%
Vehicle Speed								
Vehicle Type								

2. Accuracy and precision in terms of ultrafine particle concentration is difficult to determine in the field due the lack of particle concentration standards. However, particle counters are routinely verified in the field for accuracy in flow rate. Precision was estimated in this study by collocating UFP samplers prior to use of instruments in the field.

Table 9. Summary of Detroit Data Types, Pollutants, Methods and Sample Types and Frequency.

Data Type	Pollutant or Covariate	Method	Sample Type and Frequency
Mobile Source Air Toxics	Benzene 1,3-butadiene	TO-15	1-hour integrated 1-in-3 day schedule 2 samples each day at each road-side location
	Formaldehyde Acetaldehyde Acrolein	TO-11A	
Mobile Source Related Air Pollutants	CO	NDIR	Continuous
	NO, NO_2, NOx	Chemiluminescence	
	Black carbon	Aethalometer	
	$PM_{2.5}$	TEOM	
	PM_{10}		
	PM-Coarse		
	$PM_{2.5}$	FRM	24-hour integrated 1-in-3 day schedule 1 sample each day at each road-side location
Traffic	Vehicle count Vehicle length Vehicle speed	Radar	Continuous
Meteorology	Wind speed/direction; Temperature Relative humidity	RM Young Sonic Anemometer; Vaisala Temp/Humidity	
Video	Images	Video camera	Semi-continuous

6 Data Management, Analysis and Validation

It should be noted that with the extremely large data sets that are a result of the data collection efforts for this project, it will take a significant amount of staff time to thoroughly quality assure the data. Moreover, data analysis will also require a significant amount of staff time. Both activities are ongoing processes.

6.1 Data Management

6.1.1 Purpose/Background

The following section identifies the processes and procedures that were used to acquire, transmit, transform, reduce, analyze, store, and retrieve data. These processes and procedures will maintain the data integrity and validity through application of the identified data custody protocols. Figure 2 shows the data flow from the shelters, lab analysis and traffic data to raw data storage, data review and analysis.

6.1.2 Data Recording

The majority of the data collected for this study was recorded electronically. Field/lab personnel/teams used EPA-provided forms and checklists or develop documents as needed to accomplish data recording (EPA/FHWA Near-Road QAPP). To accomplish this, each monitoring site was equipped with data loggers. A data logger was set up to record each air quality monitor's output, perform specific data manipulations, and format the resulting data in preparation for downloading and subsequent loading to a SAS database(s). Data collected from real-time monitors (e.g., gas analyzers, sonic anemometers, etc.) were recovered via computers on a daily or near-daily basis.

Data that required manual entry, such as those obtained from the integrated particulate samplers or MSAT canister and DNPH sampling, were entered into a custom designed EXCEL spreadsheet that was used to generate sample labels, record data, and generate sample tracking forms for the integrated VOC, carbonyl and $PM_{2.5}$ samples. The spreadsheet generated the unique sample codes and labels for each sampling day, location, time period, and sample type. All sample collection parameters (e.g., pressures, flows) were hand recorded on a printed blank form by the field operator at the time of sample collection. This information was then entered

by the field operator into the electronic data collection form where embedded formulas made all necessary calculations and generated a summary page later entered into the study database. From this information, the chain-of-custody (COC)/tracking forms were generated and printed. Information recorded in the electronic data sheet included sample start and end times, pressures, and flow rates. The electronic files were copied to a dedicated flash drive that was shipped with the samples from the field to the EPA RTP facility. At this point EPA staff retrieved the data files from the flash drive, verified the data entries, made necessary corrections and delivered the corrected field files to the database administrator. All datasheet entries made by the field site operator were 100% verified at the laboratory by EPA staff. Verification compares the original handwritten datasheets to the field generated electronic datasheet. This electronic datasheet formed the basis of the final EPA database for the integrated samples. The spreadsheets were designed to reduce human error and provide a simple, effective means to collect and process a large number of samples. After laboratory analysis, EPA contractor staff provides the analysis data in EXCEL spread sheet format that was imported by the Database Administrator (DBA), into the database. Linkages between the field data and the laboratory analysis were made using the field sample codes.

Traffic data were downloaded by EPA staff approximately every 4 weeks. This data was in the form of an ASCII text file. These data were transmitted to the EPA DBA for entry into a SAS dataset.

6.1.3 Field and Laboratory Data Validation

Data validation occurred at each level of data collection and reporting with each activity recorded in laboratory notebooks. Data were conditionally validated after collection and after analysis. Conditional validation was the acknowledgment that field and laboratory staff did not or did notice problems with sample collection or analysis of a particular sample. Conditional validation helped identify problems during collection, storage, shipping, and analysis that may invalidate samples. Questionable data – defined as unusual values which the DBA determines can find no basis for being invalidated, were considered valid and annotated as such in the database. EPA is in the process of reviewing the database and making final determinations of data validity.

6.1.3.1 Instrument Performance Assessment Procedures

Each day, data was accessed using WinCollect software. Graphical reports were run to determine instrument status and data validity. Examples of these graphical reports are shown in the Appendices.

Instrument issues were identified and noted in a logbook at the computer being used to run WinCollect. The graphs and any instrument issues were noted in an email to the site operator, EPA and contractor staff.

6.1.3.2 Laboratory Data Verification

Data validation continued with the inspection of received samples/documents and the integration of the laboratory analyses with the corresponding field monitoring data. Validation consisted of an assessment of the reasonableness of the data, determination of data completeness, and comparison to the criteria defined for each specific parameter (such as pump flow rates, sampling duration, etc). Analytical data not appearing to be valid or not meeting validation criteria were flagged in the database.

6.1.4 Data Reduction

Original data will be kept and archived as a part of the project's record keeping. This archiving activity was carried out by the EPA DBA.

Data recorded on a continuous basis by data loggers were electronically retrieved on a weekly or near-weekly basis by the EPA DBA. In the event that continuously logged data was not electronically transmitted, the data would be sent to the EPA DBA via DVD or other appropriate media. (This use of DVD or other media never occurred for the continuous analyzers. This only occurred for video data.) Non-continuous data, such as filter samples, canister or cartridge samples, were first analyzed by laboratory analysis. In any event, all data were submitted to the EPA DBA for this project and entered into the SAS database(s). The only exception was the video data. The video data would have consumed too many network resources and thus was maintained on external hard drives.

6.1.5 Data Related Organizational Deliverables

The Field Site operator was responsible for ensuring the data loggers, computers, and communications were in good working order so that data were retrieved on a weekly or near-weekly basis by the EPA DBA.

Continuous data that were retrieved on a weekly or near-weekly basis by the EPA DBA included:

- Meteorological data:
  - Wind speed
  - Wind direction
- Real time CO, NO, NO_2, NO_X, black carbon, coarse PM, $PM_{2.5}$, $PM_{10.}$
- Traffic data:
  - Vehicle Count
  - Vehicle Type (length)
  - Vehicle Speed

The Field Site operator was responsible for ensuring that non-continuous samples were recorded properly in logbooks, chain-of-custody forms. This data included:

- Integrated PM Filter samples
- VOC data from samples collected via Summa canister, DNPH cartridge

The Field Site operator was responsible for ensuring that all logbooks, chain-of-custody forms, notes, etc were maintained in an orderly fashion so that a complete record of the project was documented.

Laboratory analysis staff was responsible for reporting the laboratory analytical results for the canister, DNPH and $PM_{2.5}$ integrated samples to EPA. The data were provided in electronic format, Excel data worksheets. The data were reviewed for completeness. If any changes were necessary the data were investigated and changes documented in both the hardcopy and electronic files. The data were then submitted to the DBA for inclusion in the study database.

The following table (Table 10) lists the data-related deliverables, format of each deliverable, and personnel responsible.

Table 10. Data-related deliverables.

Deliverable	Custodian	Person Delivered To	Format
CO, NO, NO2, NO_X,	Field Site Operator	EPA DBA	Electronic
BC			
Coarse PM, PM_{10}, $PM_{2.5}$			
Meteorological Data			
DNPH Cartridge Sample Collection Information	Field Site Operator/Lab Tech	EPA DBA	Electronic
Canister Sample Collection Information			
PM Filter Sample Collection Information			
DNPH Cartridge Laboratory Data	Laboratory Staff	EPA WAM, EPA WAM Delivers to DBA	Electronic
Canister Laboratory Data			
PM Filter Laboratory Data			
Traffic Data	Field Site Operator	EPA DBA	Electronic

6.1.6 Data Completeness

The DBA for this project developed a SAS program that provided an overview of the data completeness for this project. This table was updated as required by the needs of the project (weekly, bi-weekly, monthly, etc.). This table provided at a glance the overall instrument up-time versus instrument maintenance, failures or other field site issues. The following tables (Table 11) shown are for the time period of September 29, 2010 thru Mid-June, 2011.

Table 11. Summary of Data Completeness across by Site for Major Parameters.

Parameter	Station ID				
	Total	Station 1	Station 2	Station 3	Station 4
		10 m roadside	100 m downwind	300 m downwind	100 m upwind
BC	98.73	99.76	98.25	98.69	98.22
CO	77.80	72.16	88.29	57.29	92.53
NO	89.53	95.99	95.12	70.95	95.34
NO_2	89.55	96.00	95.13	70.97	95.36
NO_x	89.55	96.01	95.13	70.97	95.36
PM_{10}	88.20	78.25	99.05	88.22	87.31
$PM_{2.5}$	86.98	77.72	99.40	88.13	82.82
PM Coarse	89.43	78.98	99.32	90.42	89.06
Wind Direction	85.38	79.30	98.44	75.82	87.60
Wind Speed	99.11	99.76	98.85	98.78	99.05
Traffic	> 99 (est.)				

Black Carbon – Digital Data

Site name	Distance from Road	N[a] (hours)	Completeness Time span: 09/29/2010-06/20/2011
Station 1	10 m roadside	6142	97%
Station 2	100 m downwind	6146	97%
Station 3	300 m downwind	6166	97%
Station 4	100 m upwind	6179	98%

[a]A complete hour of sampling was set at a minimum of 10 five minute data points (50 min)

Sample	% Total
TO-15 canisters (VOCs)	88
TO-11 cartridges (aldehydes)	90
$PM_{2.5}$ Filters	94

6.1.7 Data Storage and Retrieval

The EPA Project Officer will be consulted prior to disposal of records. The EPA DBA or similar designee is responsible for archiving, storage, and retrieval of all field and laboratory data files developed during the study at EPA. Copies of all study information (records/data) are retained and archived in accordance with Federal record storage guidelines.

6.1.8 Data Dictionary

The data dictionary provides a description of each database variable including range (minimum, maximum), type (numeric, alpha), missing value codes, and error flags (See Appendix). Descriptive information required to understand or interpret variables, including calculations or other manipulation, was included for each variable, as needed. This data dictionary is an on-going effort and is refined on an as needed basis.

6.2 Data Review, Verification, and Validation

The purpose of this section is to identify the procedures, and responsible parties that performed data review, verification and validation. Data verification is the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements. Data validation is an analyte- and sample-specific process that extends the evaluation of data beyond method, procedural, or contractual compliance (i.e. data verification) to determine the analytical quality of a specific data set.

Verification and validation of the procedures used to collect and analyze data are critical to the goals of this project and are performed after data collection, but prior to performing the flux calculations and uncertainty determinations. Study personnel were responsible for ensuring that the sampling methods, quality control protocols, and validation methods were followed and completed.

6.2.1 Validating and Verifying Data

Ideally, data undergoing evaluation should be compared to actual events. However, exceptional field events may occur, and field and laboratory activities may negatively affect the integrity of samples. In addition, some of the QC checks may indicate that the data failed to meet the

acceptance criteria. Data identified as suspect, or does not meet the acceptance criteria, were flagged as indicated in the appendix.

While reviewing the CO data for Site 4 (100 m upwind), we observed a baseline shift in the data for the time period of September 29, 2010 thru December 6, 2010. After a review of the multi-point calibration datasheets, correction factors were applied. More detail may be found in the appendix.

6.2.2 Verification

As the data were being compiled (continuous and non-continuous data), a review of the data was conducted for completeness and data entry accuracy. All raw data that were hand entered from data sheets was checked prior to entry to the appropriate database. Once the data were entered, the data were reviewed for routine data outliers and conformance to acceptance criteria. Unacceptable or questionable data was flagged appropriately.

6.2.3 Validation

Validation of measurement data required two stages, one at the measurement value level and the second at the batch level. Records of all invalid samples were retained in the appropriate database. Information included a brief summary of why the sample was invalidated along with the associated flags. Logbook notes and field data sheets have more detailed information regarding the reason a sample was flagged. These documents were retrieved from the field sites and are stored at EPA.

The flags listed in Appendices were used to indicate that individual samples, or samples from a particular instrument, were invalidated.

6.3 Data Analysis

6.3.1 Statistical Analysis – Overall Project

The data analyses recommended below focused on the most basic issues of roadway emission impacts:

- To what extent do roadway traffic emissions elevate concentrations of MSATs and vehicle emission surrogates above background levels?
- Over what spatial scale do roadway emissions cause significant elevation of MSAT and surrogate compound levels above the upwind background?
- What are the long-term (e.g., annual) and daily average concentrations of MSATs and vehicle emission surrogates within the spatial scale of impact of roadway emissions?

Additional data analyses may address additional questions such as the respective impacts of meteorological conditions, traffic volume, vehicle type, etc.

Given the complexity of the data set, multivariate analysis approaches using statistical analysis software such as JMP or SAS was necessary to assess the impact of various parameters of interest on the pollutant dispersion. However, emphasis was placed on reporting clear and understandable results from the statistical analysis. The field studies were conducted to understand the relation of mobile source emissions to key air contaminants and to determine if there was a statistically significant difference between the pollutant concentration measured at each site and the background concentration.

Data were analyzed using a combination of programs, including MATLAB version R2009b, Microsoft Excel 2007, JMP 8/9 and Sigma Plot 11/12. The data analysis included calculating summary statistics of data for each site for all wind conditions and for winds only from the West (downwind) (+/- 60 degrees from perpendicular), estimating concentration gradients for winds from the West, and observing concentrations as a function of wind direction for all winds.

7 Results and Discussion

The study design, methods, and general data trends are the focus of this report. An assessment of one of the data quality indicator (DQI) goals as stated in the quality assurance project plan (QAPP) is shown in Table 11 for certain major parameters.

7.1 Traffic Activity

As shown in Figure 16, traffic activity exhibited a bi-modal distribution. This is typical of most cities in the U.S. Figures 18, 19, and 20 shows traffic activity by day of the week, box-whisker plot by weekday and weekend, and traffic volume by season for the study period.

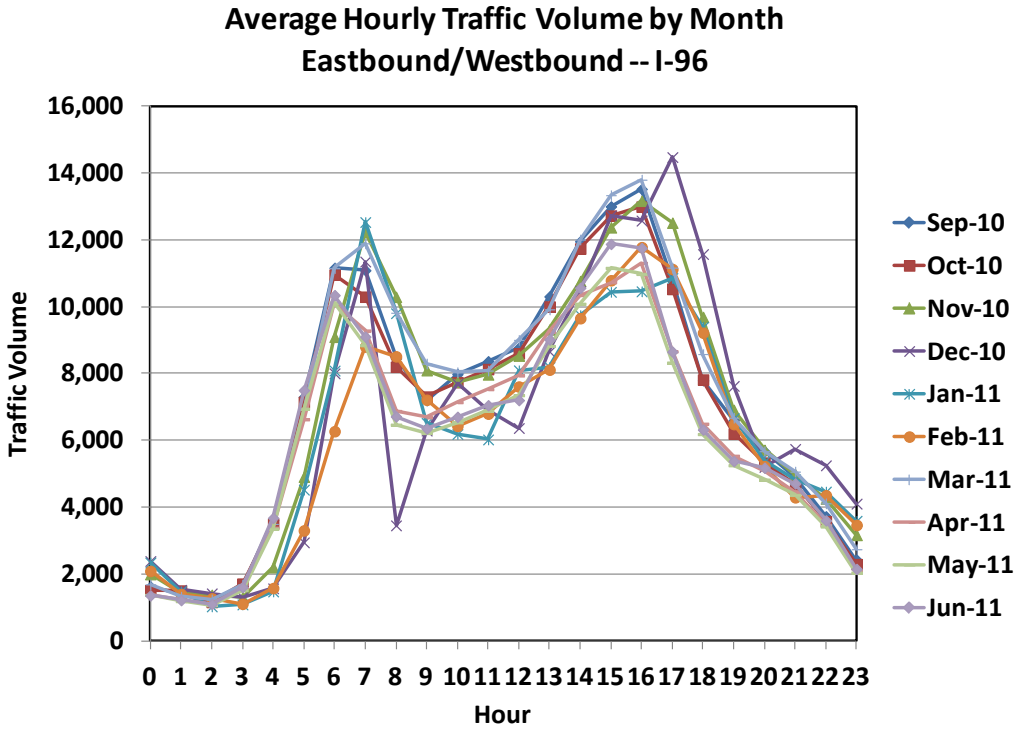


Figure 16. Average Hourly Traffic Volume by Month at I-96 Site.

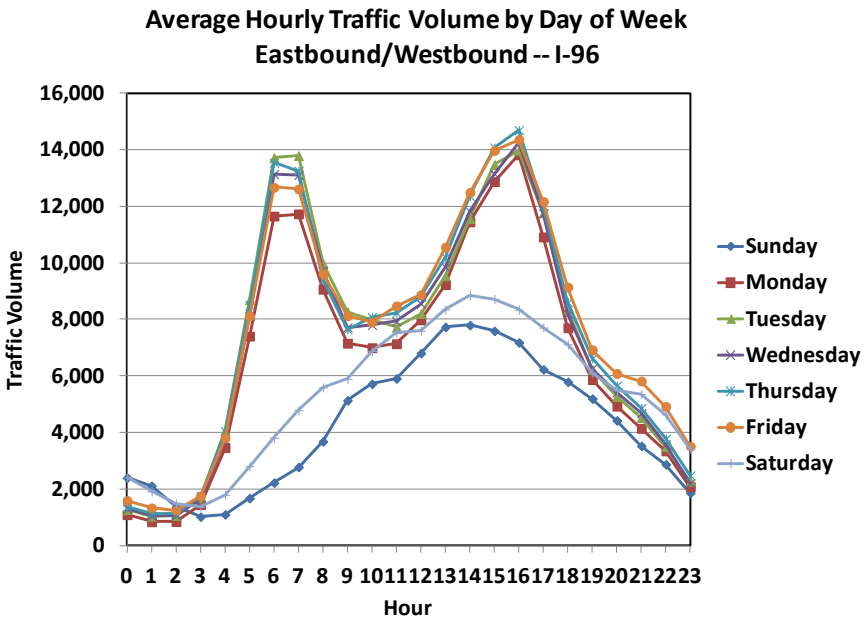


Figure 17. Average Daily Traffic Volume by Day-of-Week at I-96 Site.

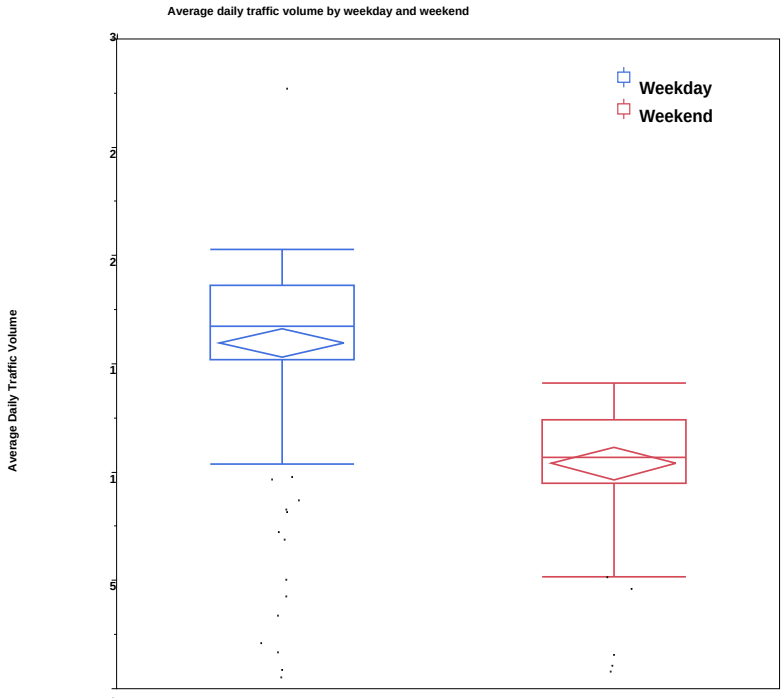


Figure 18. Box-Whisker Plot -- Average Daily Traffic Volume by weekday and weekend[1].

[1] The boundary of the box closest to zero indicates the 25th percentile, the line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (error bars) above and below the box indicate the 90th and 10th percentiles. Points above the whiskers are outliers. The diamond within the box marks the mean .

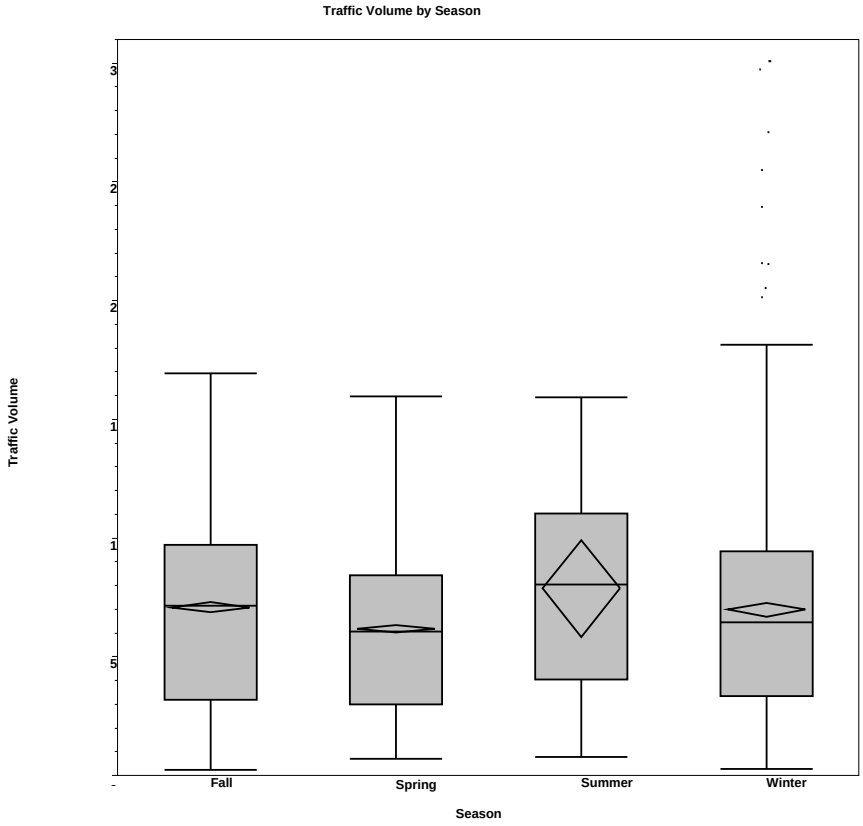


Figure 19. Box-Whisker Plot -- average hourly traffic volume by season.

7.2 Meteorology

Figure 4 shows the wind direction and wind speeds observed during the course of the study. As can be seen from the wind roses, there were strong northwesterly winds during the morning commute hours. One implication of these wind conditions is that the study sites may have been influenced by nearby sources such as roadway traffic from US-24, Telegraph Road. Telegraph Road is a 6-lane divided highway approximately 440 meters west of Station 2 and 380 meters west of Station 3. An additional nearby source of air pollutants emissions was the apartment complex immediately adjacent (west of Station 2 and 3). The source of emissions at the apartment complex was most probably cold-start emissions from passenger vehicles.

7.3 Continuous Analyzers

7.3.1 CO and NO_X

Figure 20 and Figure 21 show the mean concentrations by site from all wind directions and winds from the road, respectively. The mean CO concentration for the 10 m roadside site is approximately 46% higher than the 100 m downwind site for all wind conditions. The mean concentration for the 10 m roadside site is approximately 37% higher than the 300 m downwind site for all wind conditions. The mean concentration for the 10 m roadside site is approximately 11% higher than the 100 m upwind site for all wind conditions.

The mean CO concentration for the 10 m roadside site is approximately 76% higher than the 100 m downwind site for downwind conditions (winds from the road). The mean concentration for the 10 m roadside site is approximately 59% higher than the 300 m downwind site for downwind conditions (winds from the road). The mean concentration for the 10 m roadside site is approximately 89% higher than the 100 m upwind site for downwind conditions (winds from the road).

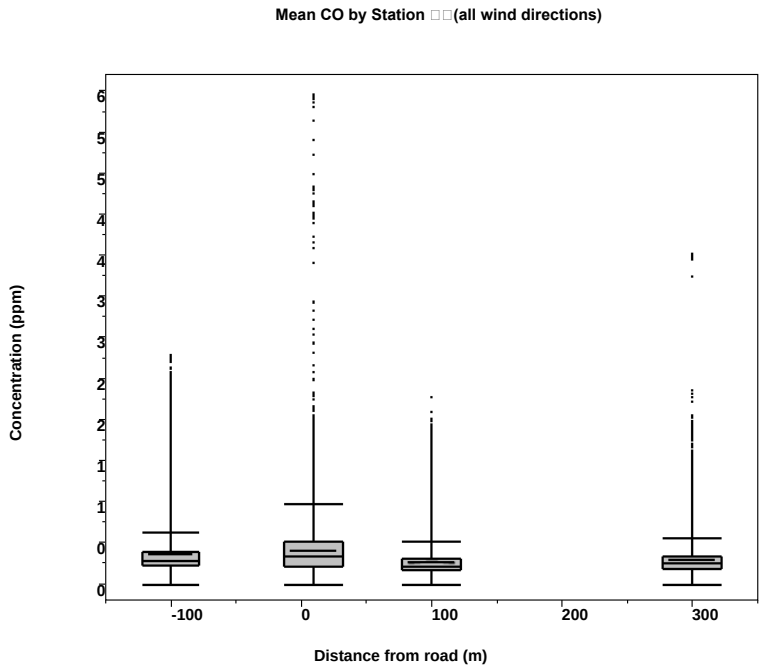


Figure 20. Box-Whisker Plot Mean CO Concentration by Site (all wind directions).

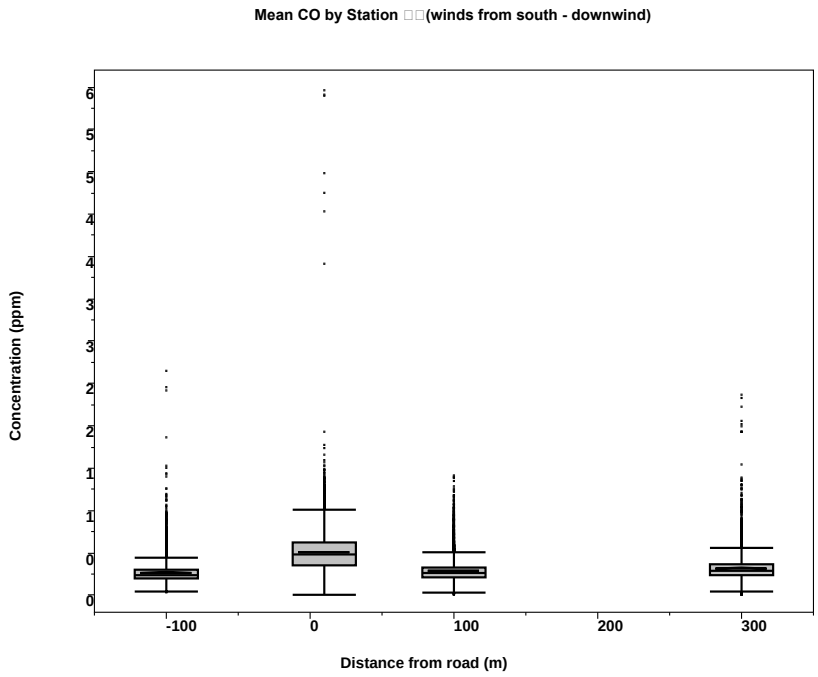


Figure 21. Box-Whisker Plot Mean CO Concentration by Site (winds from road).

Figure 22 shows the mean CO concentration by hour for all stations when winds are from the road. Figure 23 shows the mean CO concentration by hour for all four stations when the winds are from the road vs. hourly average traffic.

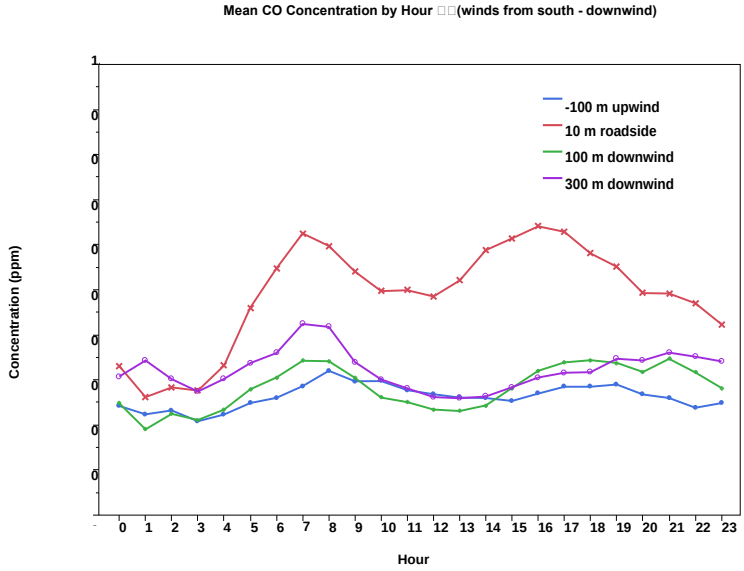


Figure 22. Mean CO Concentration by Hour: all stations (winds from road).

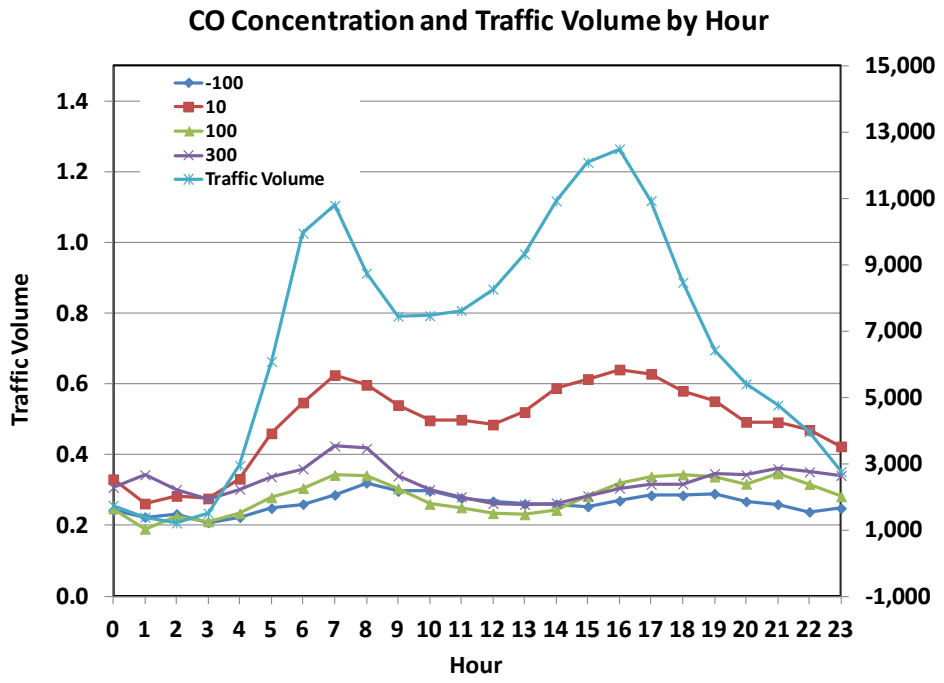


Figure 23. Mean CO Concentration and Traffic Volume by Hour: all stations (winds from road).

Figure 24 shows the normalized spatial gradient for NO_2, CO and BC for all wind conditions. The spatial gradient for each pollutant has been normalized to the relevant pollutant for Site 1.

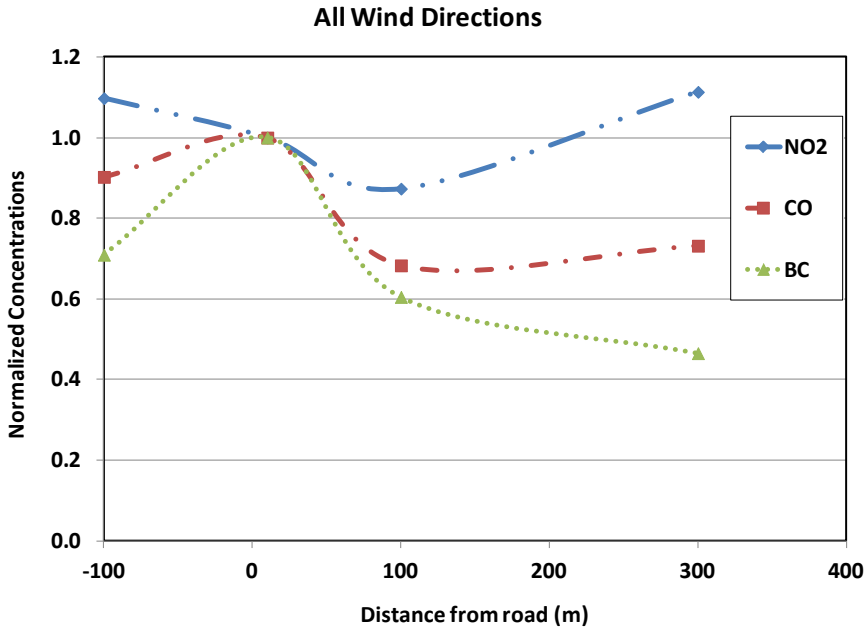


Figure 24. Mean NO2, CO, BC Normalized Concentrations – all wind conditions.

Figure 25 shows the normalized spatial gradient for NO_2, CO and BC for downwind conditions (winds from road). The spatial gradient for each pollutant has been normalized to the relevant pollutant for Site 1.

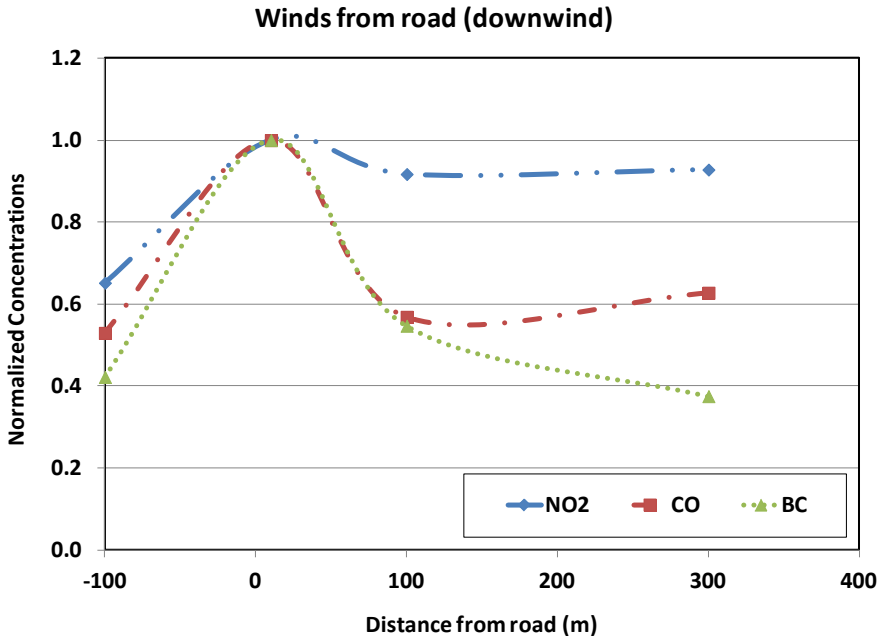


Figure 25. Mean NO2, CO, BC Normalized Concentrations – winds from road (downwind).

Figure 26 and **Figure 27** show the mean hourly NO concentrations by site from all wind directions and winds from road, respectively. The mean NO concentration for the 10 meter roadside site is approximately 243% higher than the 100 meter upwind site (**Figure 26**) for all wind directions. The mean NO concentration for the 10 meter road is approximately 100% higher than the 100 meter upwind site (**Figure 27**) for downwind conditions (winds from road). Figure 28 shows the mean NO concentration by hour for all stations when winds are from the road.

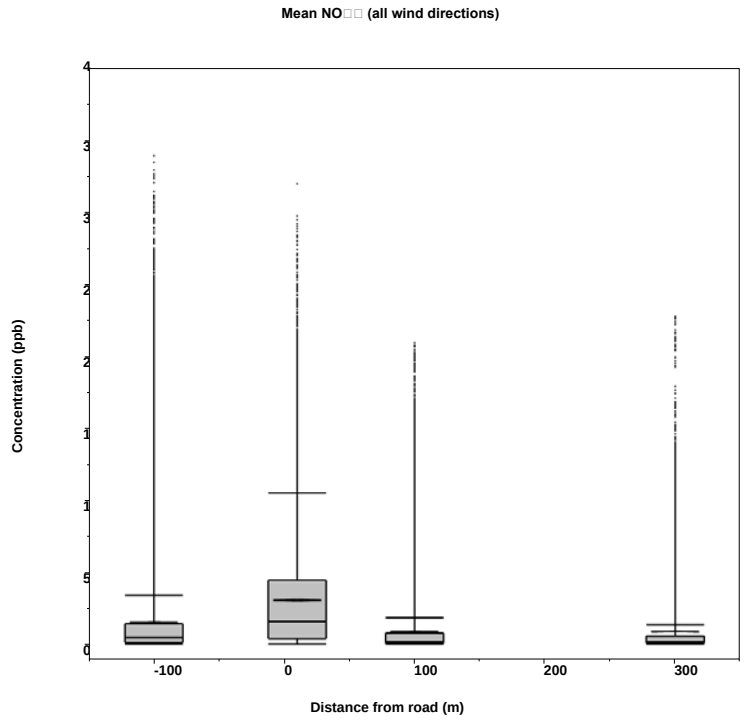


Figure 26. Box-Whisker Plot for NO by Station (all wind directions).

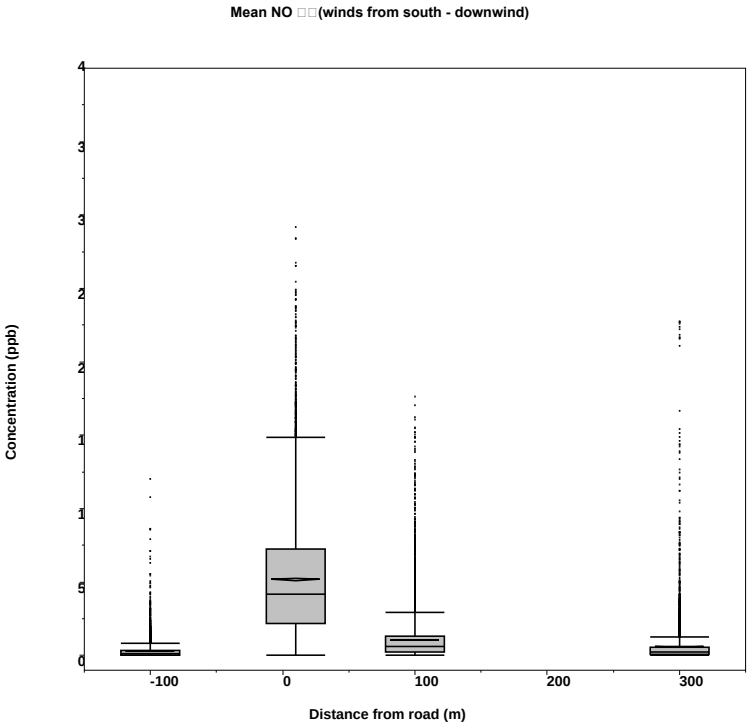


Figure 27. Box-Whisker Plot for NO by Station (winds from road).

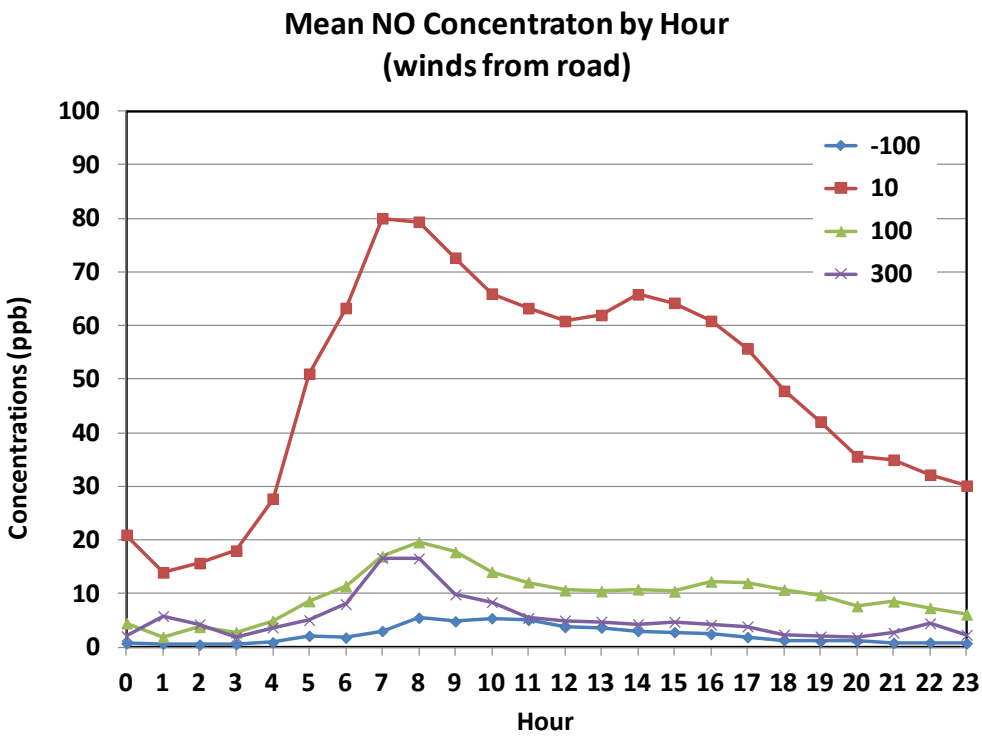


Figure 28. Mean NO Concentration by Hour: all stations (winds from road).

Figure 29 and Figure 30 show the mean hourly NO_2 concentrations by site from all wind directions and winds from road, respectively. The mean NO_2 concentration for the 10 meter roadside site is approximately 15% higher than the 100 meter upwind site (Figure 29) for all wind directions. The mean NO_2 concentration for the 10 meter roadside site is approximately 11 % higher than the 100 meter upwind site (Figure 30) for downwind conditions (winds from road). Figure 31 shows the mean NO_2 concentration by hour for all stations when winds are from the road.

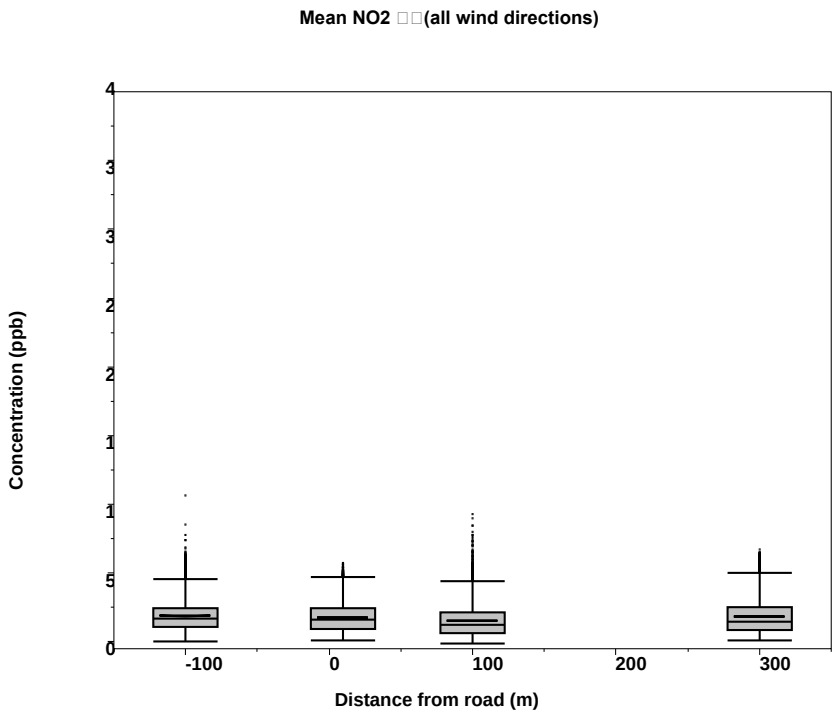


Figure 29. Box-Whisker Plot for NO_2 by Station (all wind directions).

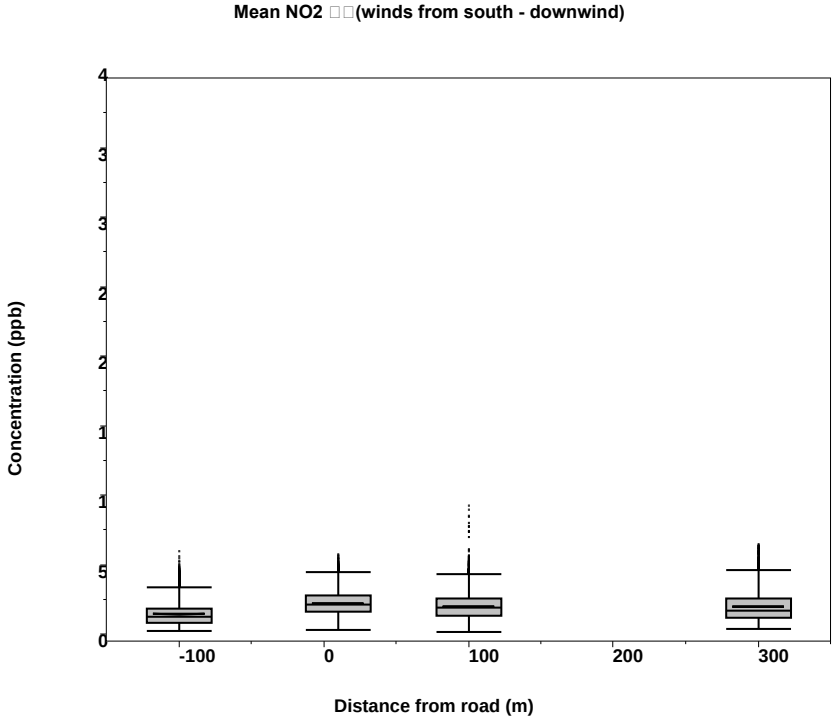


Figure 30. Box-Whisker Plot for NO_2 by Station (winds from road).

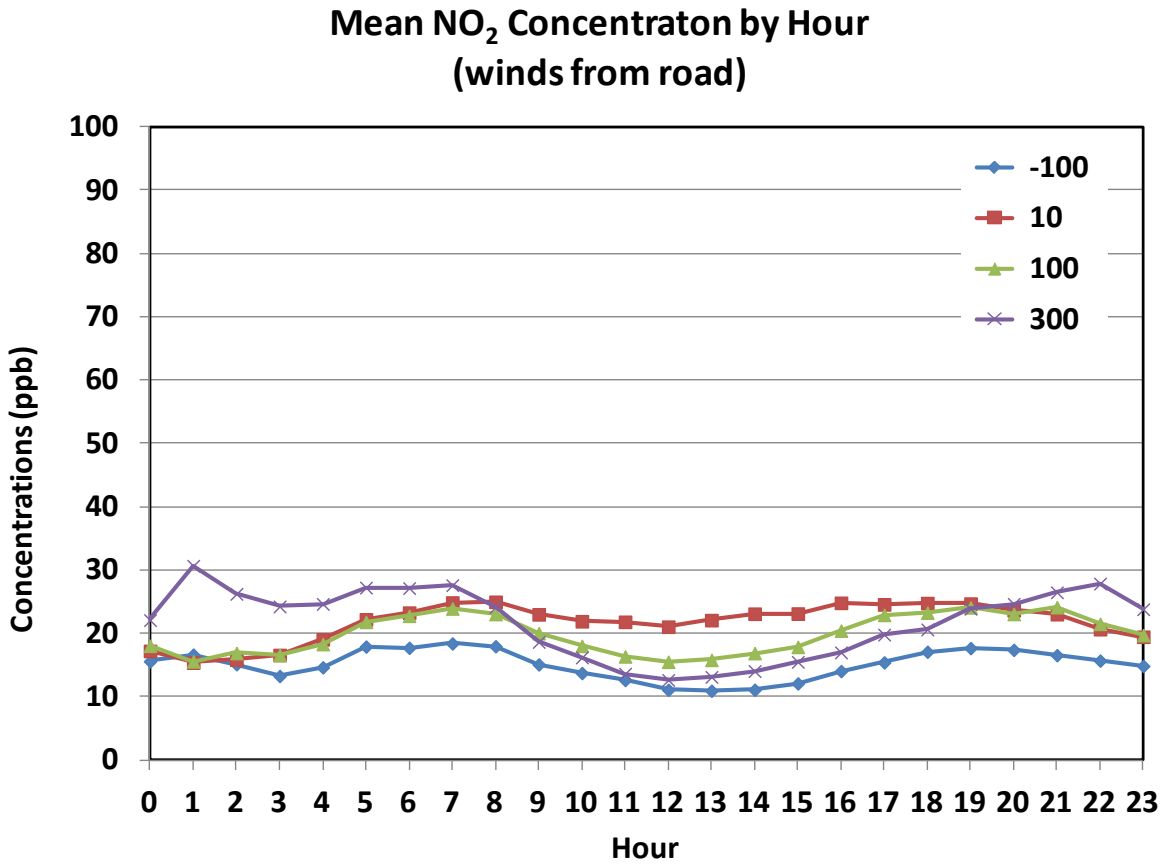


Figure 31. Mean NO_2 Concentration by Hour: all stations (winds from road).

Figure 32 and Figure 33 show the mean hourly NO_X concentrations by site from all wind directions and winds from road, respectively. The mean NO_X concentration for the 10 meter roadside site is approximately 41% higher than the 100 meter upwind site (Figure 32) for all wind directions. The mean NO_X concentration for the 10 m roadside site is approximately 143 % higher than the 100 meter upwind site (Figure 33) for downwind conditions (winds from road). Figure 34 shows the mean NO_X concentration by hour for all stations when winds are from the road.

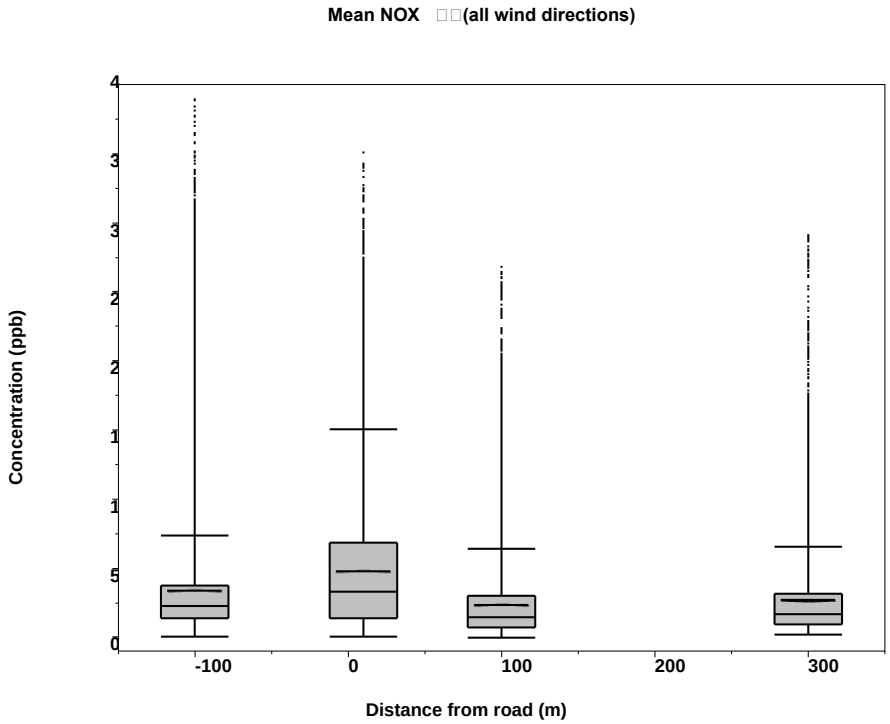


Figure 32. Box-Whisker Plot for NO_X by Station (all wind directions).

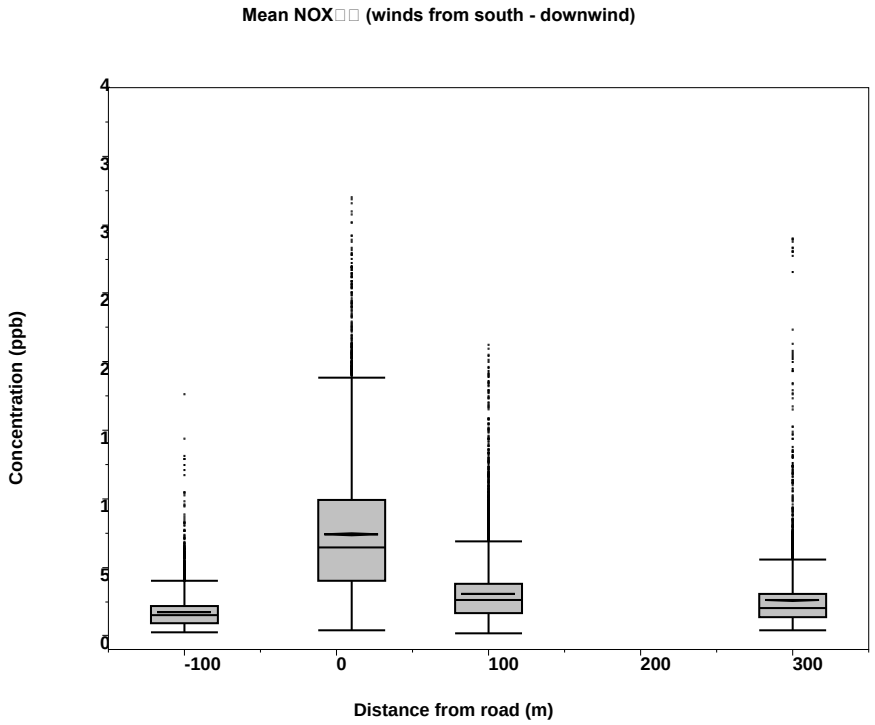


Figure 33. Box-Whisker Plot for NO_X by Station (winds from road).

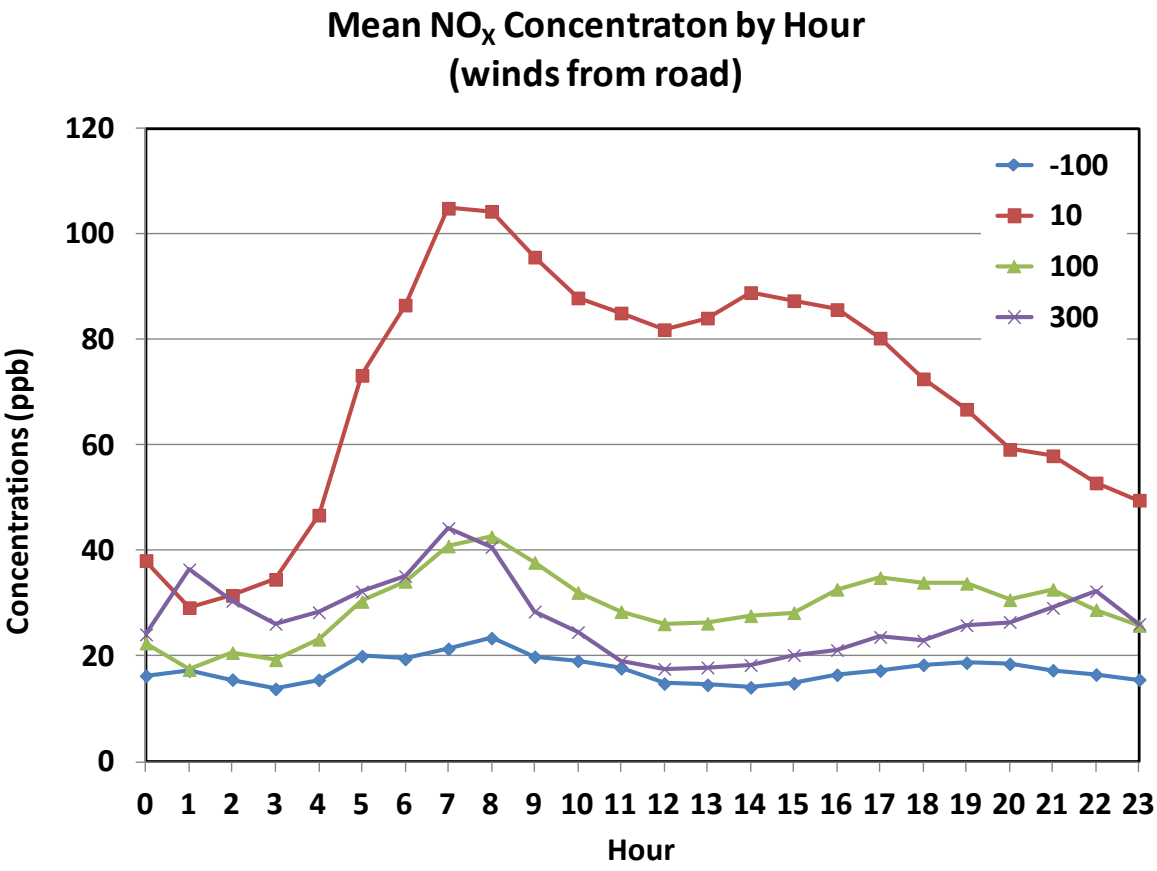


Figure 34. Mean NO_X Concentration by Hour: all stations (winds from road).

Long term averages for NO, NO_2, NO_x, and CO for all wind directions are shown in Table 12 and Table 13. Figure 35 shows a polar plot for CO and Figure 36 show polar plots for NO, NO_2, NO_X. The radial dimension indicates wind speed and wind direction. The plots indicate relative air pollutant concentrations for all wind conditions. As may be seen in the figures, the higher air pollutant concentrations are observed during low wind speeds.

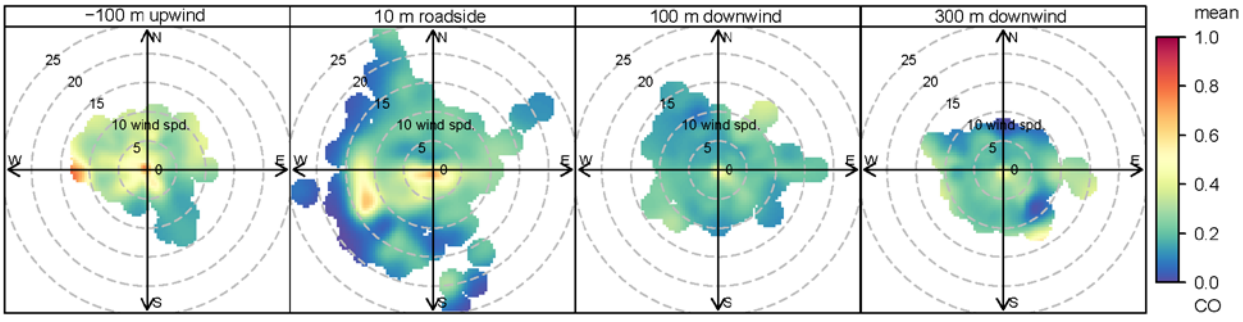


Figure 35 Polar plot for CO for all stations and all wind conditions—units = ppm.

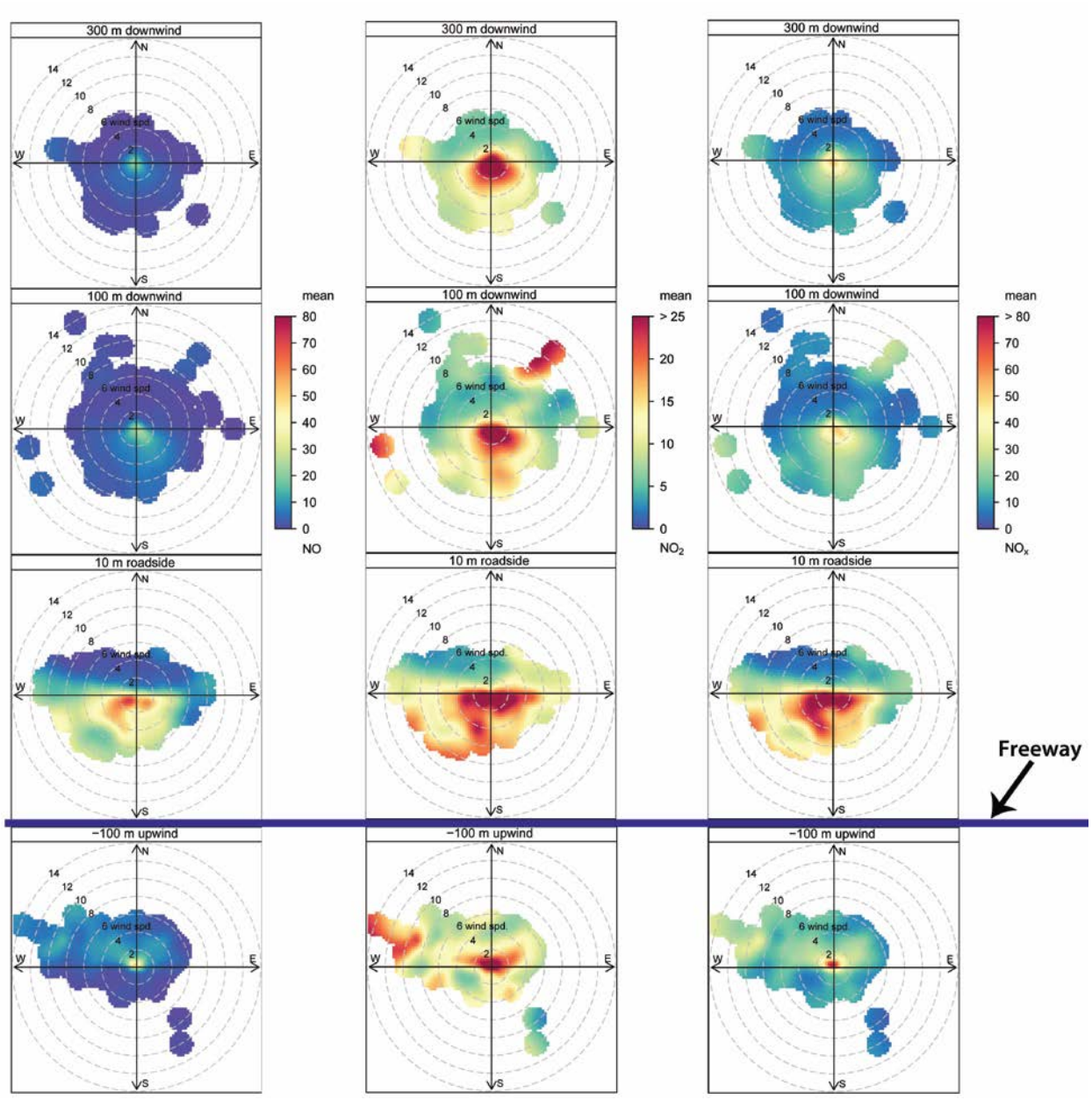


Figure 36 Polar plot for NO, NO_2 and NO_X for all stations and all wind conditions—units = ppb.

Table 12. Long-term averages at near-road monitoring stations for NO, NO2, NOx, and CO - all wind directions.

		CO (ppm)			NO (ppb)			NO_2 (ppb)			NO_X (ppb)		
Location	Time span	N	Avg	95% CI	N	Avg	95% CI	N	Avg	95% CI	N	Avg	95% CI
-100	09/29/2010 to 06/20/2011	70197	0.37	0.36 - 0.37	65414	15.51	15.27 - 15.76	65414	18.83	18.75 - 18.91	65414	34.34	34.05 - 34.63
10	09/29/2010 to 06/20/2011	52834	0.41	0.40 - 0.41	51009	31.06	30.73 - 31.38	51009	17.41	17.32 - 17.50	51009	48.46	48.07 - 48.86
100	09/29/2010 to 06/20/2011	66761	0.28	0.27 - 0.28	66737	9.05	8.90 - 9.19	66737	15.17	15.09 - 15.25	66737	24.21	24.01 - 24.41
300	09/29/2010 to 06/20/2011	41068	0.30	0.30 - 0.30	20295	9.04	8.74 - 9.33	20295	18.31	18.14 - 18.48	20295	27.35	26.94 - 27.76

Table 13. Long-term averages a near-road monitoring stations for NO, NO2, NOx, and CO - winds from the South.

		CO (ppm)			NO (ppb)			NO_2 (ppb)			NO_X (ppb)		
Location	Time span	N	Avg	95% CI	N	Avg	95% CI	N	Avg	95% CI	N	Avg	95% CI
-100	09/29/2010 to 06/20/2011	11689	0.27	0.27 - 0.27	10339	2.89	2.79 - 2.99	10339	14.39	14.24 - 14.54	10339	17.28	17.06 - 17.50
10	09/29/2010 to 06/20/2011	11521	0.51	0.50 - 0.51	11519	51.86	51.15 - 52.58	11519	22.19	22.03 - 22.34	11519	74.05	73.23 - 74.86
100	09/29/2010 to 06/20/2011	17477	0.29	0.29 - 0.29	17477	10.49	10.29 - 10.69	17477	20	19.87 - 20.13	17477	30.49	30.20 - 30.79
300	09/29/2010 to 06/20/2011	9616	0.32	0.32 - 0.32	6869	6.02	5.68 - 6.36	6869	19.75	19.50 - 20.00	6869	25.77	25.25 - 26.29

7.3.2 Black Carbon

Summaries of the annual BC averages and confidence intervals at each site are presented in Table 14 and shown in Figure 37. The data show that, on an average basis with winds from all directions, the BC annual average at 10 m from the highway is significantly higher than at further distances from the road. In addition, BC average values at 100 m in the predominant downwind direction (South of the highway) are significantly higher than at 100 m in the opposite direction, as well as higher than at 300 m on the downwind side of the road. Station 1 BC is approximately 65%, 115%, and 41% higher than Station 2 (100 m downwind), Station 3 (300 m downwind), and Station 4 (100 m upwind) sites, respectively.

Table 14. BC averages for all data (09/29/2010-06/15/2011)

Site name	Distance from Road	N	Mean ($\mu g/m^{-3}$)	95% CI ($\mu g/m^{-3}$)
Station 4	100 Meter Upwind	60,480	.61	0.61 – 0.62
Station 1	10 meter roadside	71,771	.86	0.85 – 0.86
Station 2	100 Meter Downwind	71,150	.52	0.52 – 0.53
Station 3	300 Meter Downwind	69,981	.40	0.39 – 0.40

BC hourly values were also isolated for time periods with winds from the south, designated as 180 ± 60 degrees (Table 15). On the downwind side of the road, BC values at Station 1 are significantly higher than all other stations. **Figure 38** and **Figure 39** show the mean BC concentrations by site from all wind directions and winds from road, respectively. Station 1 BC is approximately 83%, 167%, and 137% higher than Station 2 (100 m downwind), Station 3 (300 m downwind), and Station 4 (100 m upwind) sites, respectively. **Figure 40** shows the mean BC concentration by hour for all stations when winds are from the road.

Table 15. BC averages, wind from the South (09/29/2010-06/15/2011)

Site name	Distance from Road	N	Mean ($\mu g/m^{-3}$)	95% CI ($\mu g/m^{-3}$)
Station 4	100 Meter Upwind	14341	0.54	0.54 – 0.55
Station 1	10 meter roadside	18184	1.28	1.26 – 1.29
Station 2	100 Meter Downwind	18240	0.70	0.70 – 0.71
Station 3	300 Meter Downwind	18356	0.48	0.47 – 0.48

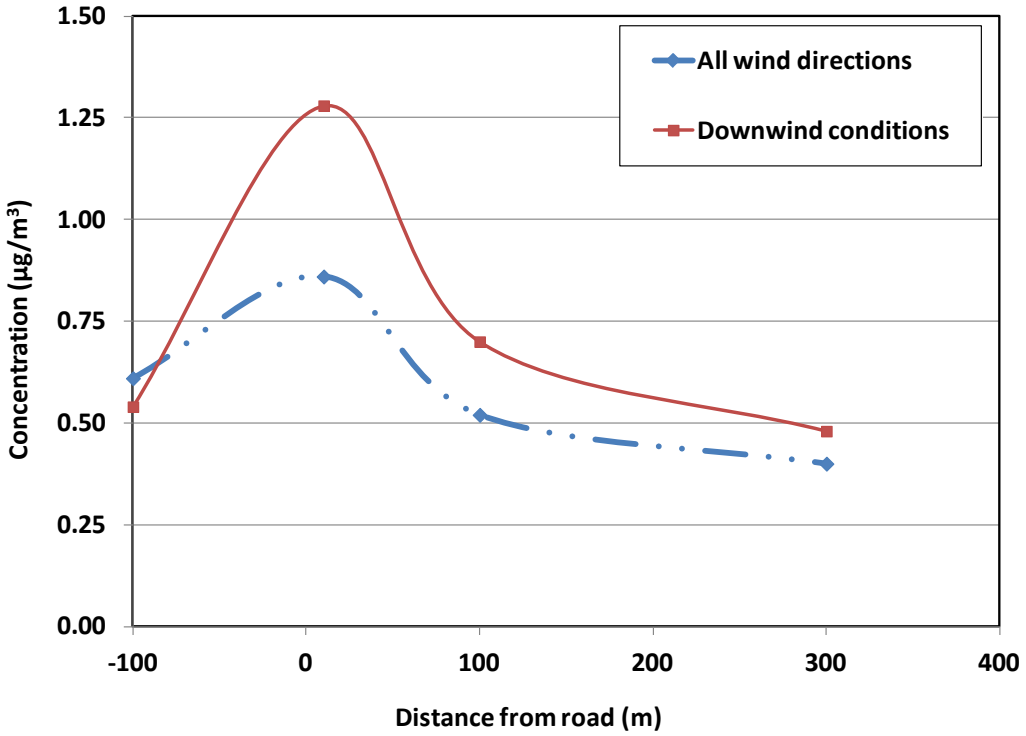


Figure 37. Average black carbon concentrations as a function of distance from the road for all data and during time periods with wind from the South (120-240 degrees).

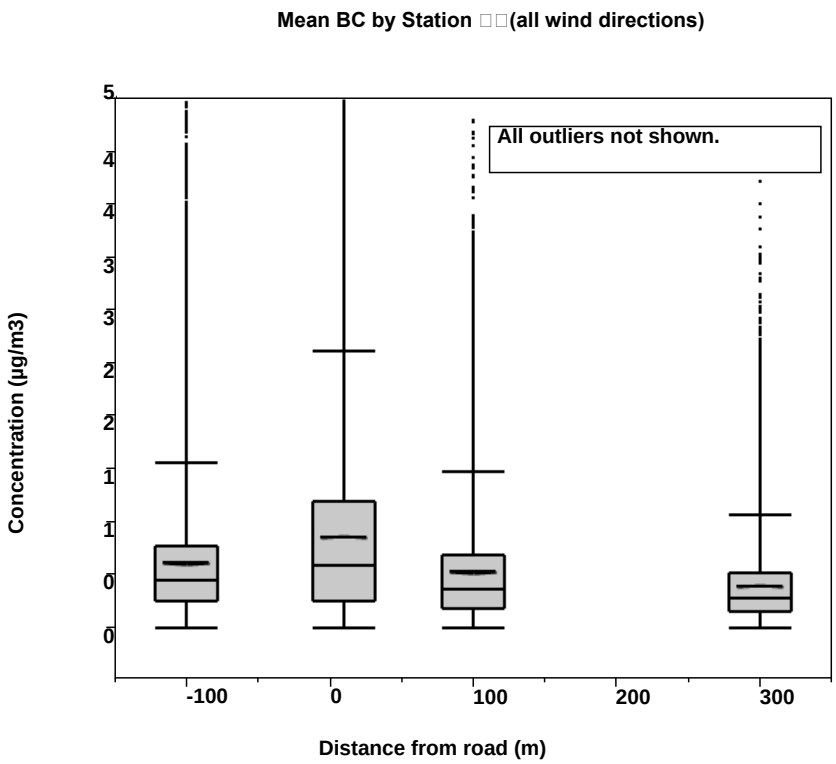


Figure 38. Box-Whisker Plot for BC by Station (all wind directions).

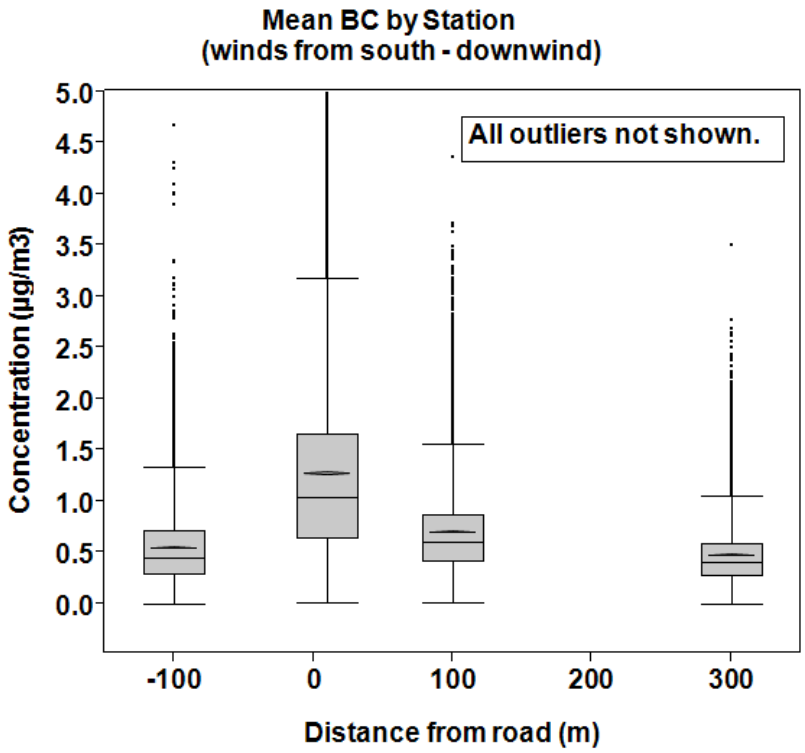


Figure 39. Box-Whisker Plot for Hourly BC by Station (winds from road).

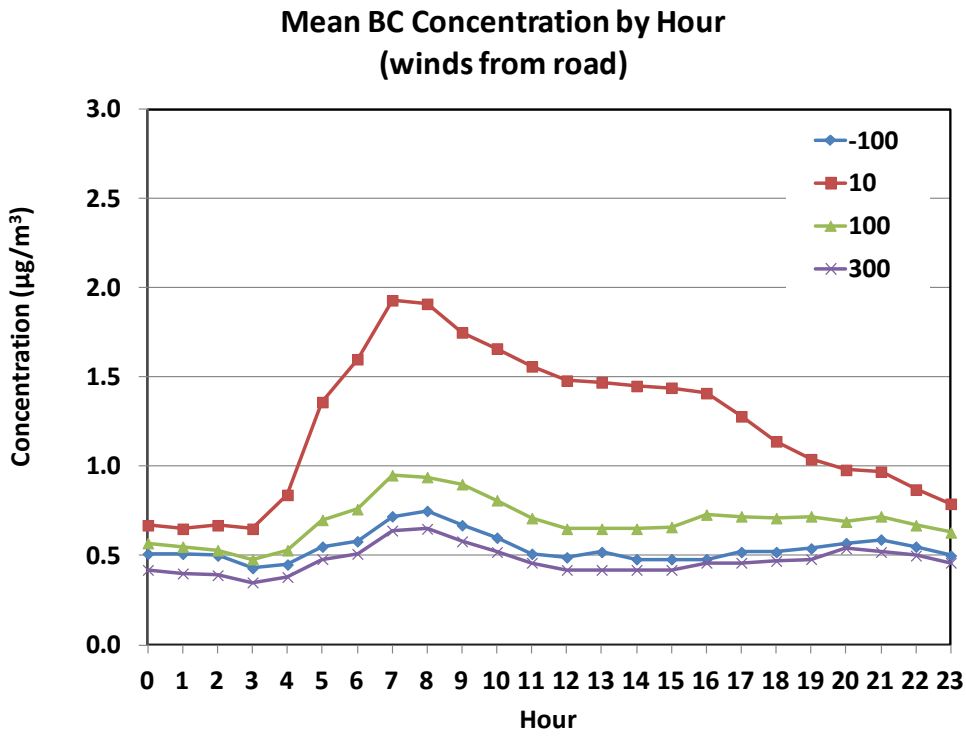


Figure 40. Mean BC Concentration by Hour: all stations (winds from road).

7.4 Continuous Particulate Data (TEOM)

Table 16 and **Table 17** and **Figure 42** show data that were measured by a TEOM 1405 FDMS and are the five-minute data summarized over the period of the study. Most analyzers deployed for this study performed well with the exception of the TEOMs. This instrument had both design and manufacturing issues that only became apparent after the instruments had been deployed. The remedy for this situation was that the manufacturer performed an "in the field upgrade" by technical staff from ThermoScientific in late November 2009 and early December 2009—during the Las Vegas study. While these upgrades improved instrument performance and stability, data collected over the course of the study is problematic.

Table 16. PM_{10}, $PM_{2.5}$ and PM Coarse averages for all wind directions (09/29/2010-06/15/2011)

Site name	Distance from Road	N	Mean ($\mu g/m^3$)	95% CI ($\mu g/m^3$)
PM_{10}				
Station 4	100 Meter Upwind	60196	15.71	15.60 - 15.82
Station 1	10 meter roadside	30386	22.71	22.46 - 22.95
Station 2	100 Meter Downwind	39704	18.67	18.54 - 18.79
Station 3	300 Meter Downwind	28934	20.99	20.50 - 21.48
$PM_{2.5}$				
Station 4	100 Meter Upwind	57004	11.00	10.91 - 11.09
Station 1	10 meter roadside	30185	13.89	13.73 - 14.04
Station 2	100 Meter Downwind	39708	11.55	11.46 - 11.63
Station 3	300 Meter Downwind	28911	17.00	16.48 - 17.52
PM Coarse				
Station 4	100 Meter Upwind	61373	5.41	5.34 - 5.47
Station 1	10 Meter Roadside	30646	8.95	8.81 - 9.10
Station 2	100 Meter Downwind	39790	7.10	7.04 - 7.16
Station 3	300 Meter Downwind	30296	5.87	5.68 - 6.06

Table 17. PM_{10}, $PM_{2.5}$ and PM Coarse averages for winds from road (09/29/2010-06/15/2011)

Site Name	Distance from Road	N	Mean ($\mu g/m^3$)	95% CI ($\mu g/m^3$)
PM_{10}				
Station 4	100 Meter Upwind	10453	17.26	17.02 - 17.50
Station 1	10 Meter Roadside	7829	33.45	33.00 - 33.89
Station 2	100 Meter Downwind	10270	25.72	25.50 - 25.95
Station 3	300 Meter Downwind	6914	27.98	26.83 - 29.12
$PM_{2.5}$				
Station 4	100 Meter Upwind	9734	13.19	12.98 - 13.40
Station 1	10 Meter Roadside	7819	19.84	19.60 - 20.08
Station 2	100 Meter Downwind	10270	15.58	15.43 - 15.74
Station 3	300 Meter Downwind	6913	22.20	20.94 - 23.47
PM Coarse				
Station 4	100 Meter Upwind	10692	4.77	4.66 - 4.87
Station 1	10 Meter Roadside	7839	13.69	13.38 - 14.00
Station 2	100 Meter Downwind	10279	10.13	10.00 - 10.26
Station 3	300 Meter Downwind	7104	7.14	6.96 - 7.33

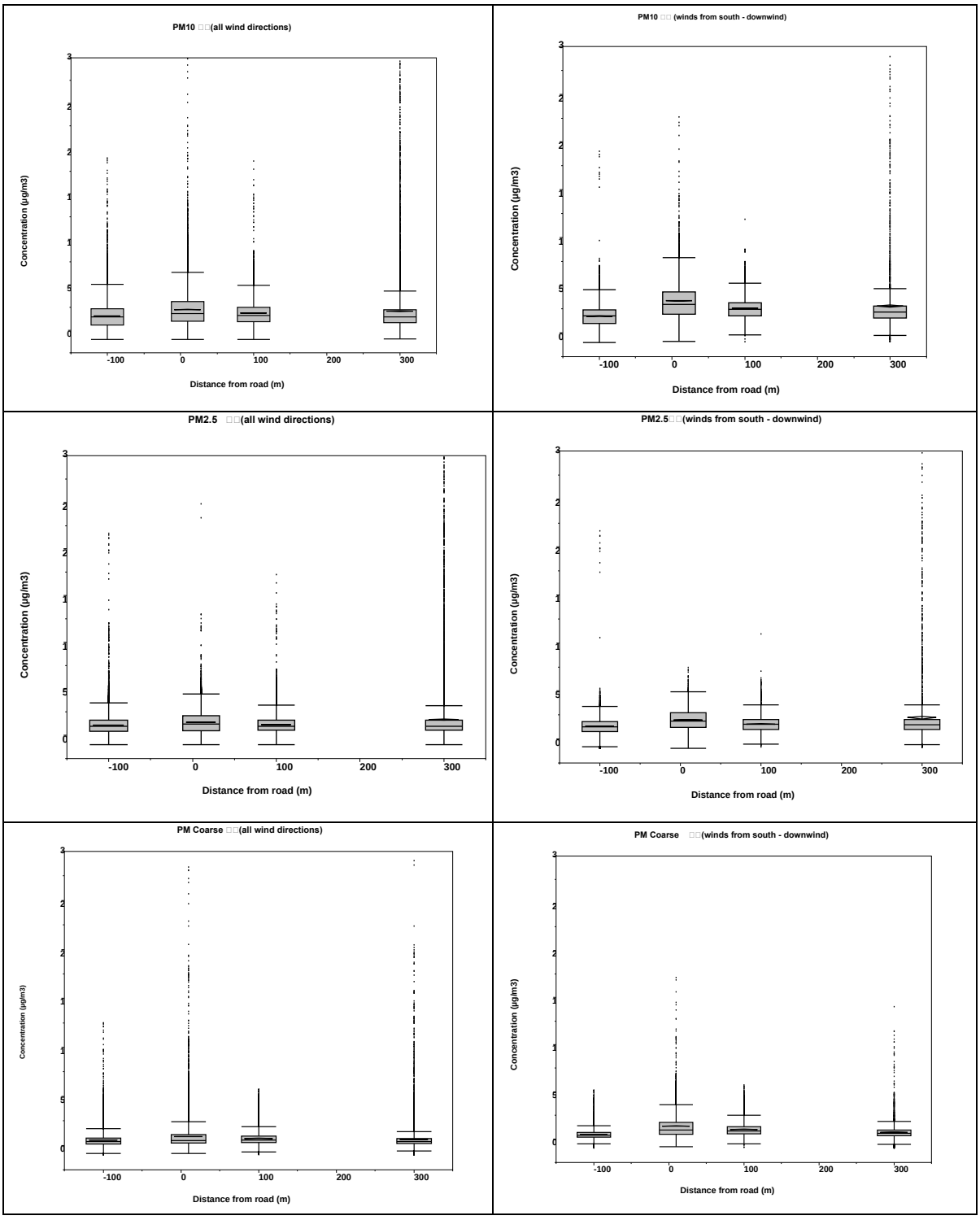


Figure 41 Box-Whisker Plots for PM_{10}, $PM_{2.5}$ and PM Coarse for all stations; all wind directions and winds from road.

7.5 Integrated Sample Data

7.5.1 Integrated MSAT Data (TO-15 — VOC)

Table 18. VOC -- averages for all wind directions (09/29/2010-06/15/2011)

Site name	Distance from Road	N (Obs.)	Mean (ppb)	95% CI (ppb)
Acrolein				
4	100 m upwind	32	0.72	0.55 – 0.89
1	10 m roadside	37	0.69	0.56 – 0.82
2	100 m downwind	21	0.68	0.54 – 0.81
3	300 m downwind	34	0.63	0.51 – 0.74
1,3-Butadiene				
4	100 m upwind	31	0.13	0.08 – 0.18
1	10 m roadside	37	0.19	0.14 – 0.24
2	100 m downwind	21	0.13	0.07 – 0.18
3	300 m downwind	34	0.12	0.07 – 0.16
Benzene				
4	100 m upwind	32	0.36	0.27 – 0.44
1	10 m roadside	37	0.46	0.36 – 0.55
2	100 m downwind	21	0.29	0.19 – 0.40
3	300 m downwind	34	0.32	0.24 – 0.40

NOTE: Data are for valid samples only.

7.5.2 Data Caveats– Integrated Samples – VOC

All sample results are presented with no blank or recovery correction. This was deemed unnecessary as the field blank values were either zero, below the method detection limit, or not statistically significant. Blank and control values may be found in the SAS/JMP data sets.

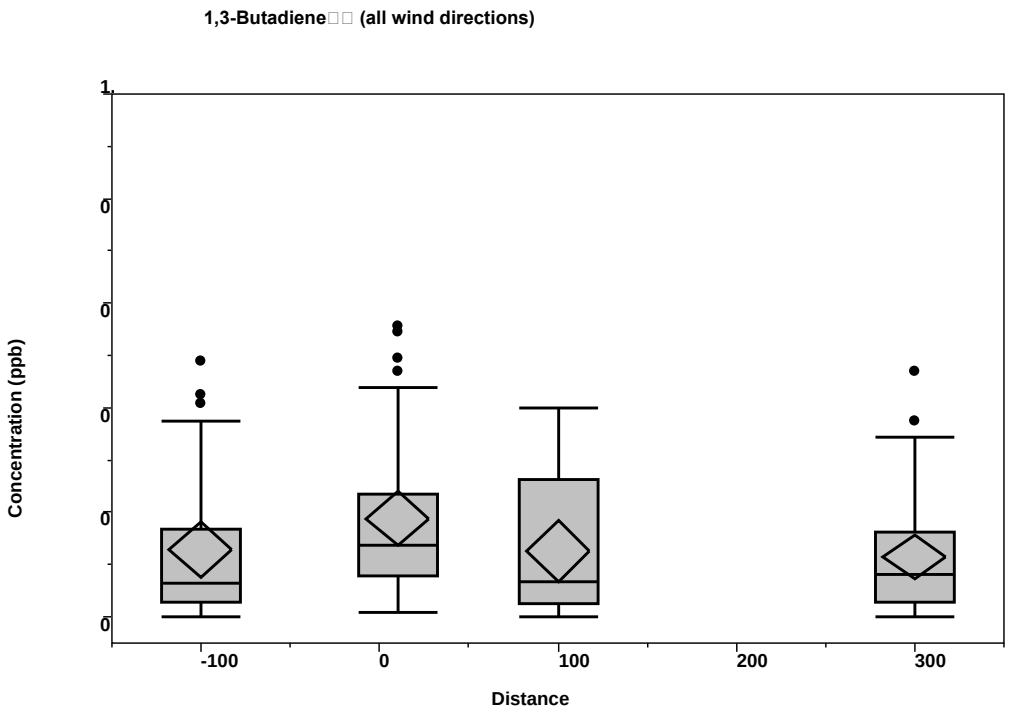


Figure 42 Box-Whisker Plot for 1,3-Butadiene all stations, all sample times, all wind directions.

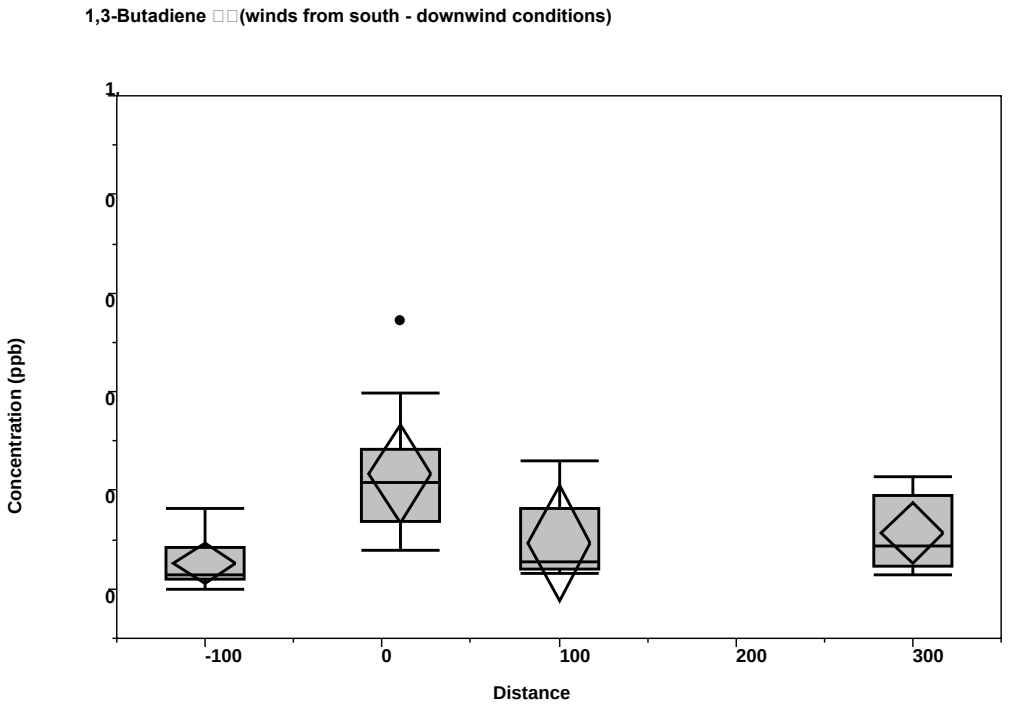


Figure 43 Box-Whisker Plot for 1,3-Butadiene all stations, all sample times, downwind conditions.

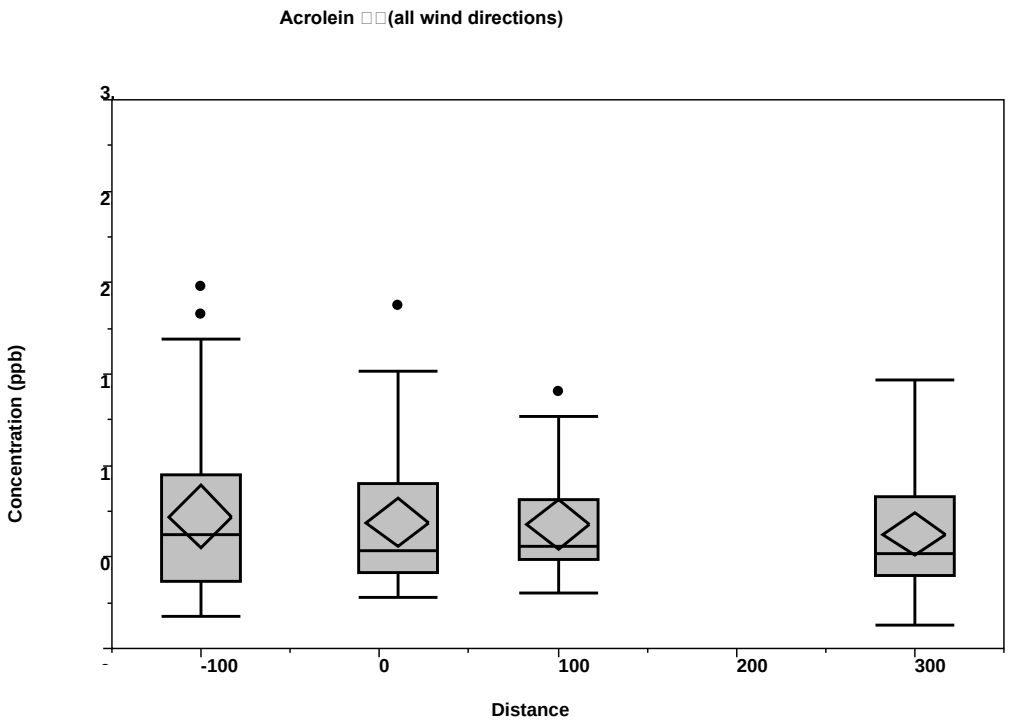


Figure 44 Box-Whisker Plot for Acrolein all stations, all sample times, all wind directions.

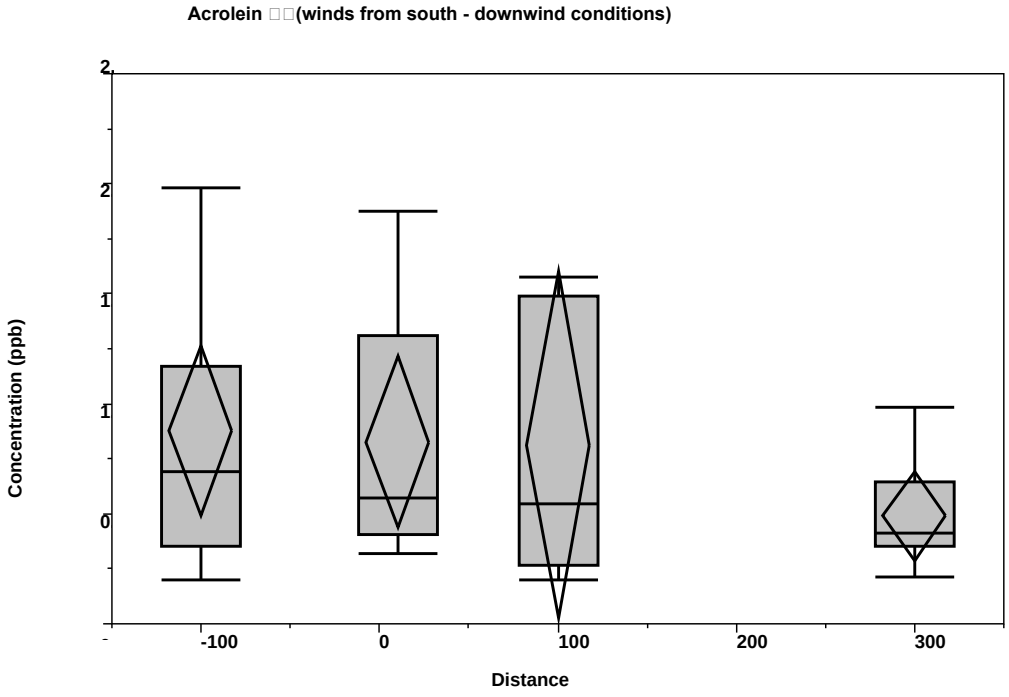


Figure 45 Box-Whisker Plot for Acrolein all stations, all sample times, downwind conditions.

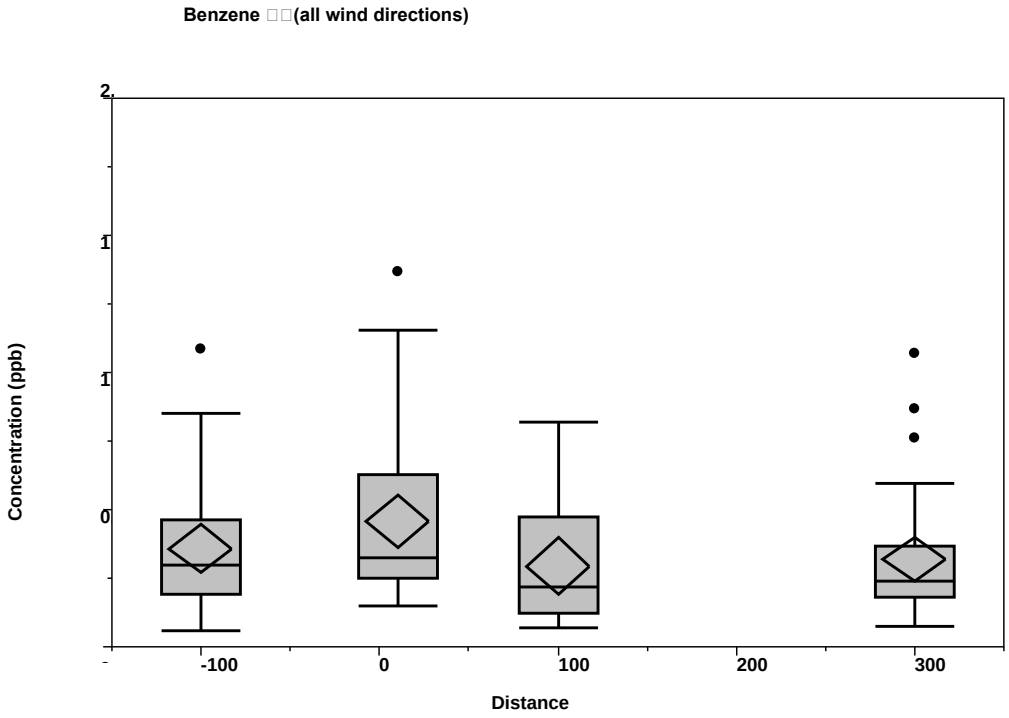


Figure 46 Box-Whisker Plot for Benzene all stations, all sample times, all wind directions.

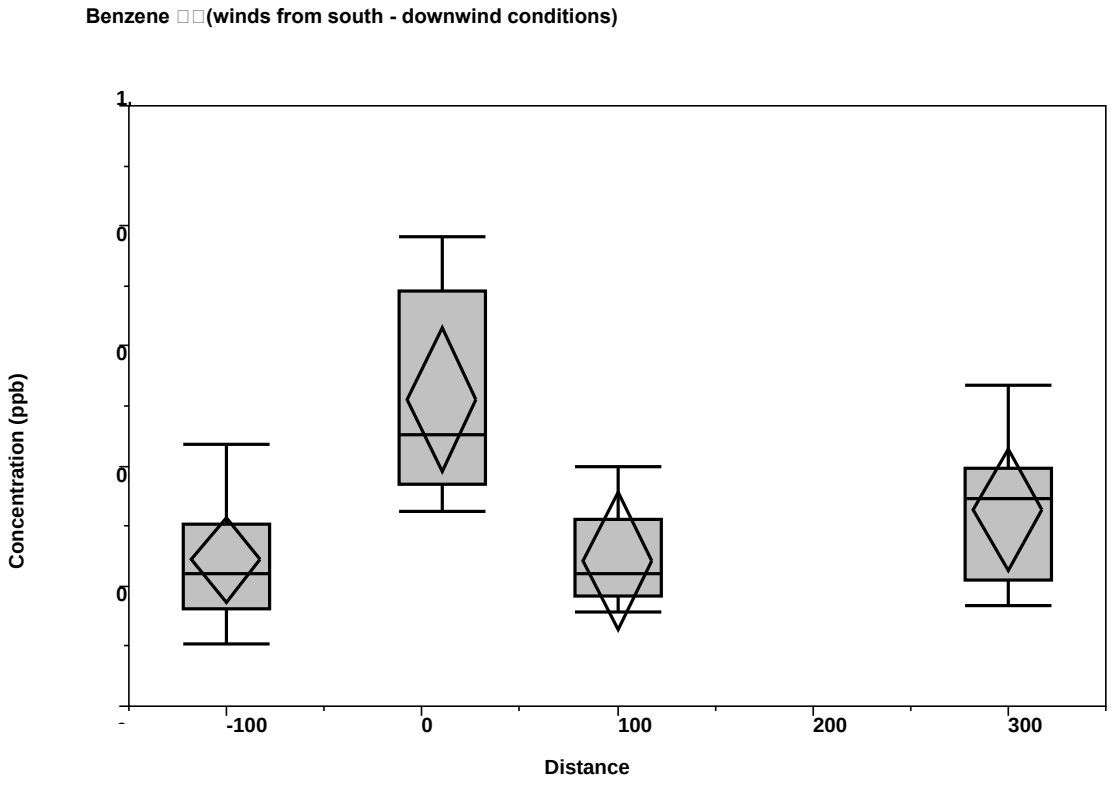


Figure 47 Box-Whisker Plot for Benzene all stations, all sample times, downwind conditions.

7.5.3 Integrated MSAT Data (TO-11a — carbonyl)

Table 19. Carbonyl -- averages for all wind directions (09/29/2010-06/15/2011)

Site name	Distance from Road	N (Obs.)	Mean (ppb)	95% CI (ppb)
Acrolein				
4	100 m upwind	32	3.83	1.02 – 6.64
1	10 m roadside	34	4.08	1.43 – 6.74
2	100 m downwind	30	1.21	0.17 – 2.25
3	300 m downwind	36	1.12	0.34 – 1.90
Acetaldehyde				
4	100 m upwind	32	2.16	1.38 - 2.94
1	10 m roadside	34	2.67	1.10 - 4.23
2	100 m downwind	30	2.05	1.24 - 2.87
3	300 m downwind	36	1.68	0.90 - 2.45
Formaldehyde				
4	100 m upwind	32	3.14	1.93 - 4.35
1	10 m roadside	34	3.27	2.02 - 4.53
2	100 m downwind	30	2.6	1.30 - 3.89
3	300 m downwind	36	3.13	1.94 - 4.32

NOTE: Data are for valid samples only.

7.5.4 Data Caveats– Integrated Samples – Carbonyl

Background corrections were not performed on the carbonyl data. This was deemed unnecessary as the field blank values were either zero, below the method detection limit, or not statistically significant. A field blank, as defined in the EPA Compendium TO-11A DNPH carbonyl method, is a DNPH cartridge that is treated in the same manner as a sample cartridge except no sample air is drawn through the field blank. These field blanks are sent back to the laboratory, analyzed and values were reported for carbonyls.

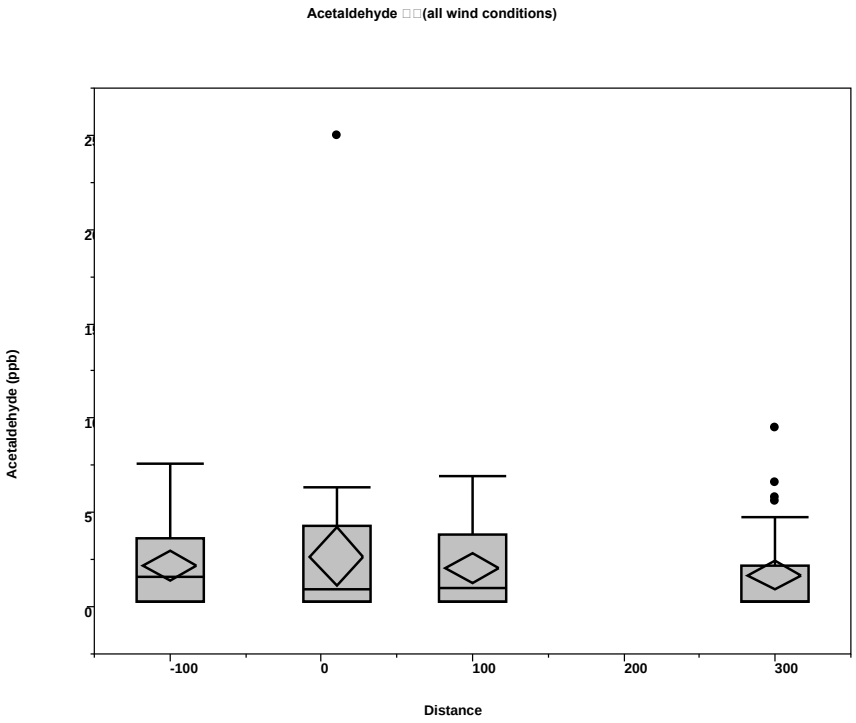


Figure 48 Box-Whisker Plot for Acetaldehyde all stations, all sample times, all wind directions.

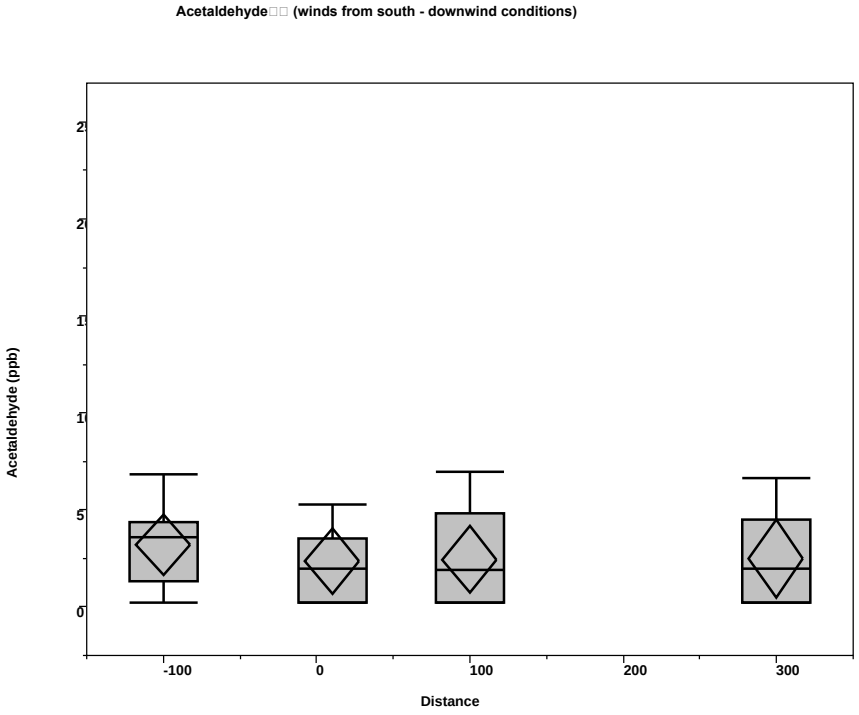


Figure 49 Box-Whisker Plot for Acetaldehyde all stations, all sample times, downwind conditions.

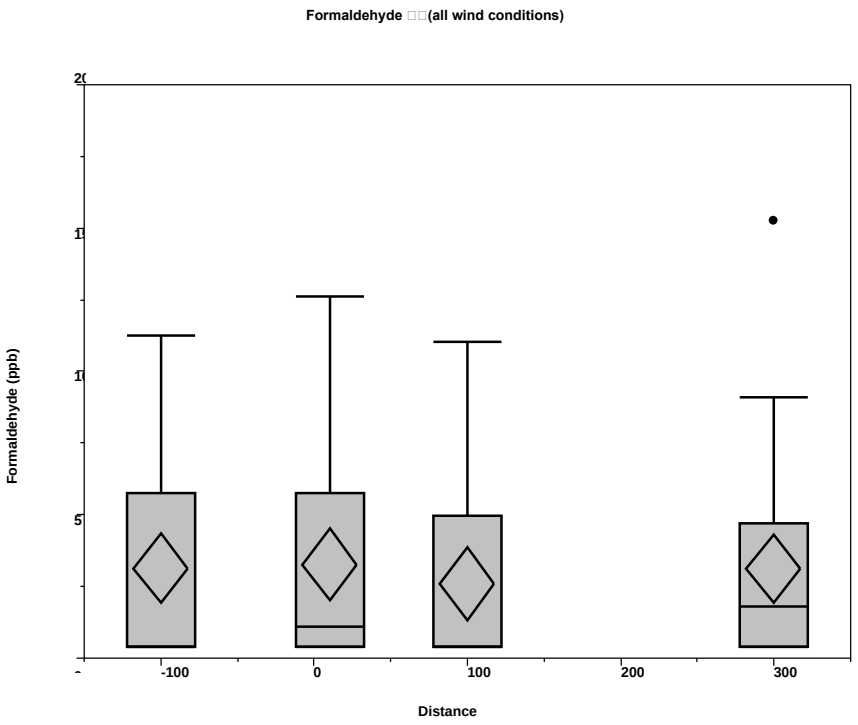


Figure 50 Box-Whisker Plot for Formaldehyde all stations, all sample times, all wind directions.

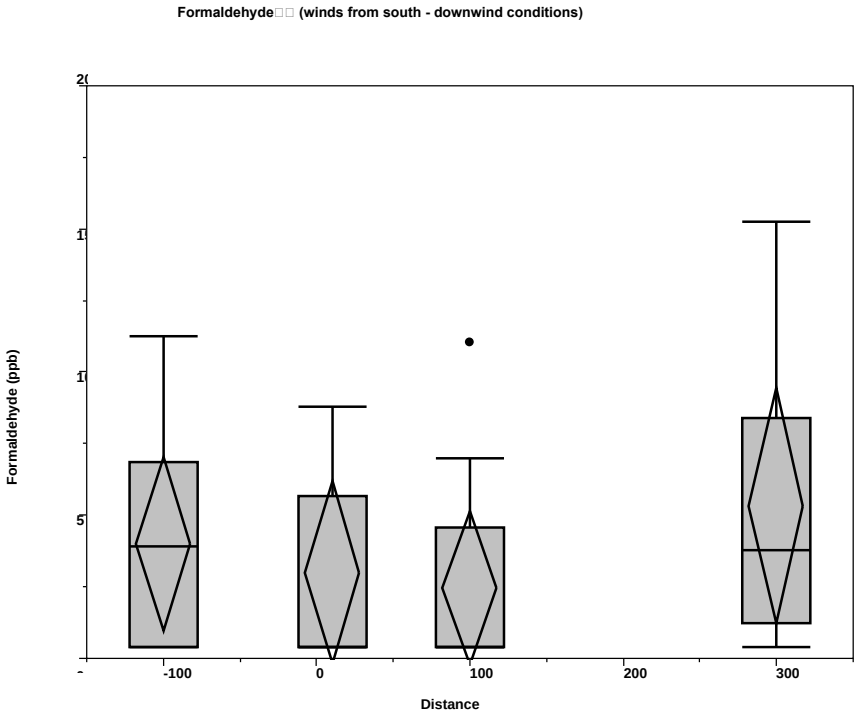


Figure 51 Box-Whisker Plot for Formaldehyde all stations, all sample times, downwind conditions.

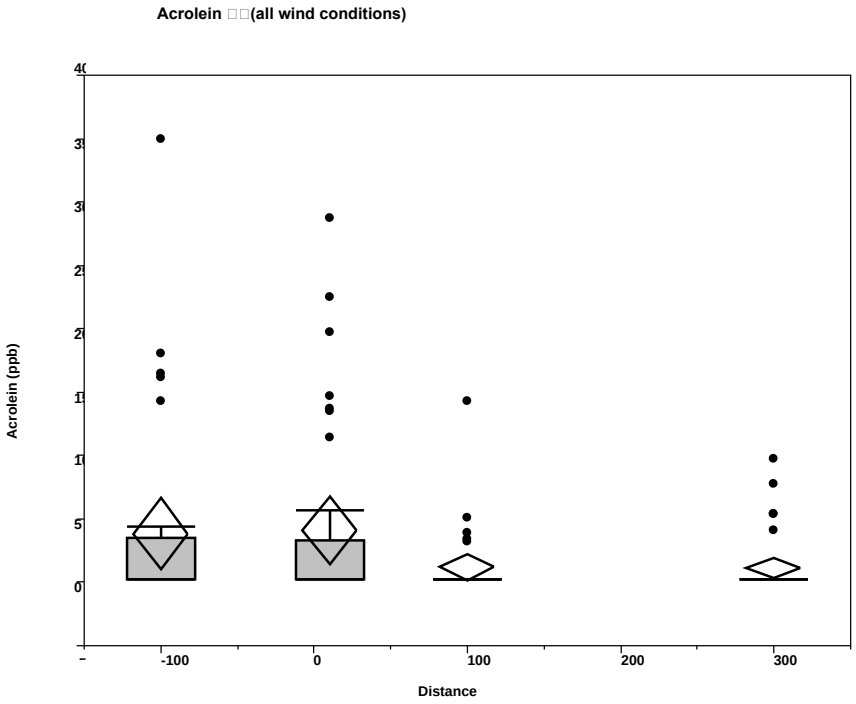


Figure 52 Box-Whisker Plot for Acrolein all stations, all sample times, all wind directions.

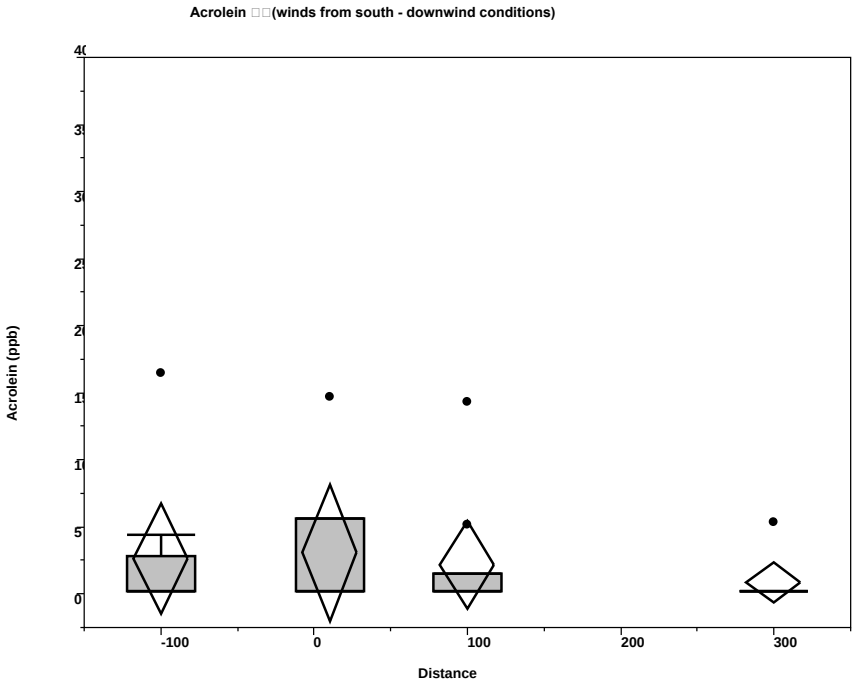


Figure 53 Box-Whisker Plot for Acrolein all stations, all sample times, downwind conditions.

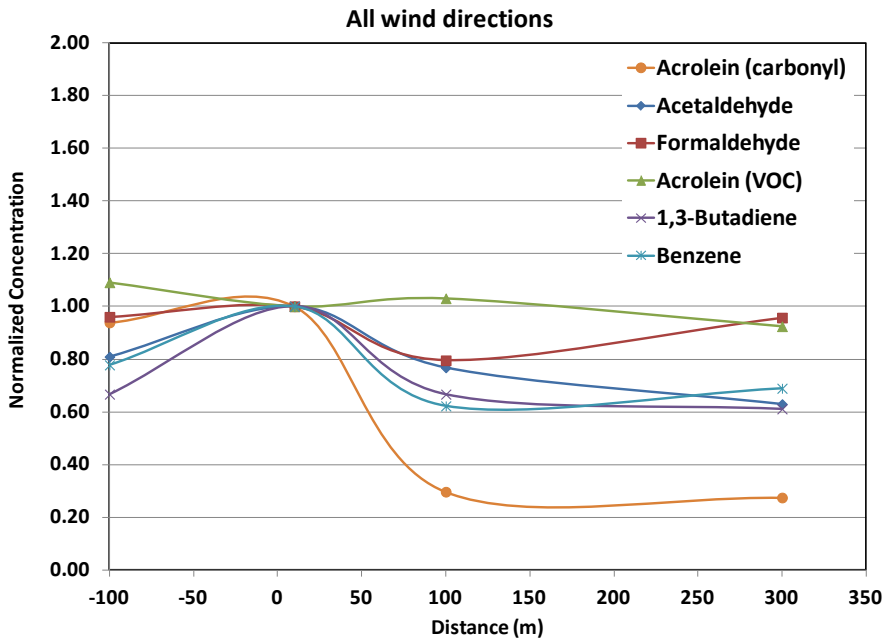


Figure 54 Mean carbonyl and VOC concentration gradients-normalized to Station 1 for each pollutant: all sites and all wind conditions. Normalized means for each site shown in Figures 55 and 56 were calculated as follows: V_{PS}/V_{Ps1}; where V = average value, p = pollutant, s = site, s1 = site 1.

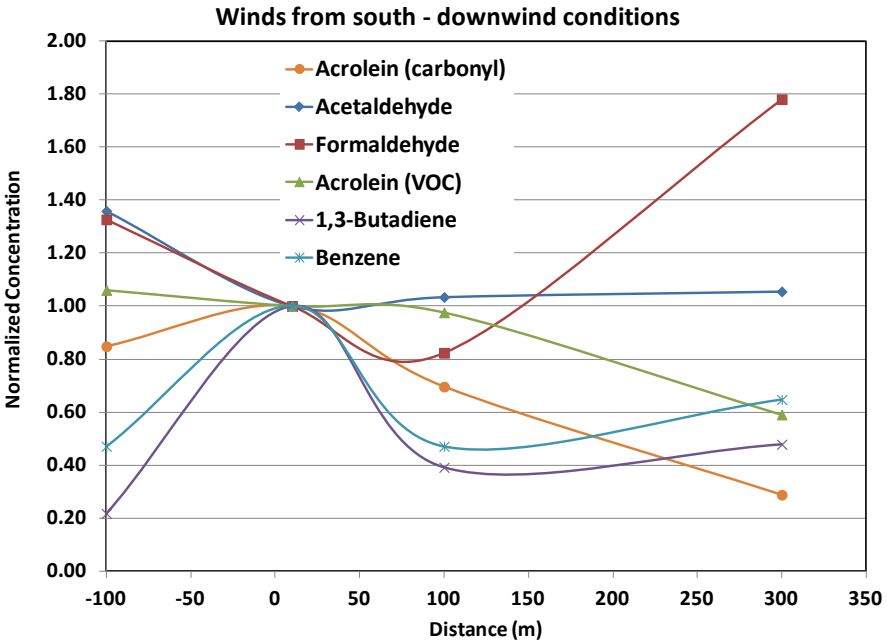


Figure 55 Mean carbonyl and VOC concentration gradients-normalized to Station 1 for each pollutant: all sites for downwind conditions (winds from south). Normalized means for each site shown in Figures 55 and 56 were calculated as follows: V_{PS}/V_{Ps1}; where V = average value, p = pollutant, s = site, s1 = site 1.

7.5.5 Data Caveats– Integrated Samples – Acrolein

Acrolein results are presented for both TO-15 (VOCs) and TO-11a (carbonyls) methods and the results should be used with caution. Method TO-15 utilizes passivated stainless steel canisters under vacuum to be filled at a constant rate to near ambient pressure for a specified time period. The air collected in the canisters undergoes laboratory analysis using a GC/MS. Method TO-11a utilizes cartridges containing DNPH coated media. These cartridges are connected to a sampler that draws ambient air at a constant rate for a specified time period. These cartridges undergo laboratory analysis using High-Performance Liquid Chromatography (HPLC)

Both methods are considered problematic as both methods have issues with the measurement of acrolein. The TO-15 method is considered problematic due to the "growth" of acrolein inside cleaned canisters. Acrolein concentrations inside cleaned canisters containing zero humidified air have been shown to increase over time due to unknown reasons. The TO-11a method is considered inaccurate due to the retention instability on the DNPH coated absorbent and low acrolein capture efficiency.

Moreover, caution should be used when comparing Las Vegas acrolein measurements to Detroit acrolein measurements. Acrolein values for Las Vegas were reported using TO-11a, while acrolein values for Detroit are reported using TO-11a and TO-15. We observed "growth" of acrolein in canisters during the Las Vegas study and for this reason we had very low confidence in the data and did not report acrolein results using TO-15. We did not observe "growth" of acrolein in canisters during the Detroit study.

EPA is continuing to research acrolein measurement methods, specifically focusing on the TO-15 method. This research is currently identified as a priority in EPA ORD's research action plan.

7.5.6 Particulate Data (FRM Filters)

A summary of $PM_{2.5}$ averages and confidence intervals are shown in Table 20. Figure 56 shows box-whisker plots $PM_{2.5}$ integrated filter samples. Figure 57 shows $PM_{2.5}$ data by date and site.

Table 20. $PM_{2.5}$ Filters -- averages for all wind directions (09/29/2010-06/15/2011)

Site name	Distance from Road	N (Obs.)	Mean (µg m^3)	95% CI (µg m3)
Station 4	100 m upwind	17	11.46	8.14 - 14.78
Station 1	10 m roadside	19	12.87	8.84 - 16.90
Station 2	100 m downwind	16	12.12	8.53 - 15.71
Station 3	300 m downwind	18	10.4	7.10 - 13.69

NOTE: Data are for valid samples only.

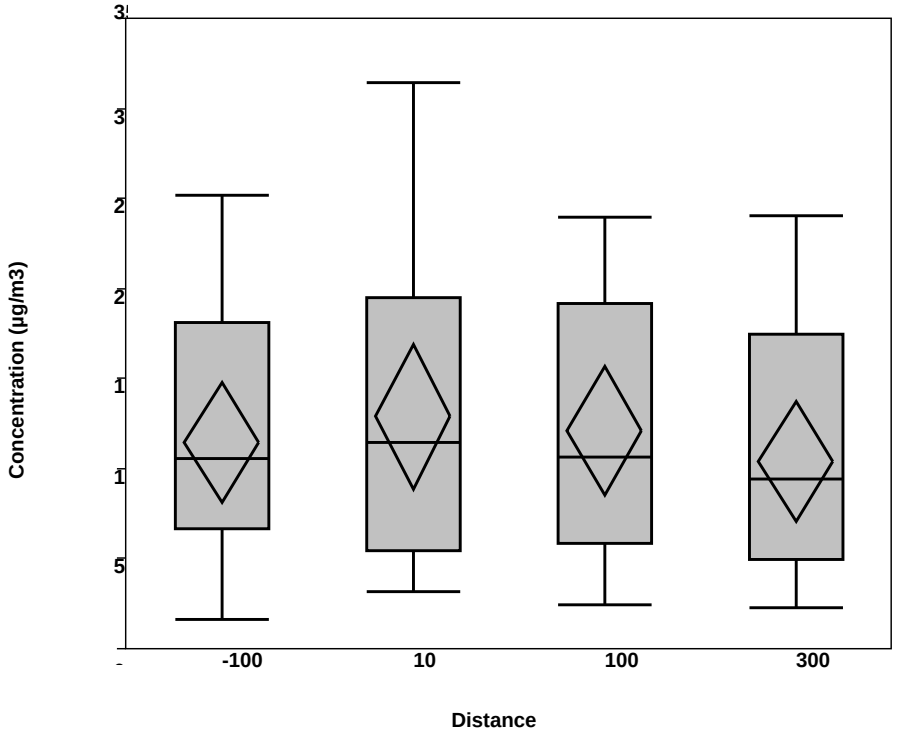


Figure 56 Box-Whisker Plot for $PM_{2.5}$ for all stations, all sample times, all wind directions.

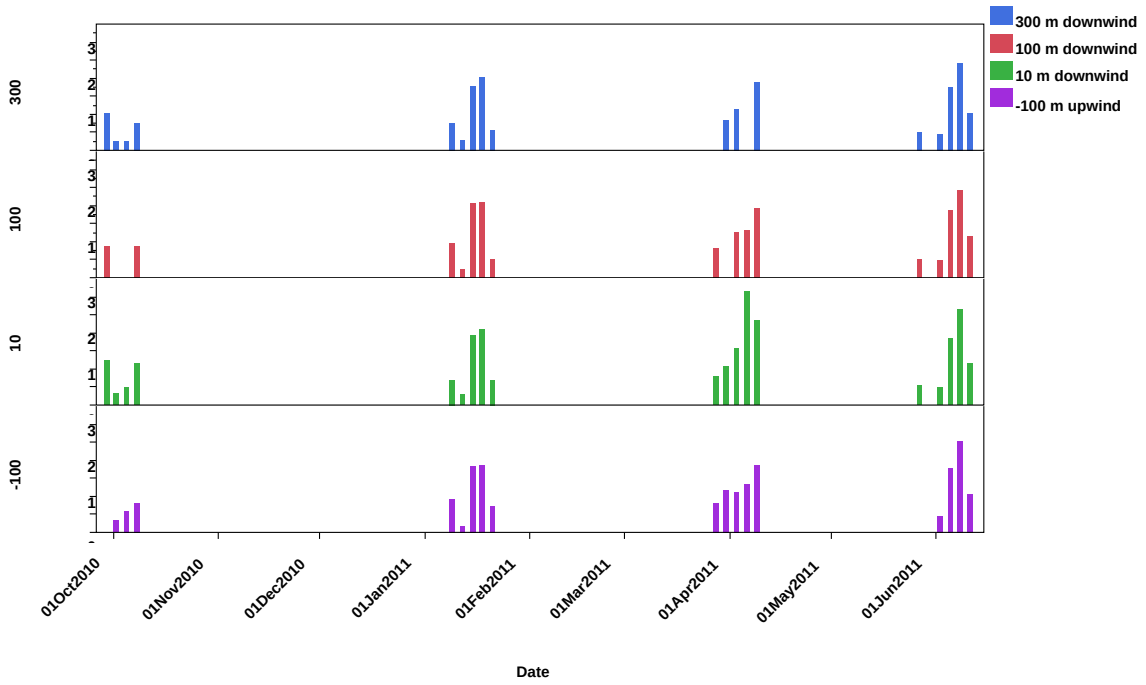


Figure 57 Bar chart for $PM_{2.5}$ ($\mu g/m^3$) for all stations, all sample times, all wind directions.

8 Summary

This report provides a summary of a field study conducted in Detroit, MI from September 29, 2010 thru June 20, 2011. The objective of this research study has been to determine MSAT concentrations and variations in concentrations as a function of distance from the highway and to establish relationships between MSAT concentrations as related to highway traffic flows including traffic count, vehicle types and speeds, meteorological conditions such as wind speed and wind direction; and other pollutants primarily emitted from motor vehicles such as CO, NO, NO_2, NO_X, BC, PM_{10}, $PM_{2.5}$, PM Coarse, and MSATs. These detailed results support the following preliminary conclusions:

- Concentration gradients are observed for gaseous pollutants and black carbon associated with distance from roadway.
- Effect of wind speed appears to be a factor with regards to concentration gradient (e.g., dilution effect).
- Non I-96 sources may be larger contributors than previously expected (Figure 7 and Figure 8), for example:

- ✓ Impact of near-by apartment complex at 300 meter downwind site.
- ✓ Telegraph Road (300 meter downwind site)

Preliminary results of this study provide indications that highway vehicle emissions impact near-road air quality. Known highway vehicle pollutants such as CO, PM 10 and PM_{course}, NO, NO_2, NOx and BC have elevated concentrations in a near-road environment and decrease as one moves away from the road. Additional analysis of the data is needed to more accurately quantify the effect of wind speed as well as other near-road effects.

9 Lessons Learned

Costs, timeliness and other operational factors are just some of the site implementation variables that may be difficult to control. These implementation variables include site access and permissions, electrical connectivity, security, communications, site operators and equipment. Costs may be estimated but there are many unknown factors that influence the outcome of the costs. Projects of this nature present myriad challenges both from a programmatic and technical perspective.

Access to sites owned by private citizens can be challenging. Adjacent property owners may understand the necessity of improving the state-of-the-science, benefiting the community at-large and have a desire to be a "good" citizen, but existing lease and financial issues are a deterrent to participation. In addition, liability, insurance compensation, hassle factor(s), and other real and perceived issues present obstacles to site access.

Electrical and communications companies have numerous requirements for obtaining their services. This process requires interactions with utility companies as well as local (i.e., county or city) inspections departments.

10 Uncertainties

Study Design. This study focused on a single location (freeway) in one city. Additional locations will be needed to fully assess air pollutant concentration gradients from different roadway types; different traffic patterns; geographic locations; meteorological conditions, etc.

Methods. The analytical methods implemented during this study followed EPA standard methods and Federal Reference Methods for performing ambient air measurements. Refinements to methods can and do occur over the course of time due to improved technologies and measurement techniques, however the most current technologies and techniques were implemented for this study

Data. Uncertainties in the data may be considered in two parts: overall data integrity, individual measurements. Electronic data streaming was utilized whenever possible to lessen the chance of human error (i.e., transcription error) and ensure overall data integrity. When hardcopy data sheets, notes, chain-of-custody forms were utilized; an EPA staff member reviewed the hardcopy and verified the data. Quality assurance of the data (i.e., individual measurements) is an on-going process and often occurs during more specific data analysis. Given that this project generated gigabytes of data, thorough quality assurance of the data is an on-going activity.

11 Conclusions

The U.S. FHWA and U.S. Environmental Protection Agency (U.S. EPA) collaborated on a research effort to characterize the impact and behavior of particulate matter with aerodynamic diameter less than 2.5 microns ($PM_{2.5}$) and MSATs near highways. This study was conducted from September 29, 2010 thru Mid-June, 2011.

References

1. Sierra Club vs. USDOT. IN THE UNITED STATES DISTRICT COURT FOR THE DISTRICT OF NEVADA, SIERRA CLUB v. UNITED STATES DEPARTMENT OF TRANSPORTATION; Secretary of Transportation NORMAN MINETA; FEDERAL HIGHWAY ADMINISTRATION (FHWA); Administrator of the FHWA MARY PETERS, Division Administrator of FHWA Nevada Division SUSAN KLEKAR,. CV-S-02-0578-PMP-RJJ San Francisco.2005.

2. U.S. FHWA. Detailed monitoring protocol for U.S. 95 settlement agreement. Washington, DC, FHWA.2006.

3. Kimbrough, S., D. A. Vallero, et al. "Enhanced, multi criteria based site selection to measure mobile source toxic air pollutants." Transportation Research Part D: Transport and Environment, 2011, **16**(8): 586-590.

4. Kimbrough, S., D. Vallero, et al. "Multi-criteria decision analysis for the selection of a near road ambient air monitoring site for the measurement of mobile source air toxics." Transportation Research Part D: Transport and Environment, 2008, **13**(8): 505-515.

5. Reponen, T., S. A. Grinshpun, et al. "Concentration gradient patterns of aerosol particles near interstate highways in the Greater Cincinnati airshed." J Environ Monit, 2003, **5**(4): 557-62.

6. Zhu, Y., W. C. Hinds, et al. "Concentration and Size Distribution of Ultrafine Particles Near a Major Highway." Journal of Air and Waste Management Association, 2002, **52**(9): 1032-1042.

7. Baldauf, R., E. Thoma, et al. "Traffic and meteorological impacts on near-road air quality: Summary of methods and trends from the Raleigh near-road study." Journal of the Air & Waste Management Association, 2008, **58**(7): 865-878.

8. Zhou, Y. and J. Levy. "Factors influencing the spatial extent of mobile source air pollution impacts: a meta-analysis." BMC Public Health, 2007, **7**(1): 89.

9. Zhu, Y., W. Hinds, et al. "Seasonal trends of concentration and size distribution of ultrafine particles near major highways in Los Angeles." Aerosol Science and Technology, 2004, **38**: 5-13.

10. Zhu, Y. F., T. Kuhn, et al. "Comparison of daytime and nighttime concentration profiles and size distributions of ultrafine particles near a major highway." Environmental Science & Technology, 2006, **40**(8): 2531-2536.

11. Ntziachristos, L., Z. Ning, et al. "Particle concentration and characteristics near a major freeway with heavy-duty diesel traffic." Environmental Science & Technology, 2007, **41**(7): 2223-2230.

12. Riediker, M., R. Williams, et al. "Exposure to particulate matter, volatile organic compounds, and other air pollutants inside patrol cars." Environmental Science & Technology, 2003, **37**(10): 2084-2093.

13. Black, K., V. Martinez, et al. "Study Design to Evaluate Mobile Source Air Toxics Compounds in the Near-Roadway Environment." Environmental Manager, 2009.

14. Gamper, C. D. and C. Turcanu. "On the governmental use of multi-criteria analysis." Ecological Economics, 2007, **62**(2): 298-307.

15. Xenarios, S. and I. Tziritis. "Improving pluralism in Multi Criteria Decision Aid approach through Focus Group technique and Content Analysis." Ecological Economics, 2007, **62**(3-4): 692-703.

16. ESRI. ArcGIS. Redlands, Environmental Systems Research Institute, Inc.2006.

17. Ecotech. WinAQMS air quality monitoring software: user manual. Victoria, Australia.2007.

18. Ecotech. WinCollect Data Evaluation and Reporting Software. Victoria, Australia.20007.

19. U.S. EPA. "2010 Ambient Air Monitoring Schedule." 2010, from http://www.epa.gov/ttn/amtic/files/ambient/pm25/CALENDAR_2010.pdf, 2010.

20. Virkkula, A., T. Makela, et al. "A simple procedure for correcting loading effects of Aethalometer." Journal of the Air & Waste Management Association, 2007, **57**: 1214-1222.

21. Dutkiewicz, V. A., S. Alvi, et al. "Black carbon aerosols in urban air in South Asia." Atmospheric Environment, 2009, **43**(10): 1737-1744.

12 Appendix – Carbon monoxide measurements at Site 4 (100 m upwind)

12.1 CO Analyzer data

Carbon monoxide (CO) was measured continuously at each station using Ecotech 9830 analyzers. Data logging software reported the data in 5-minute intervals. Data from all sites were reviewed as a part of the quality assurance (QA) process. During this review, it was noted that Site 4 exhibited a baseline shift in the data for the time period of September 29, 2010 through December 6, 2010. We reviewed the multi-point calibration worksheets for Site 4 and determined that the instrument during this period of time did indicate a linear response to the calibration points but the instrument did indicate higher than expected response values. In other words measured values were higher than expected values. From these multi-point calibration worksheets, it was determined that the following correction factors should be applied to specific time periods.

The appropriate linear regression equations are as follows:

1. $y = 0.84x + 0.81$
2. $y = 0.8373x + 0.2135$

   where y = measured concentration and x = expected concentration.

For our purposes we need to solve for x. Therefore we have the following two equations for the relevant time periods:

1. corCO = |(0.81-CO)/0.84 |for September 29, 2010 12:00:00 AM thru December 3, 2010 8:10:00 AM
2. corCO = |(0.2135-CO)/0.8373| for December 3, 2010 10:35:00 AM thru December 3, 2010 1:35:00 PM

   where: corCO = corrected CO concentration and CO = original measured concentration.

The following graph (Figure 58) show the results of correcting Site 4 (100 m upwind) CO values for the relevant time periods. The first is a time series graph showing uncorrected and corrected

CO values for Site 4. Sites 1, 2 and 3 are show for comparative purposes. No corrections were made to Sites 1, 2, and 3 CO values

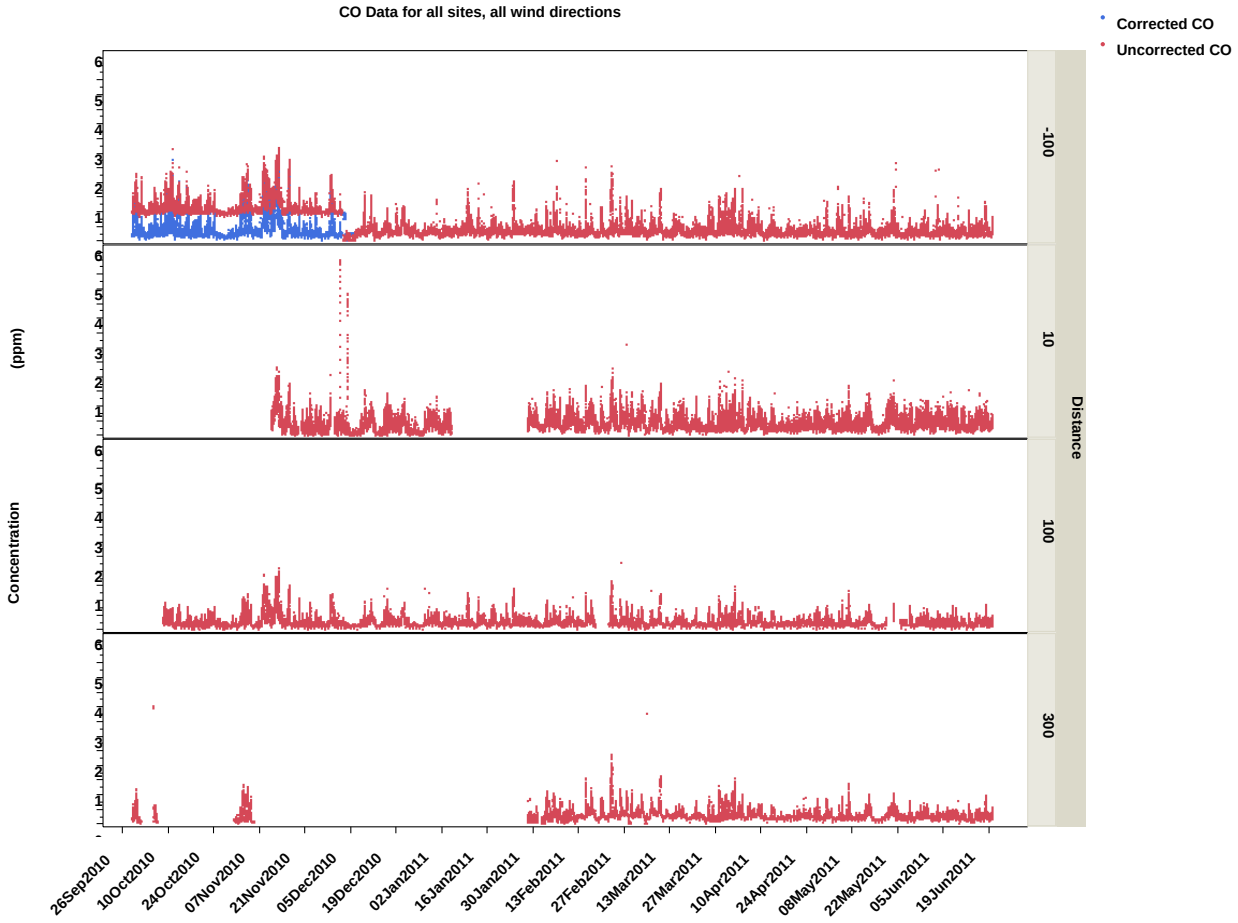


Figure 58 Time series – CO data for all sites, all wind conditions. Baseline shift is obvious for Site 4 (100 m upwind); uncorrected and corrected data are shown.

13 Appendix -- Black carbon measurements

13.1 Digital Aethalometer

Black carbon (BC) was measured continuously at each station using dual-wavelength rackmount Aethalometers (Magee Scientific, Inc.), which is displayed in Figure 59. This report focuses on the results from the main station monitors that were operated for approximately one year.

The Aethalometer continuously measures BC at five minute intervals by pulling air through a small spot on the sample filter and detecting incremental changes in light attenuation at a specific wavelength. Once the sample spot is loaded to a certain limit, the instrument automatically pauses, rotates the filter tape through to a new clean spot, and begins sampling again; this translates to a ten minute gap in the data approximately twice per day in the data set. The main wavelength of light used to detect BC is 880 nm, in the red region of the visible spectrum. In addition, this instrument also detects light attenuation at 370 nm and is a qualitative indicator of additional particulate organics which may absorb light at near-ultraviolet wavelengths.

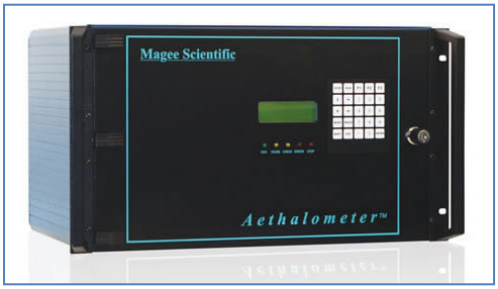


Figure 59 Image of a rackmount Aethalometer (Image source: mageesci.com)

Black carbon values are calculated by the below equation,

$$BC = \Delta ATN * A / SG * Q * \Delta t \quad (1)$$

where, BC is the concentration of black carbon in the sample (units of ng/m^{-3}), ΔATN is the change in optical attenuation due to light absorbing particles accumulating on a filter, A is the spot area of filter, Q is the flow rate of air through filter, Δt is the change in time, SG is specific attenuation cross-section for the aerosol black carbon deposit on this filter (16.6 m^2/g). SG is an empirical value that was defined by the manufacturer as the ratio of the mass of elemental carbon

(measured using a thermal-optical process) and the detected light absorption of the same sample on a filter.

13.2 . Data Review and Validation

13.2.1 Data time synchronization and screening

BC data was automatically logged by two methods during the Detroit monitoring period – external logging its full set of data fields (17 columns of data) at five minute intervals to a rack-mounted computer, which was downloaded approximately quarterly during the study, and directly logging only the BC concentration estimated from the instrument's analog output to the station database. The analog data was used during the course of the monitoring study to observe the instrument's performance, however the digital data logged to an external rack-mounted computer was used as the primary data for analysis, per manufacturer's recommendations.

NOTE: Sections 14.1 and 14.2 discuss the data processing steps used to analyze the BC data. This discussion was first documented in the Las Vegas Final Report. The steps described were used to post-process the BC data collected during the Detroit study. Figures 57 thru 62 show BC data collected during the Las Vegas study.

Section 14.3 and Section 14.4 which includes Tables 21 thru 23 and Figure 63 report BC data collected during the Detroit study.

As the digital data timestamp was based on the instrument's internal clock, the first step of data review was to apply any necessary time corrections to the digital data to match it to the station clock. Comparison of analog to digital data streams, as well as viewing the instrument's internal clock, revealed time shifts ranging from 5 min to over 24 hr were needed to precisely overlay the data sets for each station. Each instrument's data was reviewed for time periods throughout the year to ensure that the internal instrument clock did not drift to the point that further time correction was needed. Based on the review, the instrument clocks did not appear to drift by more than 5 min within a one year time period. An example of the time adjustment is shown in Figure 60.

The top image (Figure 60) is prior to time alignment; the bottom image is after the digital data timestamp was adjusted to match the station clock. The breaks in the data indicate time periods when an internal filter change occurred.

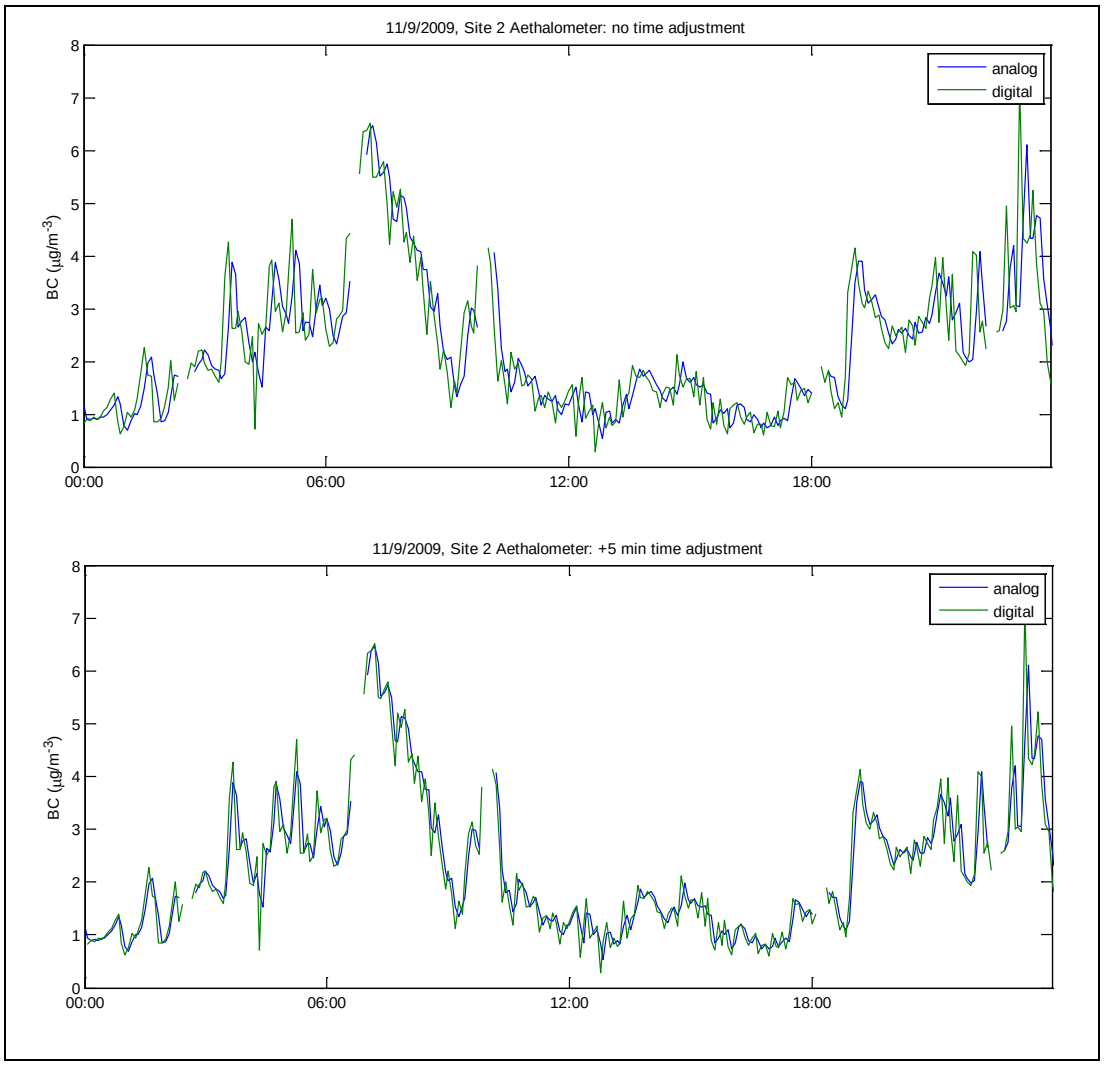


Figure 60 Time alignment of analog (blue) and digital (green) data sets.

An additional screen step for the digital BC data was flagging of any data with erroneous light attenuation values (<0 or >60), which affected <1% of the data. Finally, the data are checked for a known logging error that occurs rarely – when a filter change time period spans midnight, the digital timestamp is off by 24 hrs.

13.2.2 Occurrence of negatives

With BC calculated based upon a 5-minute incremental change in light attenuation through a filter, there are time instances when the BC concentrations are generally so low that the accumulation of particles on the filter are not sufficient to override any noise in the measurement (signal to noise ratio), thus the change in attenuation (ΔATN) may read below zero and a negative BC is reported. Since the change in light attenuation is based upon the previous time period, the following time period may then report an overly positive ΔATN and a higher BC value than reality. The manufacturer recommends that, when negatives occur in the data, one should average the data up to a time increment at which negatives no longer occur. An evaluation of the station 2 BC data is shown in Figure 61, below. In the original 5-minute time series, negatives occur in 2.6% of the data. After averaging up to an hourly time basis, negatives occur in <0.1% of the data. Based upon this evaluation, all data presented in this report are at an hourly time basis and the few, if any, hours of BC data per site that remained negative after averaging were removed from the data set.

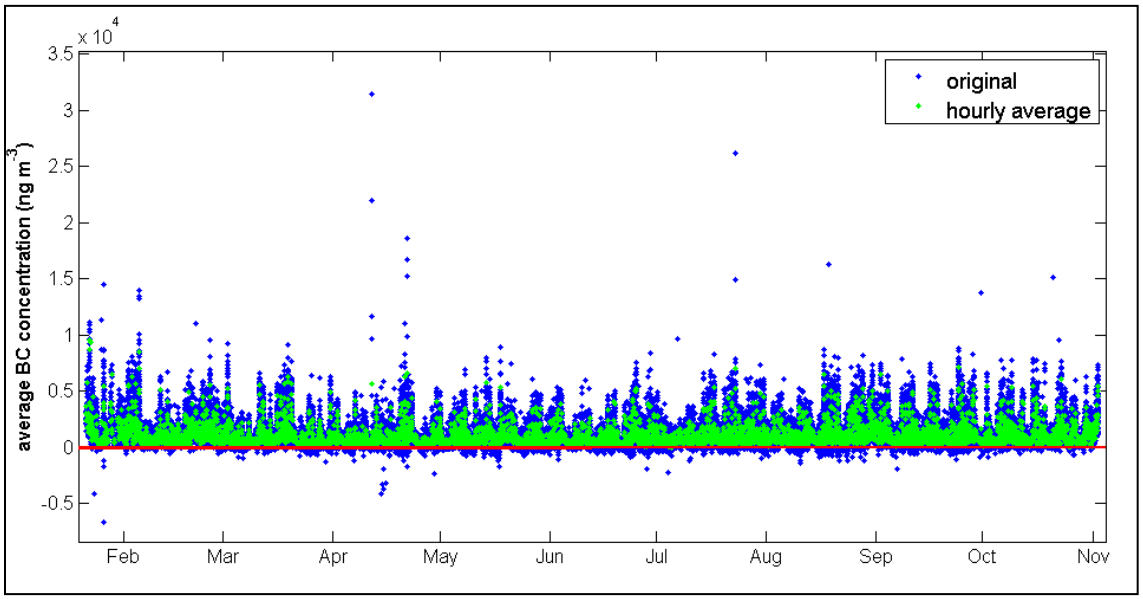


Figure 61 Assessment for negatives occurring in the original data (blue) and hourly averaged data (green) for station 2 during the Las Vegas, NV near-road monitoring study.

13.2.3 Evaluation of filter loading effect

Aethalometers are in widespread use by academic groups and governments to perform continuous monitoring of black carbon in diverse environments. Several research studies have documented that BC values reported by Aethalometers or similar filter-based BC instrumentation may be affected by a filter loading artifact. For example, measured high concentrations of BC in a subway and found that BC values were under predicted as function of filter loading[20] However, a recent study by measured ambient air quality in India and found that no filter loading effect was detectable in that environment.[21] The explanation for these differing results likely lies in the optical properties of the particles being measured relative to the samples used for original calibrations by the manufacturer. Since this effect is unpredictable, we did several different analyses to determine whether the artifact existed for the Las Vegas data set and held a meeting to discuss whether or not to apply a correction algorithm.

At a mid-way point through the study, an analysis was performed similar to that laid out by looking whether incremental changes (BC at time t+1 minus BC at time t) in BC values revealed a negative bias associated with incremental filter loading.[21] As shown in Figure 62, below, the histogram of the ΔBC_{t+1-t} revealed no positive or negative bias and it appeared no significant filter loading effect was detectable, at that time.

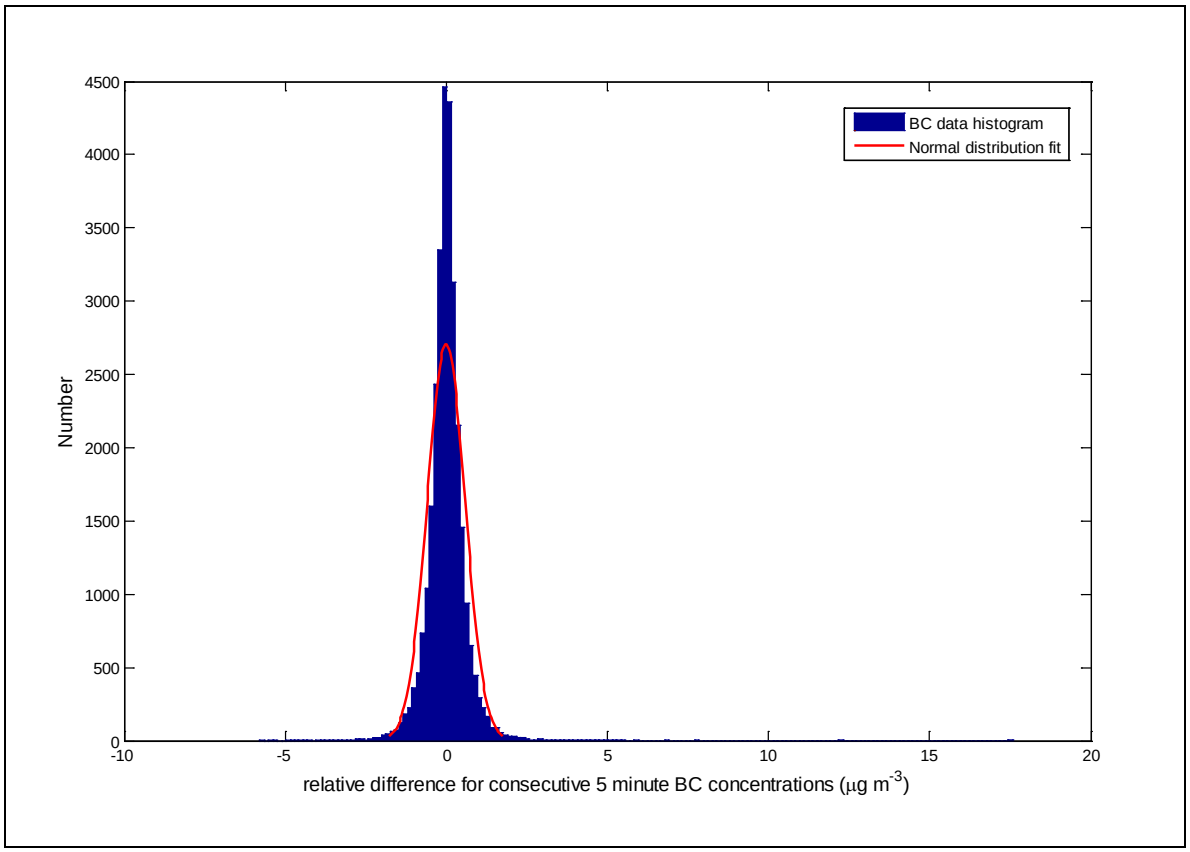


Figure 62 Histogram of differences in consecutive BC concentrations (ΔBC_{t+1-t}) calculated at station 1 over data collected during January through April, 2009. The red line is a normal distribution fitted to the data.

At the conclusion of data collection, another analysis approach was employed to determine whether a filter-loading effect was apparent – the attenuation binning method. BC data points collected over a one year period were aggregated into attenuation bins of unit value (0-1, 1-2, 2-3…up to 44-45). A plot of BC data box plots versus attenuation is shown below in Figure 63. Eliminating the tail end values, where fewest BC data points were collected, a modest negative relationship between BC and ATN is visible (Figure 64). Estimating a k-value from this relationship and applying the filter loading correction, it can be seen that BC values at low ATN values would be relatively unchanged while BC values at high ATN values would be increased slightly (Figure 65).[20] Overall, this analysis estimated that the filter-loading artifact algorithm would modify concentrations by approximately 0 to +25% depending on the filter loading state.

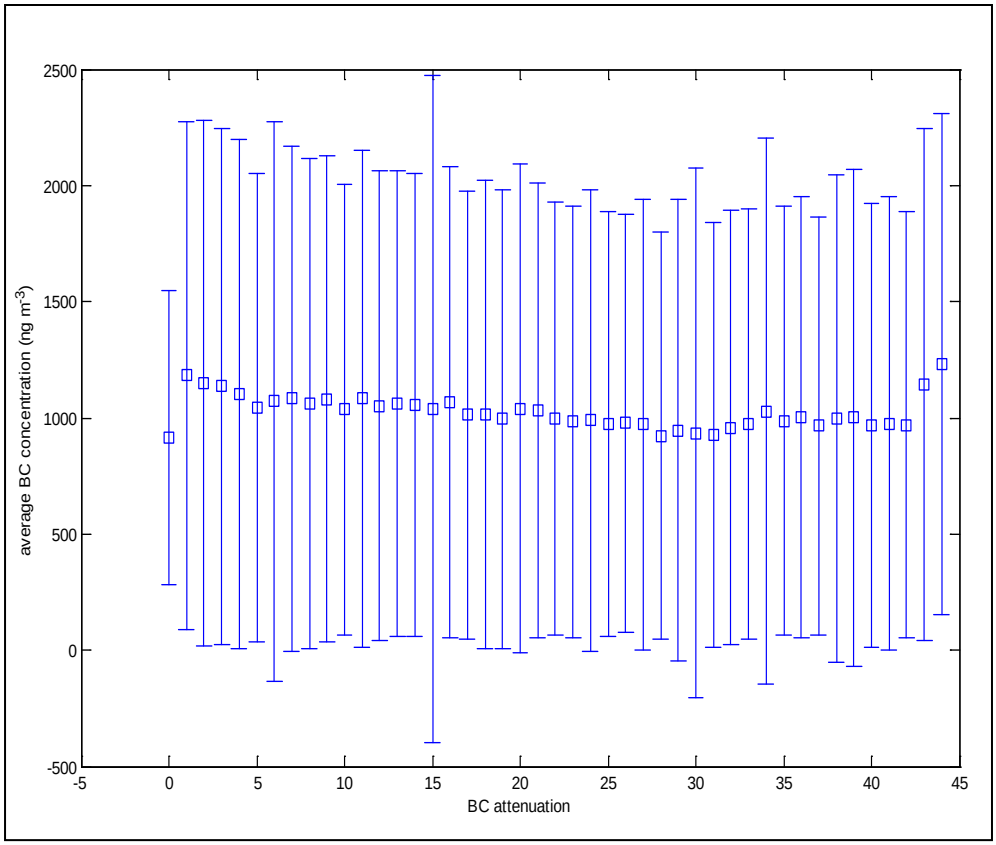


Figure 63 Box and whisker plots of approximately 12 months of 5-minute BC measurements at station 2 aggregated by attenuation bin in one-unit intervals.

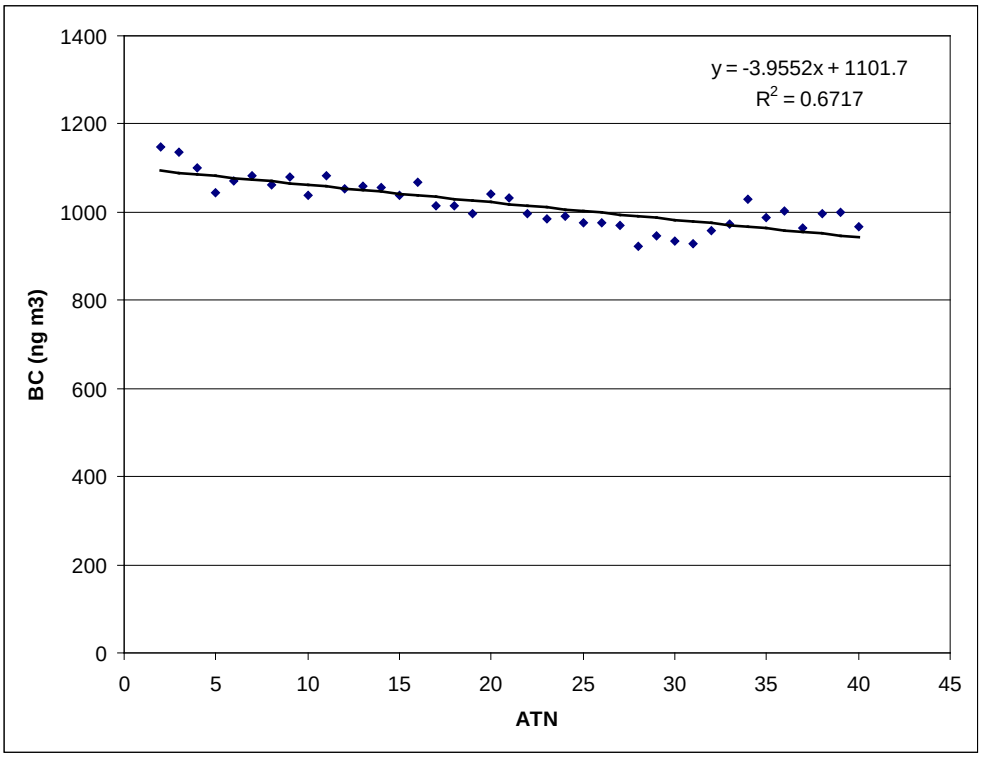


Figure 64 Median BC values of approximately 12 months of 5-minute BC measurements at station 2 aggregated by attenuation bin in one-unit intervals. A linear fit is applied to the data.

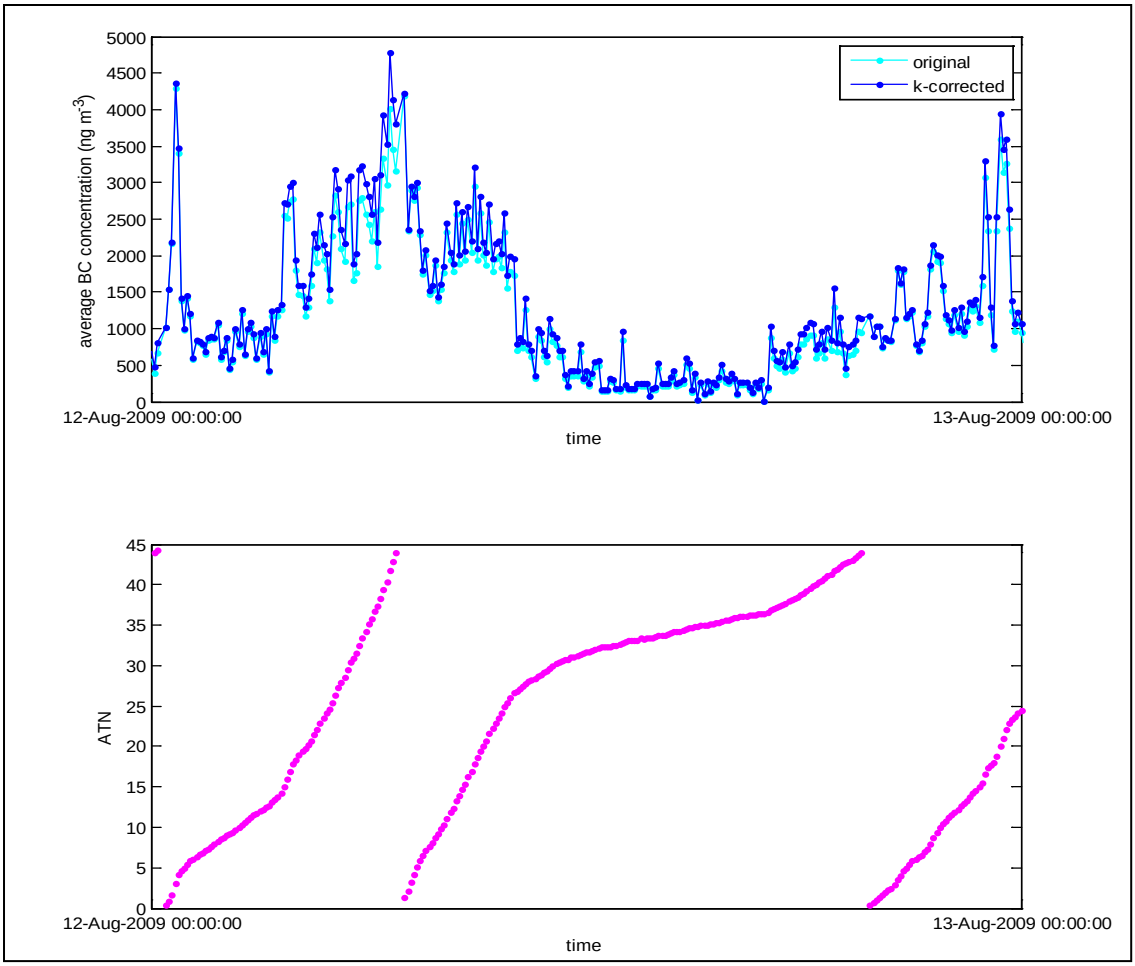


Figure 65 Example of filter-loading corrected versus original data (top) and filter loading attenuation (bottom). At low ATN values, original and k-corrected lines show little difference, while k-corrected BC values are higher than the original at higher ATN values.

One significant concern with applying the k-value correction estimated from the above analyses to the data is that this process essentially assumes that the aerosol optical properties were fixed throughout the measurement period, when in reality the aerosol optical properties likely varied by time of day, day of week, and time of year. Given that a significant amount of data is required to detect the relationship between BC and ATN in an environment with significant ambient fluctuations in concentration, trying to estimate k-values at shorter time increments increases the uncertainty of deriving a reliable value. As the analysis revealed that k-value corrections were relatively minor and given concerns about applying this algorithm without consideration of likely variable aerosol optical properties, it was decided to leave the original data as is for the purposes of this report.

13.3 Data Analysis -- Black carbon measurements

BC data were analyzed using a combination of programs, including MATLAB version R2009b, Microsoft Excel 2007, and JMP 8. The data analysis included calculating summary statistics of data for each site for all wind conditions and for winds only from the South (+/- 60 degrees from perpendicular), estimating concentration gradients for winds from the West, and observing concentrations as a function of wind direction for all winds. The results of these analyses follow in Section 13.4.

13.4 Results and Discussion -- Black carbon measurements

Black carbon data was collected over a one year period at four near-road locations along I-96 in Detroit, Michigan. Hourly concentrations were calculated from the raw five-minute data for each station, covering the time period of the official sampling program – September 29, 2010 to June 15, 2011. The completeness of the data per station is reported in Table 21, which ranged from 97% to 98% per station.

Table 21. Completeness of hourly BC data at each site

Site name	Distance from Road	N	Completeness[b] Time span: 09/29/2010-06/20/2011
Station 1	10 m East	6142	97%
Station 2	100 m East	6146	97%
Station 3	300 m East	6166	97%
Station 4	100 m West	6179	98%

Summaries of the annual BC averages and confidence intervals at each site are presented in Table 22 and shown in Figure 66. The data show that, on an average basis with winds from all directions, the BC annual average at 10 m from the highway is significantly higher than at further distances from the road. In addition, BC average values at 100 m in the predominant downwind direction (South of the highway) are significantly higher than at 100 m in the opposite direction, as well as higher than at 300 m on the downwind side of the road. Station 1 BC is

approximately 65%, 115%, and 41% higher than Station 2 (100 m downwind), Station 3 (300 m downwind), and Station 4 (100 m upwind) sites, respectively.

Table 22. BC averages for all data (09/29/2010-06/15/2011)

Site name	Distance from Road	N	Mean ($\mu g/m^{-3}$)	95% CI ($\mu g/m^{-3}$)
Station 4	100 Meter Upwind	60,480	.61	0.61 – 0.62
Station 1	10 meter roadside	71,771	.86	0.85 – 0.86
Station 2	100 Meter Downwind	71,150	.52	0.52 – 0.53
Station 3	300 Meter Downwind	69,981	.40	0.39 – 0.40

BC hourly values were also isolated for time periods with winds from the west, designated as 180 ± 60 degrees. On the downwind side of the road, BC values at Station 1 are significantly higher than all other stations. Figure 38 and Figure 39 show the mean BC concentrations by site from all wind directions and winds from road, respectively. Station 1 BC is approximately 83%, 167%, and 137% higher than Station 2 (100 m downwind), Station 3 (300 m downwind), and Station 4 (100 m upwind) sites, respectively.

Table 23. BC averages, wind from the West (09/29/2010-06/20/2011)

Site name	Distance from Road	N	Mean ($\mu g/m^{-3}$)	95% CI ($\mu g/m^{-3}$)
Station 4	100 Meter Upwind	14341	0.54	0.54 – 0.55
Station 1	10 meter roadside	18184	1.28	1.26 – 1.29
Station 2	100 Meter Downwind	18240	0.70	0.70 – 0.71
Station 3	300 Meter Downwind	18356	0.48	0.47 – 0.48

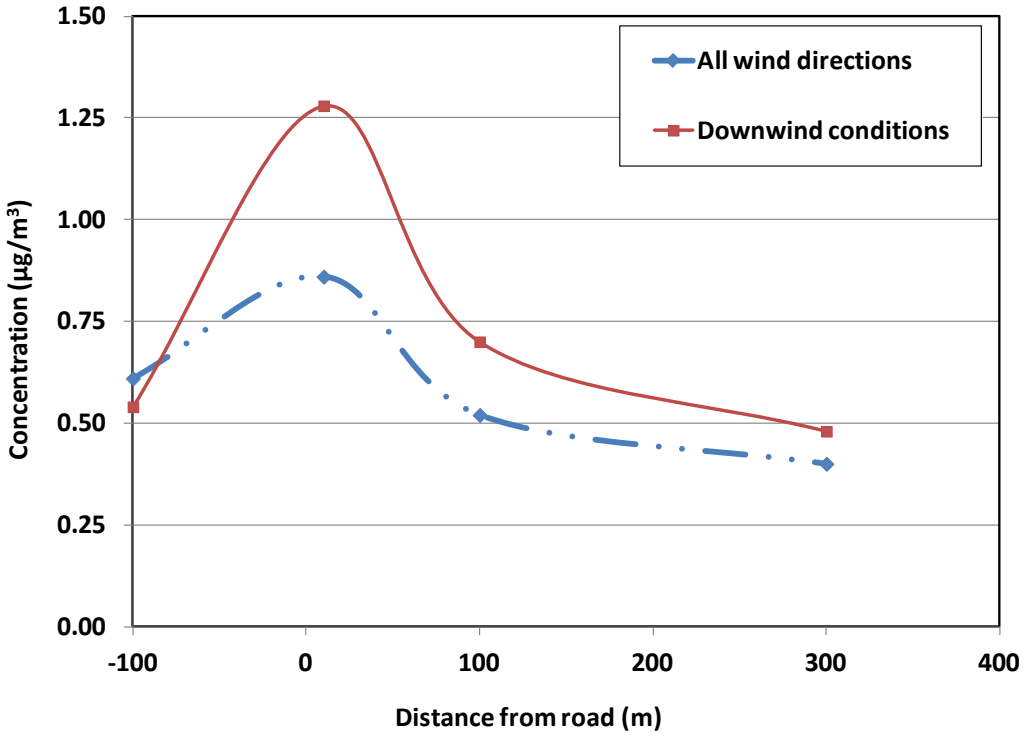


Figure 66 Average black carbon concentrations as a function of distance from the road for all data and during time periods with wind from the South (120-240 degrees).

14 Appendix -- Quality Assurance Project Plan

Attached to this report as a CD.

15 Appendix -- Data Dictionary – Parameters, Descriptions/Labels.

Parameters, descriptions/labels – Min/Max Ranges									
						range			
variable location	SAS variable name	column label from WinCollect	unit from WinCollect	description from WinCollect	Labels	Min	Max	other requirements	comments
1	ID			Station id	Station Id	Station1 Station2 Station3 Station4			
2	DateTime			Date and time of sample	09/29/2010 thru end-of-study in Detroit	09/29/2010	06/20/2011		end-of-study 06/20/2010
3	RT	RT	C	RT	rack temperature	10	40		
4	O_Vref	O Vref	V	0 Voltage ref	0 voltage reference	0	0		
5	Vref	5 Vref	V	5 Voltage ref	5 voltage reference	5	5.1		
6	NO	NO	ppb	Nitrogen Oxide	Nitrogen Oxide	0	400		
7	NO2	NO2	ppb	Nitrogen Dioxide	Nitrogen Dioxide	-10	500		
8	NOx	NOx	ppb	Oxides of Nitrogen	Oxides of Nitrogen	-10	1000		

Parameters, descriptions/labels – Min/Max Ranges

						range			
variable location	SAS variable name	column label from WinCollect	unit from WinCollect	description from WinCollect	Labels	Min	Max	other requirements	comments
9	NOx_Flow	NOx Flow	Lpm	NOx Flow	NOx Flow	0.5	0.65		
10	NOx_Pres	NOx Pres	Torr	NOx Pressure	NOx Pressure	140	160		
11	CO	CO	ppm	Carbon Monoxide	Carbon Monoxide	0	100		
12	CO_Flow	CO Flow	Lpm	CO Flow	CO Flow	0.85	1		
13	CO_Chass	CO Chass	C	CO Chassis Temp	CO Chassis Temp	25	50		
14	PM10	PM10	µg/m³	Particulate PM 10	TEOM Particulate PM 10	0	700		
15	PM2_5	PM2.5	µg/m³	PM2.5	TEOM Particulate PM2.5	0	200		
16	PM_Coars	PM Coars	µg/m³	PM Coarse	TEOM Particulate PM Coarse	0	600		
17	TEOM_Sta	TEOM Sta	Status	TEOM Status	TEOM Status	0			operating normally

Parameters, descriptions/labels – Min/Max Ranges

						range			
variable location	SAS variable name	column label from WinCollect	unit from WinCollect	description from WinCollect	Labels	Min	Max	other requirements	comments
18	TEOM_Op	TEOM Op	Mode	TEOM Operatng	TEOM Operating Mode	4			operating normally
19	Filter_A	Filter A	%	FilterLoad A	TEOM Filter Loading on Filter A	0	100		
20	Filter_B	Filter B	%	Filter Load B	TEOM Filter Loading on Filter B	0	100		
21	Mflow_A	Mflow A	Lpm	Mass flow A	TEOM Mass Flow A	2	4		
22	MFlow_B	MFlow B	Lpm	Mass Flow B	TEOM Mass Flow B	1	2.5		
23	VFlow_A	VFlow A	Lpm	Vol Flow A	TEOM Volumetric Flow A	1.5	4		
24	VFlow_B	VFlow B	Lpm	Vol Flow B	TEOM Volumetric Flow B	2	3.5		
25	MFlowBy	MFlowBy	Lpm	Mass Flow Bypass	TEOM Mass Flow Bypass	10	14		
26	VFlowBy	VFlowBy	Lpm	Vol Flow Bypass	TEOM Volumetric Flow Bypass	10	15		

Parameters, descriptions/labels – Min/Max Ranges

						range			
variable location	SAS variable name	column label from WinCollect	unit from WinCollect	description from WinCollect	Labels	Min	Max	other requirements	comments
27	TEOM_Vac	TEOM Vac	atm	TEOM Vaccuum	TEOM Vaccuum	0.25	0.5		
28	Noise_A	Noise A		Noise A	TEOM Noise A	0	0.5		
29	Noise_B	Noise B		Noise B	TEOM Noise B	0	1		
30	FreqA	FreqA	Hz	Frequency A	TEOM Frequency A	230	280		
31	FreqB	FreqB	Hz	Frequency B	TEOM Frequency B	210	270		
32	TEOM_AT	TEOM AT	C	TEOM air temp	TEOM Air Temperature	-20	50		
33	TEOM_RH	TEOM RH	%	TEOM RH	TEOM Relative Humidity	0	100		
34	TEOM_BP	TEOM BP	atm	TEOM BP	TEOM Barometric Pressure	0.8	1		
35	Dew_Poin	Dew Poin	C	Dew Point	TEOM Dew Point	-20	30		
36	Aeth	Aeth	µg/m³	Aethalometer	Aethalometer	0	60		

Parameters, descriptions/labels – Min/Max Ranges

						range			
variable location	SAS variable name	column label from WinCollect	unit from WinCollect	description from WinCollect	Labels	Min	Max	other requirements	comments
37	U	U	m/s	U	Orthogonal u wind velocity/direction	-20	20		u-axis aligned east-west
38	V	V	m/s	V	Orthogonal v wind velocity/direction	-20	20		v-axis aligned north-south
39	W	W	m/s	W	Orthogonal w wind velocity/direction	-20	20		w-axis updraft
40	Azimuth	Azimuth	Deg	Azimuth	Wind Direction in the U-V Plane	0	360		
41	D_WS	2D WS	m/s	2D WS	Wind Speed in the U-V Plane	0	30		
42	D_WS0	3D WS	m/s	3D WS	Wind Speed in 3-dimensional space	0	30		
43	Elevatio	Elevatio	ded	Elevatio	ELEVATION is the ±90.0º wind elevation angle relative to the u-v plane	-20	90		

Parameters, descriptions/labels – Min/Max Ranges

						range			
variable location	SAS variable name	column label from WinCollect	unit from WinCollect	description from WinCollect	Labels	Min	Max	other requirements	comments
44	SOS	SOS	m/s	SOS	Speed of sound	330	360		
45	Sonic_T	Sonic T	C	Sonic Temperature	SOS derived from sonic temperature	-20	50		
46	Young_Er	Young Er		Young Error	Error Code Field	0			
47	RT_F	RT-F	F	Rack temp	Rack temperature	55	100		
48	D_WS_V	2D WS-V	m/s	2D WS-Vector	Wind Speed in the U-V Plane	0	60		
49	D_WD_V	2D WD-V	Deg	2D WD-Vector	Wind Direction in the U-V Plane	0	360		
50	D_Sigma	2D Sigma		2D Sigma	Standard Deviation in the U-V Plane	0	120		
51	D_WS_V0	3D WS-V	m/s	3D WS-Vector	Wind Speed in 3-dimensional space	0	15		
52	D_WD_V0	3D WD-V	Deg	3D WD-Vector	Wind Direction in 3-dimensional space	0	360		

Parameters, descriptions/labels – Min/Max Ranges

						range			
variable location	SAS variable name	column label from WinCollect	unit from WinCollect	description from WinCollect	Labels	Min	Max	other requirements	comments
53	D_Sigma0	3D Sigma		3D Sigma	Standard Deviation in 3-dimensional space	0	120		
54	GasCal_S	GasCal S		GasCal Status	Zero Gas Calibration Status (pressure - psi)	0	10		
58	Vaisala	Vaisala	C	Vaisala Air temp	Vaisala Air Temperature	-30	45		
59	Vaisala_1	Vaisala	%	Vaisala RH	Vaisala Relative Humidity	0	100		
60	RG	RG	mm	Rain Gauge	Ecotech Rain Gauge	0	150		
61	SR	SR	W/m²	Solar Radiation	Solar Radiation	0	2000		Negative values occur at night
80	date			Date of sample		09/29/2010	06/15/2011		
81	time			Time of Sample		12:00:01 AM	11:59:00 PM		

Parameters, descriptions/labels – Min/Max Ranges

						range			
variable location	SAS variable name	column label from WinCollect	unit from WinCollect	description from WinCollect	Labels	Min	Max	other requirements	comments
82	location			Location of Sample	Station Id	Station1 Station2 Station3 Station4			

Integrated Samples – VOC

Variables for VOC Data (samples collected using Summa Canisters: Method TO-15):

id = station1, station2, station3, station4
location = 10 meter, 100 meter, 300 meter, Upwind
SampleType = Field Blank, Field Control, Field Duplicate, Lab Duplicate, Sample
SampleDateTime = Date and Time of Sample
Buta_ppb = 1,3-Butadiene (ppb)
Benz_ppb = Benzene (ppb)
Acrolein_ppb = Acrolein (ppb)
Flag_VOC = 0 or 1; 0 = valid data; 1 = invalid data (relates to the entire sample, across all pollutants)
Flag_Buta = 0 or 1; 0 = valid data; 1 = invalid data
Flag_Benz = 0 or 1; 0 = valid data; 1 = invalid data
Flag_Acrolein = 0 or 1; 0 = valid data; 1 = invalid data

Integrated Samples – Carbonyl

Variables for Carbonyl Data (samples collected using cartridges: Method TO-11A):

id = station1, station2, station3, station4
location = 10 meter, 100 meter, 300 meter, Upwind
SampleType = Field Blank, Field Control, Field Duplicate, Lab Duplicate, Sample
SampleDateTime = Date and Time of Sample
Acetaldehyde_ppb = Acetaldehyde (ppb)
Acrolein_ppb = Acrolein (ppb)
Formaldehyde_ppb = Formaldehyde (ppb)
Acetaldehyde_detect '<' (below method detection limit)
Acrolein_detect '<' (below method detection limit)
Formaldehyde_detect '<' (below method detection limit)
Flag_Carbonyl = 0 or 1; 0 = valid data; 1 = invalid data (relates to the entire sample, across all pollutants)
Flag_Acetaldehyde = 0 or 1; 0 = valid data; 1 = invalid data
Flag_Acrolein = 0 or 1; 0 = valid data; 1 = invalid data
Flag_Formaldehyde = 0 or 1; 0 = valid data; 1 = invalid data

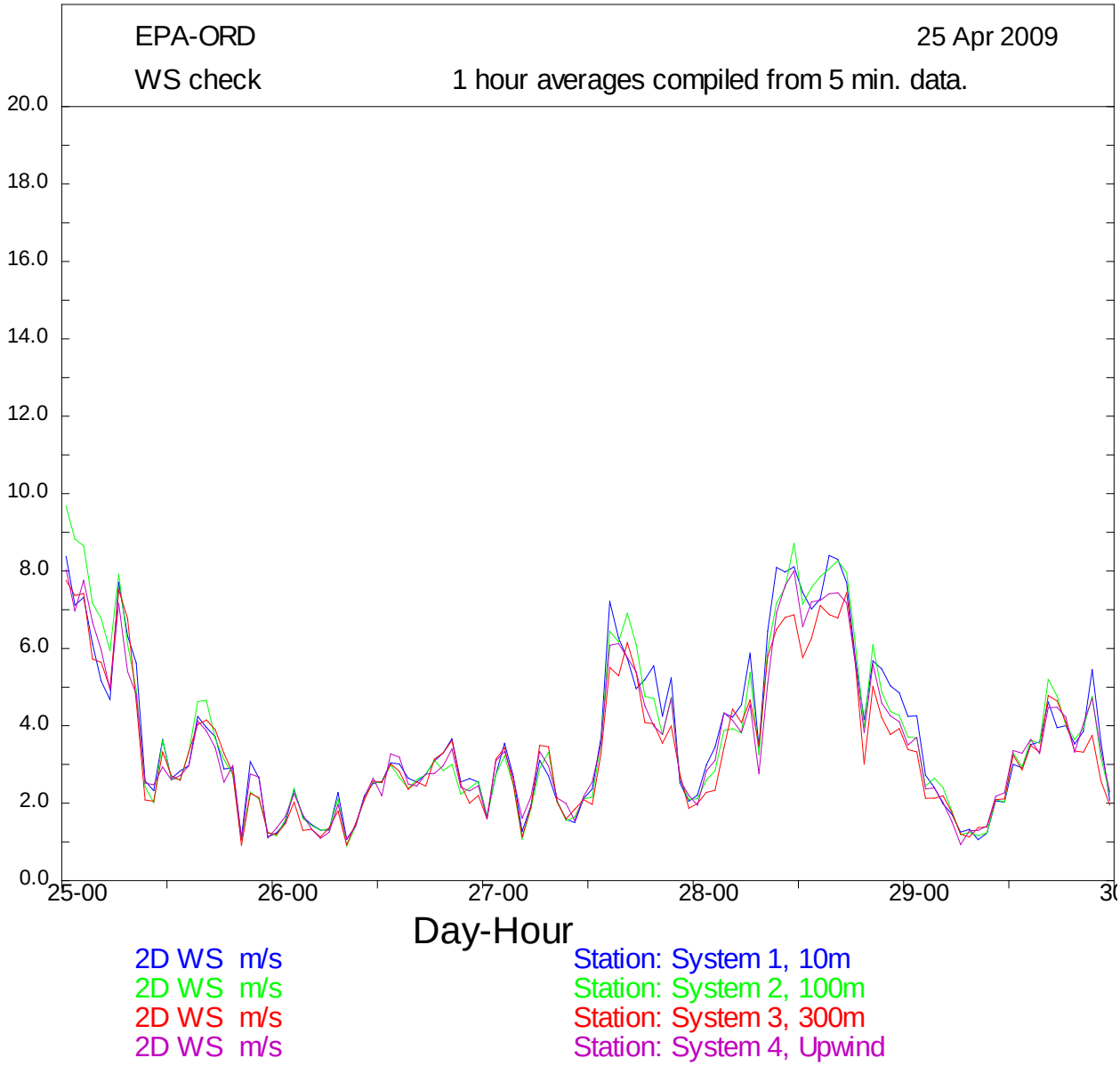
Integrated Samples – $PM_{2.5}$

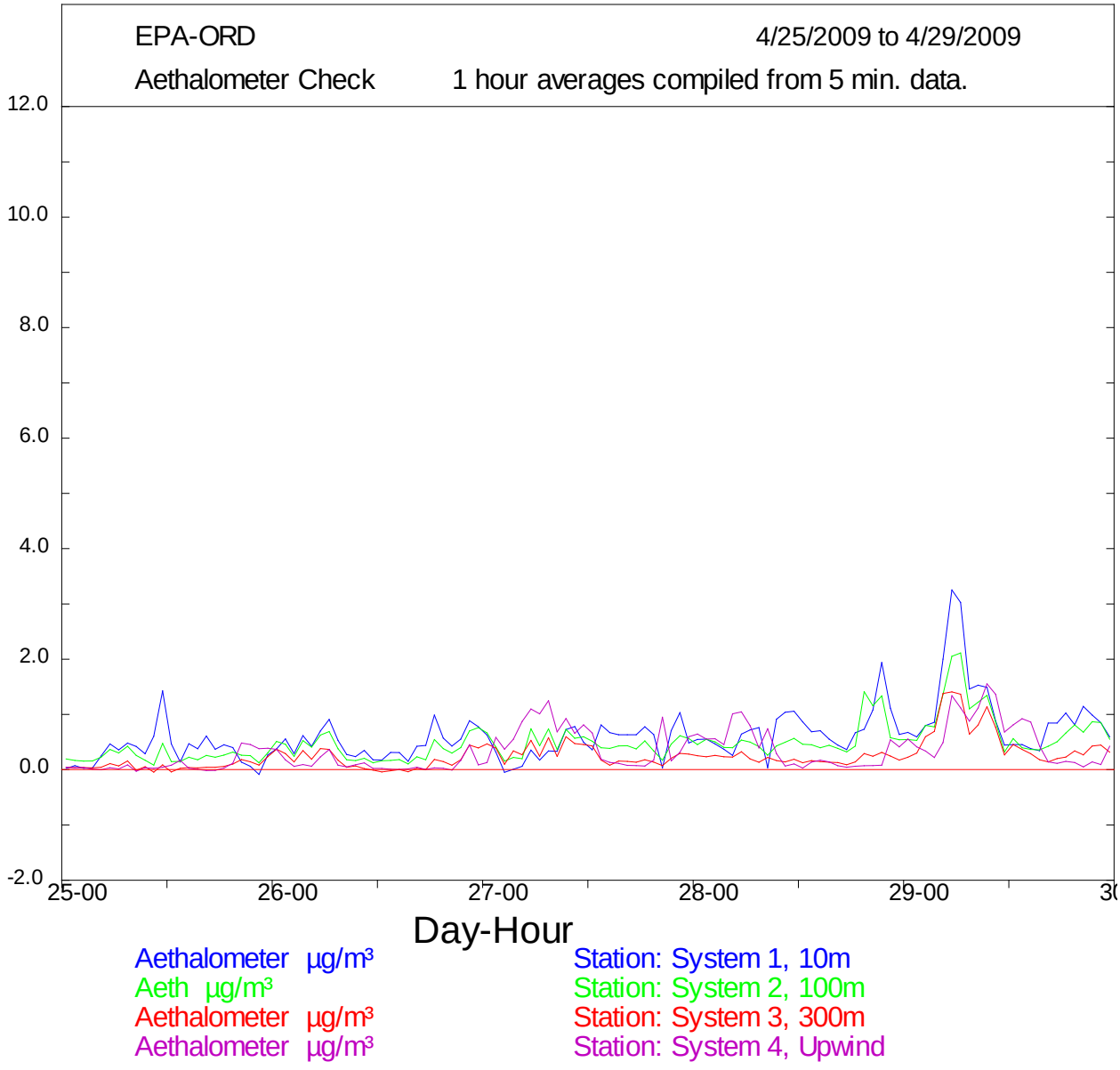
The following is a list of the variables in the $PM_{2.5}$ data set.

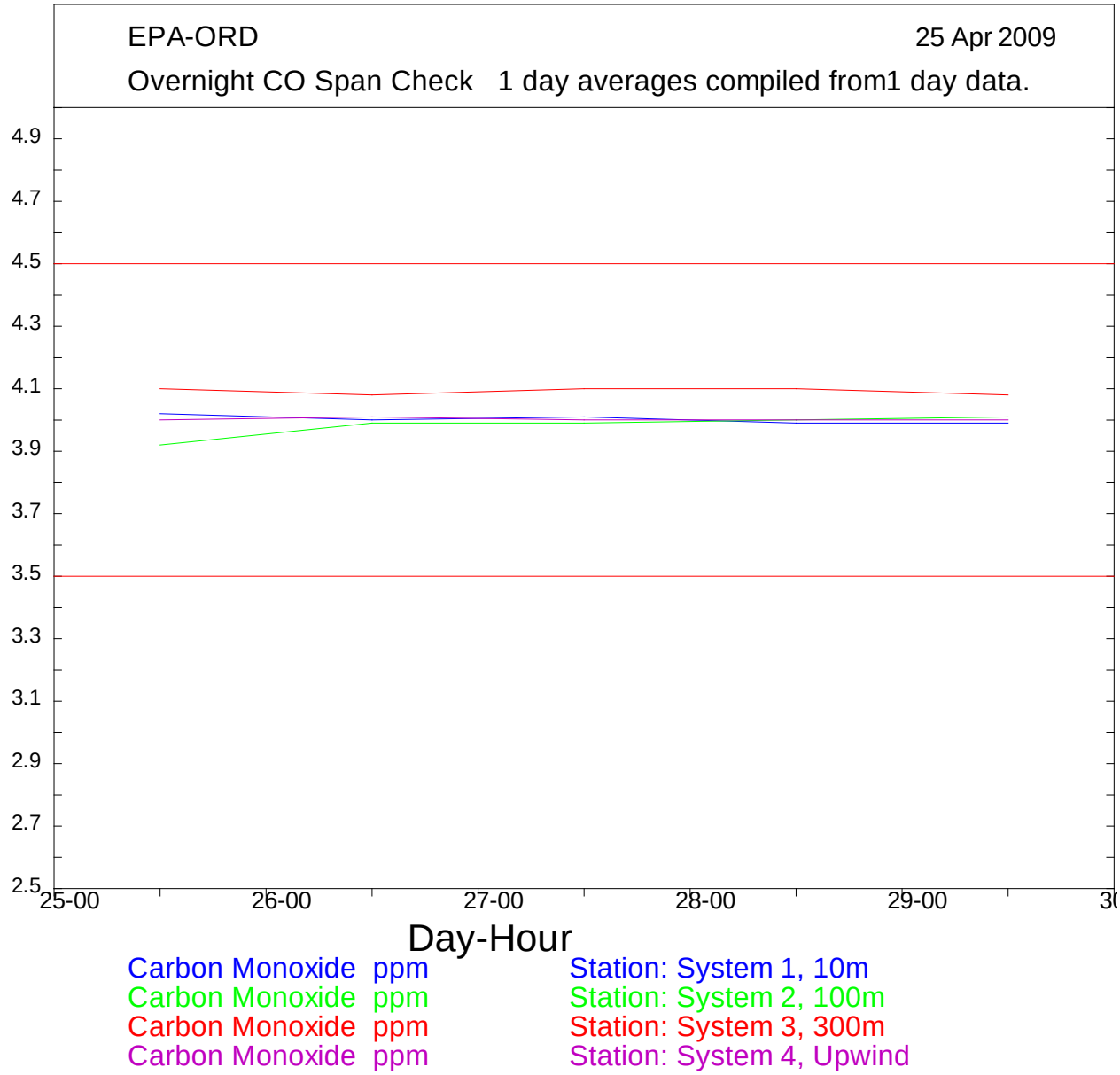
id = station identification
SampleType = Sample, Field Duplicate, Field Blank,
Date = Date Sample Collected
Flag_PM = 0 or 1; 0 = valid data; 1 = invalid data
location = Upwind, 10 meter, 100 meter, 300 meter
PM2_5mg_m3 = PM2.5 in $\mu g/m^3$

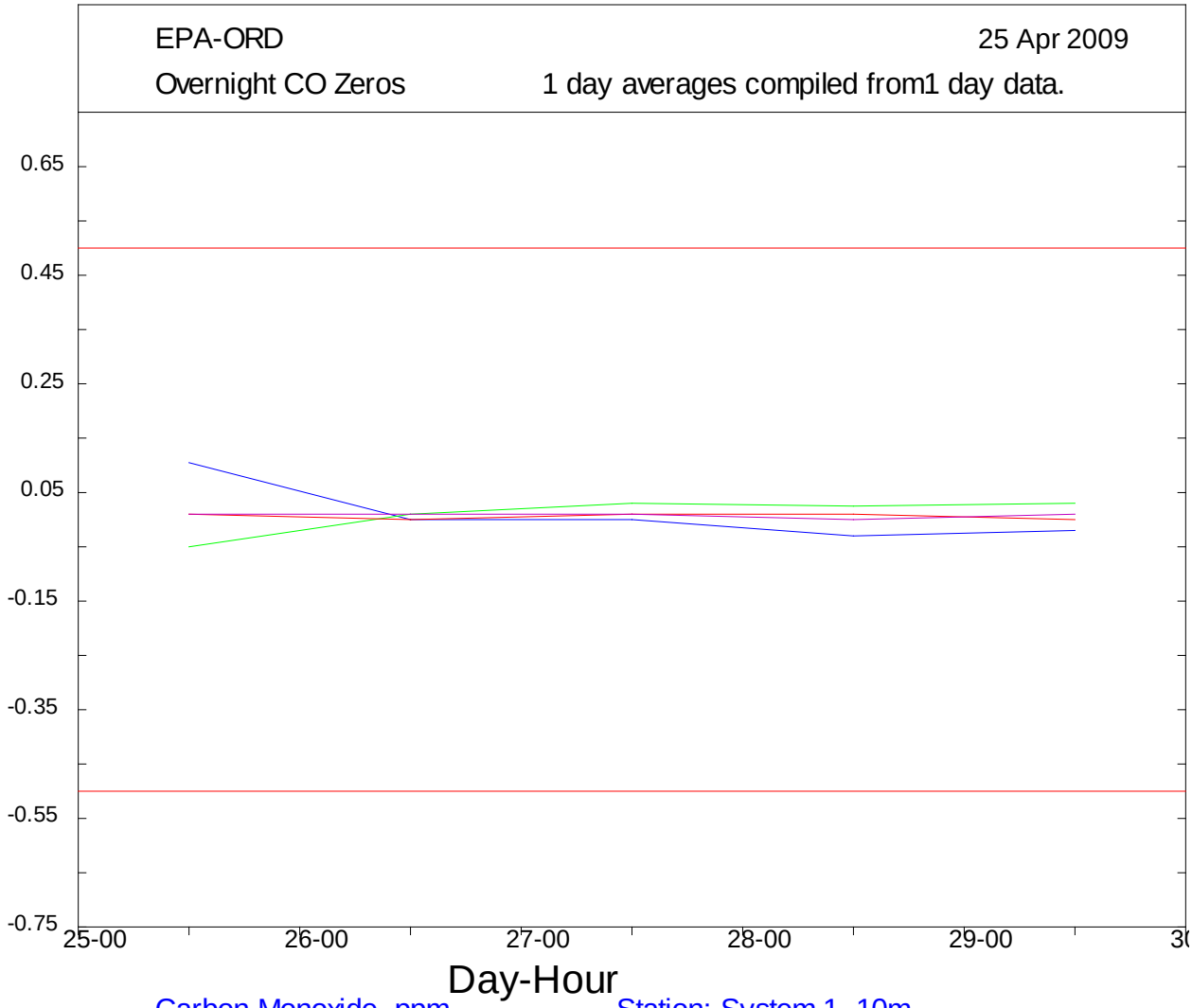
16 Appendix -- Data Validation / Instrument Checks

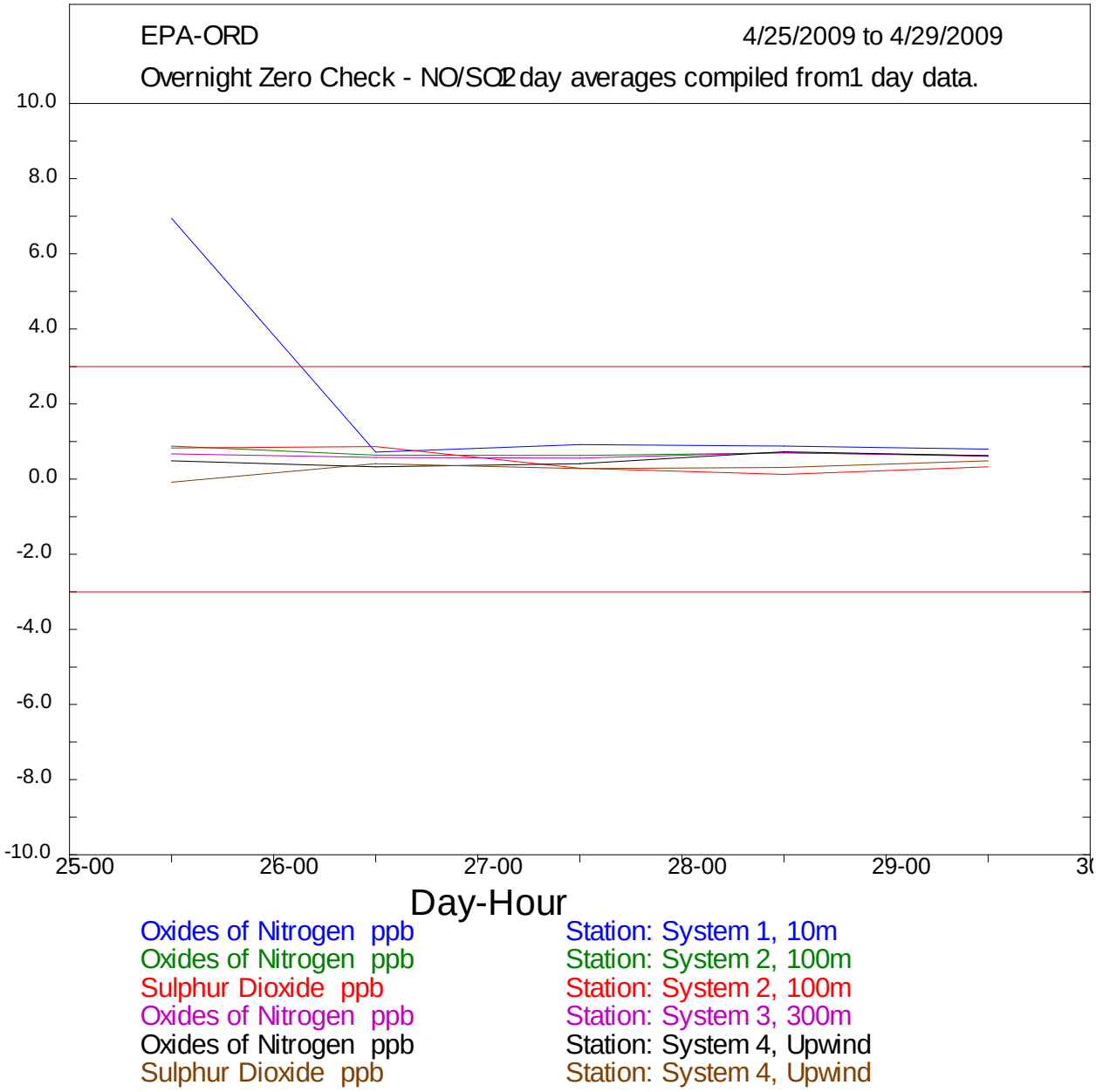
Each day, data was accessed using WinCollect. Graphical reports were run to determine instrument status and data validity. Examples of these graphical reports are shown on the following pages. Instrument issues were identified and noted in a logbook at the computer being used to run WinCollect. The graphs and any instrument issues were noted in an email to the site operator, EPA and contractor staff.

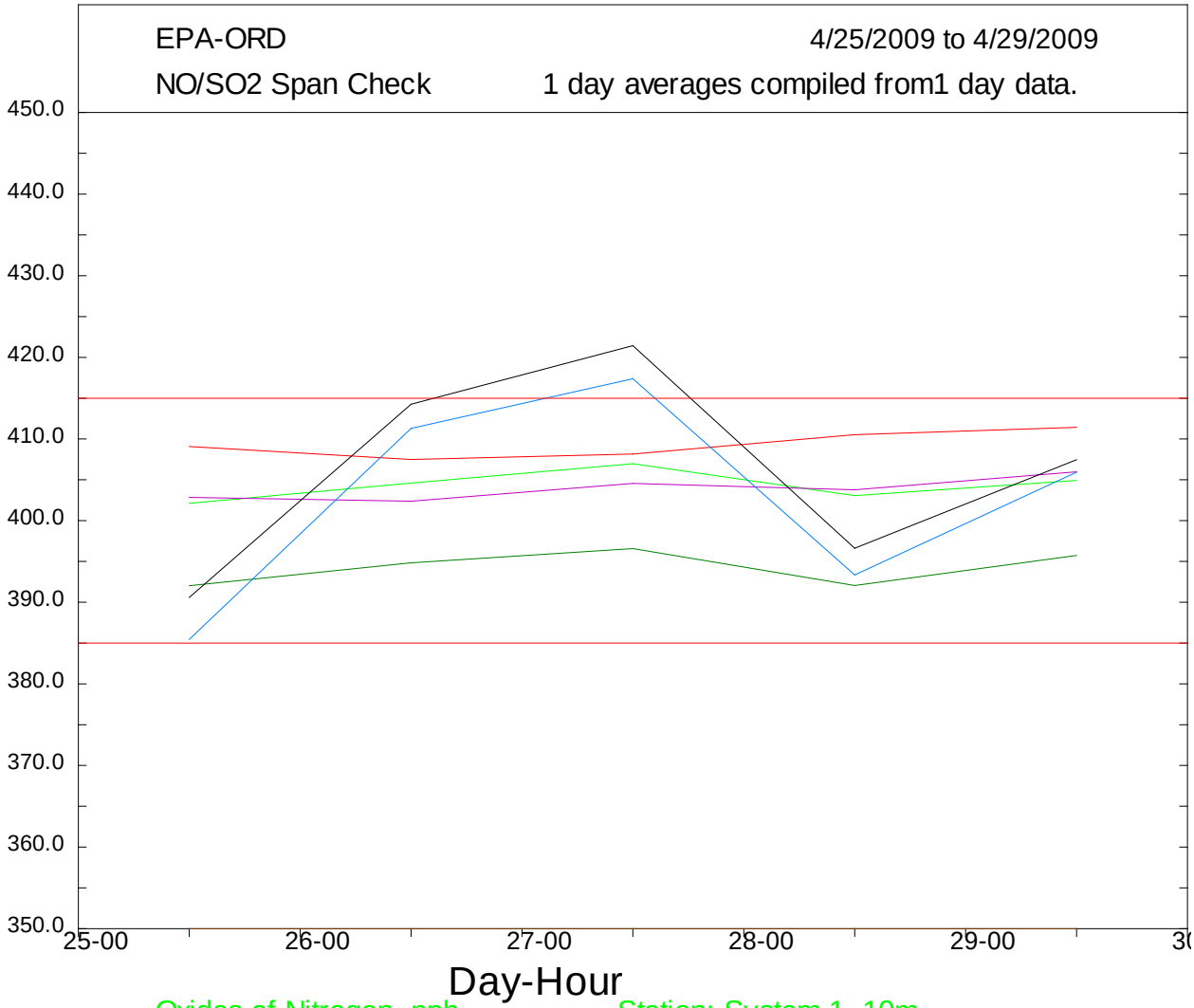

EPA-ORD
25 Apr 2009
WS check
1 hour averages compiled from 5 min. data.
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
2D WS m/s
2D WS m/s
2D WS m/s
2D WS m/s
Station: System 1, 10m
Station: System 2, 100m
Station: System 3, 300m
Station: System 4, Upwind

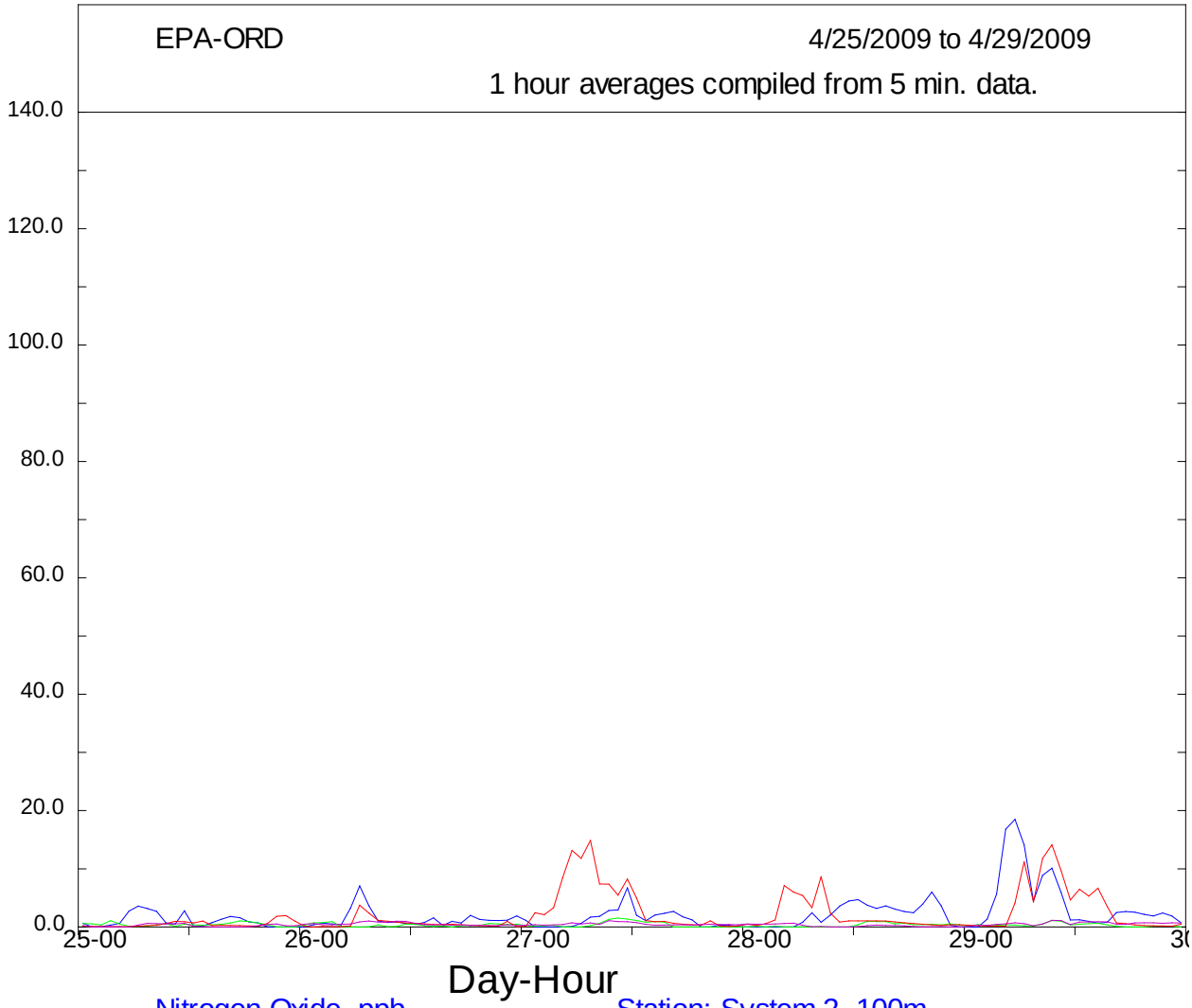

EPA-ORD
4/25/2009 to 4/29/2009
Aethalometer Check
1 hour averages compiled from 5 min. data.
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
Aethalometer µg/m³
Aeth µg/m³
Aethalometer µg/m³
Aethalometer µg/m³
Station: System 1, 10m
Station: System 2, 100m
Station: System 3, 300m
Station: System 4, Upwind

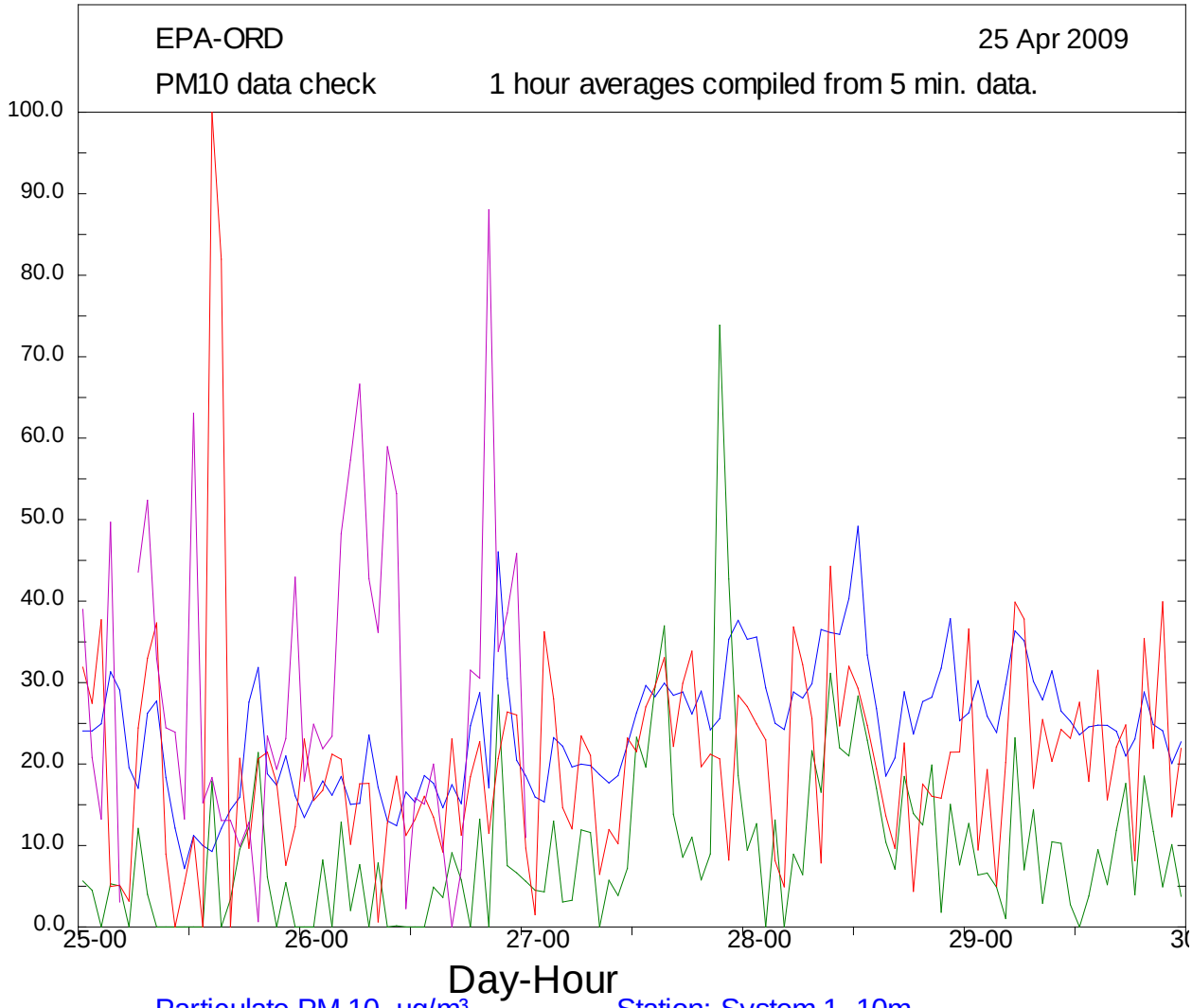

EPA-ORD
25 Apr 2009
Overnight CO Span Check 1 day averages compiled from1 day data.
4.9
4.7
4.5
4.3
4.1
3.9
3.7
3.5
3.3
3.1
2.9
2.7
2.5
25-00
26-00
27-00
28-00
29-00
Day-Hour
Carbon Monoxide ppm
Station: System 1, 10m
Carbon Monoxide ppm
Station: System 2, 100m
Carbon Monoxide ppm
Station: System 3, 300m
Carbon Monoxide ppm
Station: System 4, Upwind

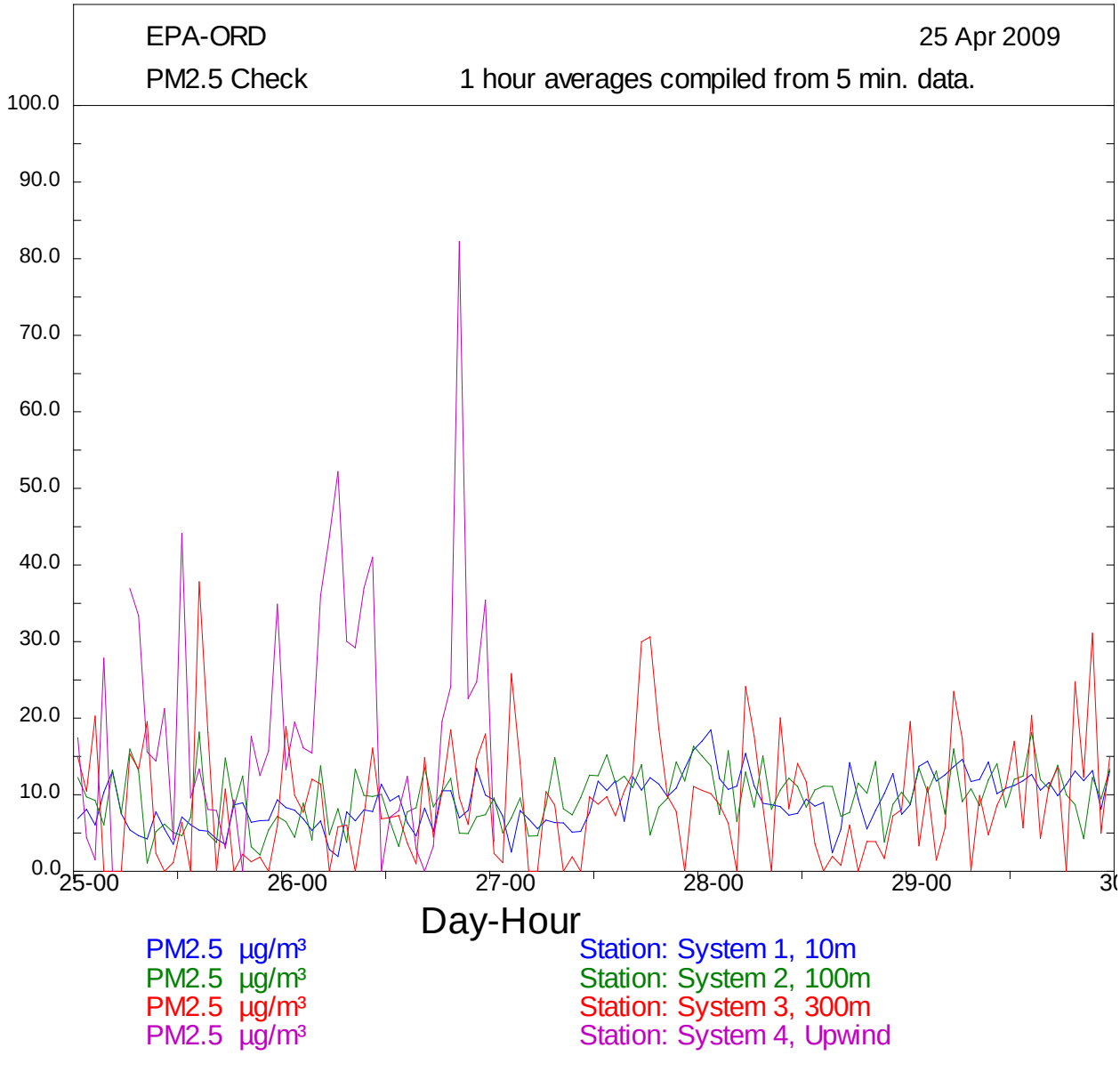

EPA-ORD
25 Apr 2009
Overnight CO Zeros
1 day averages compiled from1 day data.
0.65
0.45
0.25
0.05
-0.15
-0.35
-0.55
-0.75
25-00
26-00
27-00
28-00
29-00
Day-Hour
Carbon Monoxide ppm
Station: System 1, 10m
Carbon Monoxide ppm
Station: System 2, 100m
Carbon Monoxide ppm
Station: System 3, 300m
Carbon Monoxide ppm
Station: System 4, Upwind

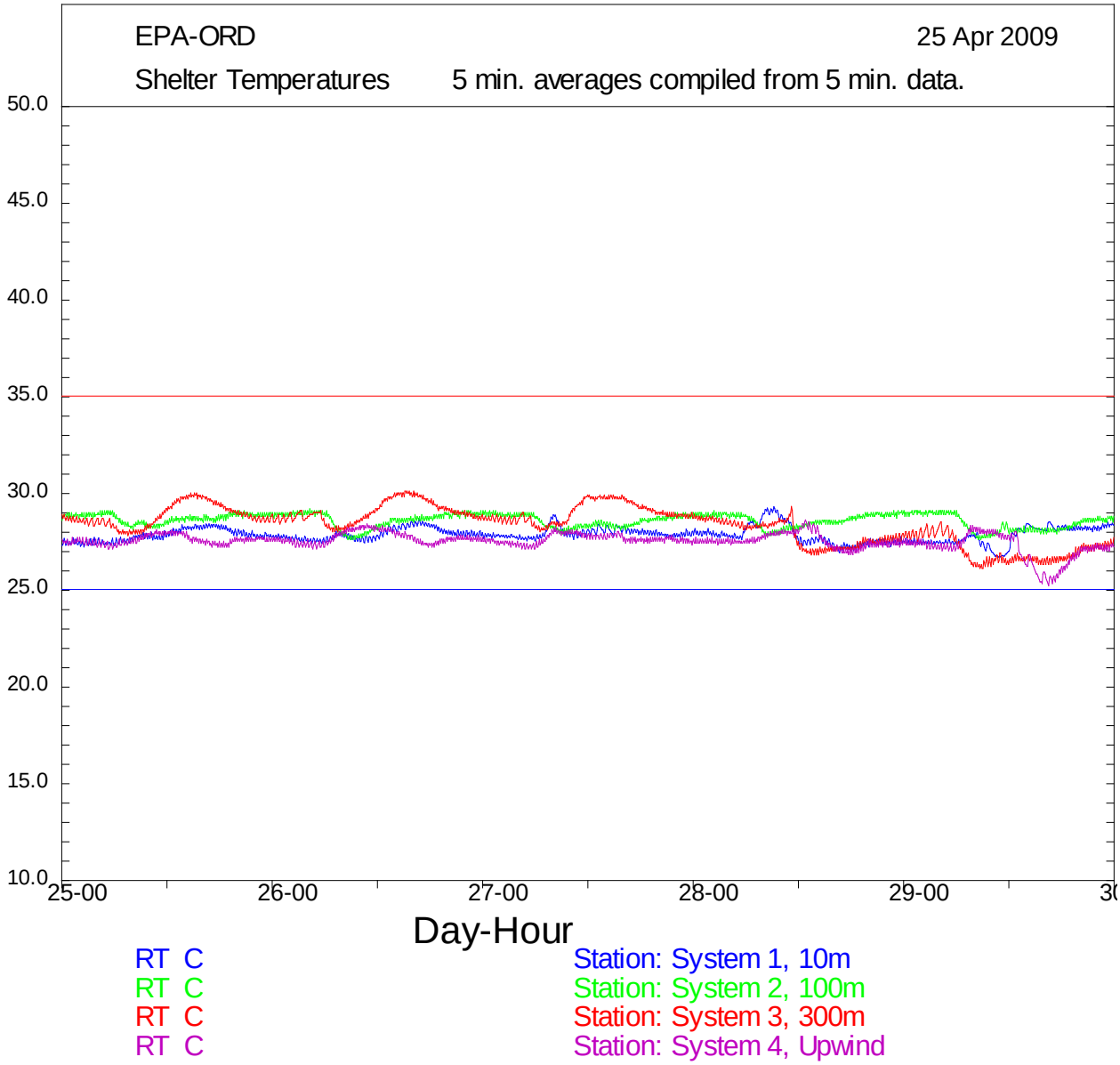

EPA-ORD
4/25/2009 to 4/29/2009
Overnight Zero Check - NO/SO2 2 day averages compiled from 1 day data.
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
Oxides of Nitrogen ppb
Station: System 1, 10m
Oxides of Nitrogen ppb
Station: System 2, 100m
Sulphur Dioxide ppb
Station: System 2, 100m
Oxides of Nitrogen ppb
Station: System 3, 300m
Oxides of Nitrogen ppb
Station: System 4, Upwind
Sulphur Dioxide ppb
Station: System 4, Upwind

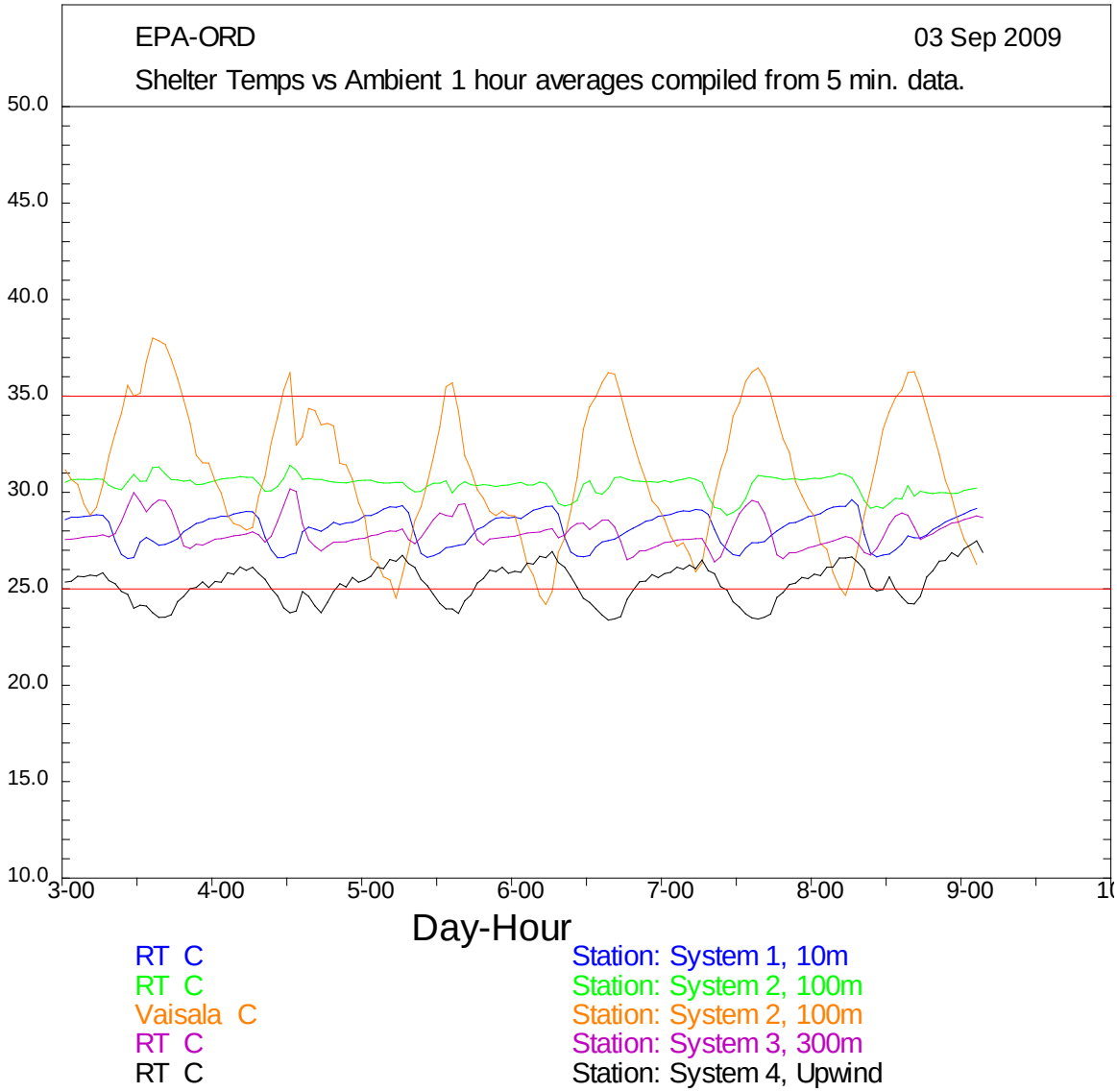

EPA-ORD
4/25/2009 to 4/29/2009
NO/SO2 Span Check
1 day averages compiled from1 day data.
450.0
440.0
430.0
420.0
410.0
400.0
390.0
380.0
370.0
360.0
350.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
Oxides of Nitrogen ppb
Station: System 1, 10m
Oxides of Nitrogen ppb
Station: System 2, 100m
Sulphur Dioxide ppb
Station: System 2, 100m
Oxides of Nitrogen ppb
Station: System 3, 300m
Nitrogen Oxide ppb
Station: System 4, Upwind
Nitrogen Dioxide ppb
Station: System 4, Upwind
Oxides of Nitrogen ppb
Station: System 4, Upwind

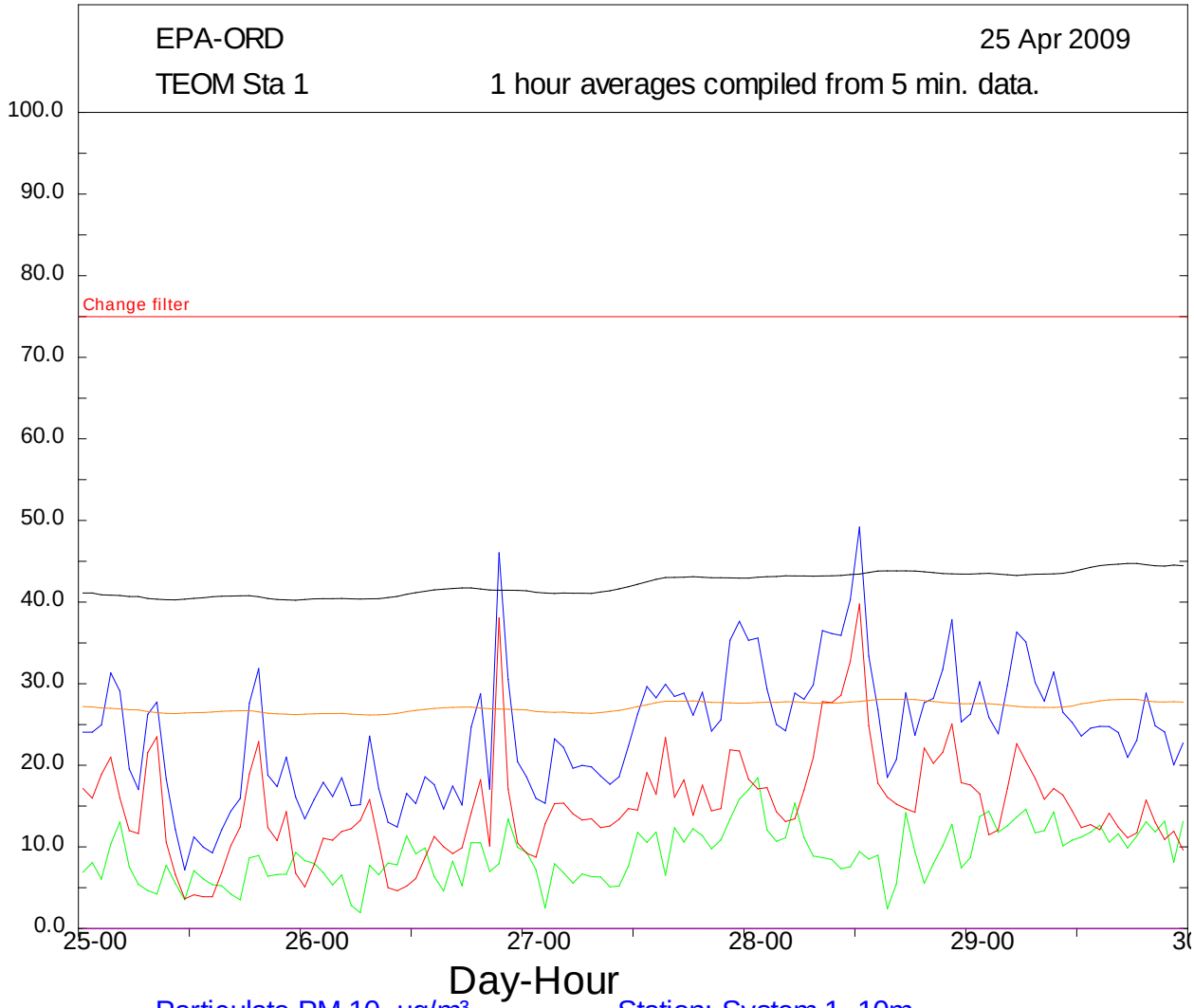

EPA-ORD
4/25/2009 to 4/29/2009
1 hour averages compiled from 5 min. data.
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
Nitrogen Oxide ppb
Station: System 2, 100m
Sulphur Dioxide ppb
Station: System 2, 100m
Nitrogen Oxide ppb
Station: System 4, Upwind
Sulphur Dioxide ppb
Station: System 4, Upwind

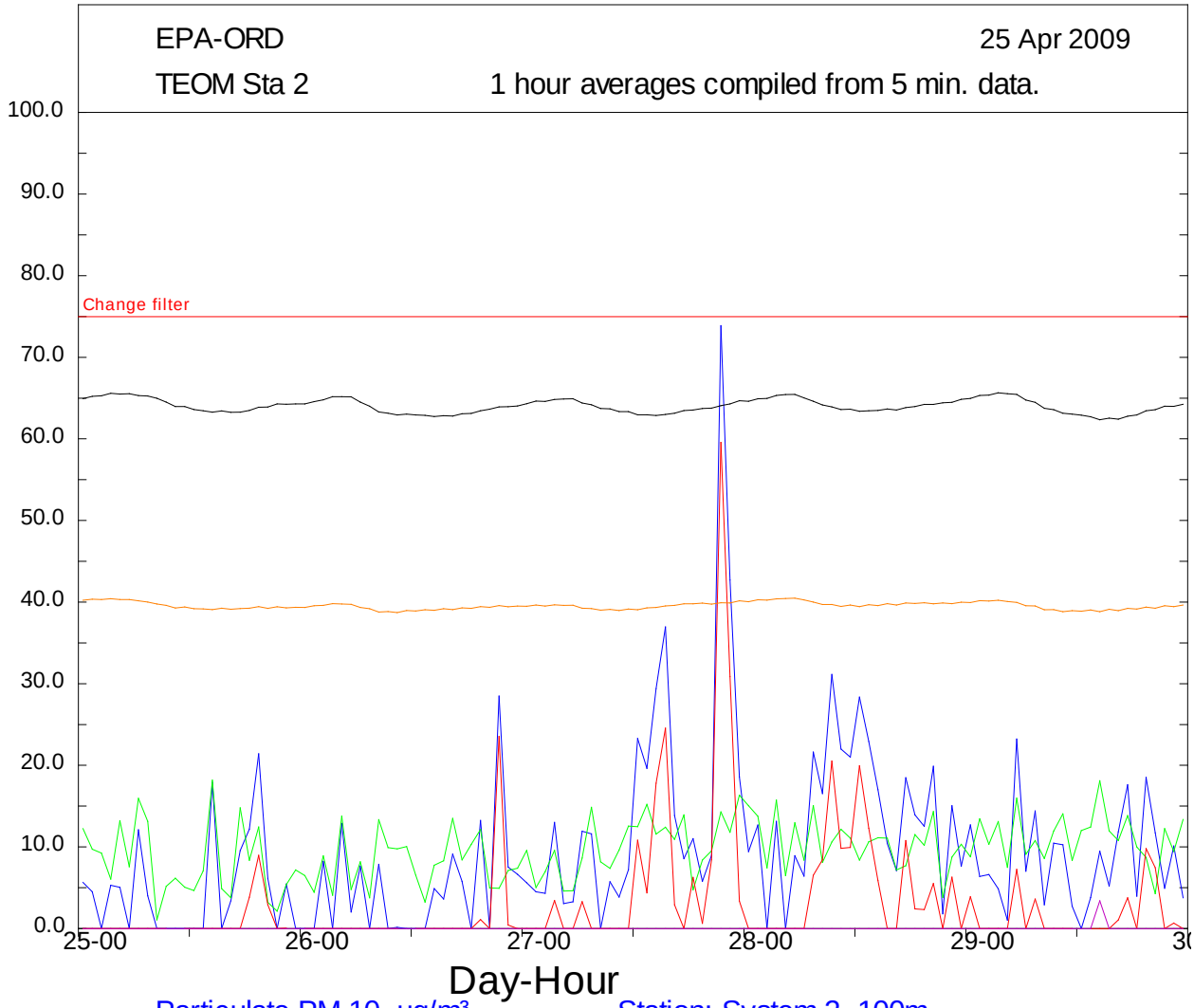

EPA-ORD
25 Apr 2009
PM10 data check
1 hour averages compiled from 5 min. data.
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
Particulate PM 10 µg/m³
Particulate PM 10 µg/m³
Particulate PM 10 µg/m³
Particulate PM 10 µg/m³
Station: System 1, 10m
Station: System 2, 100m
Station: System 3, 300m
Station: System 4, Upwind

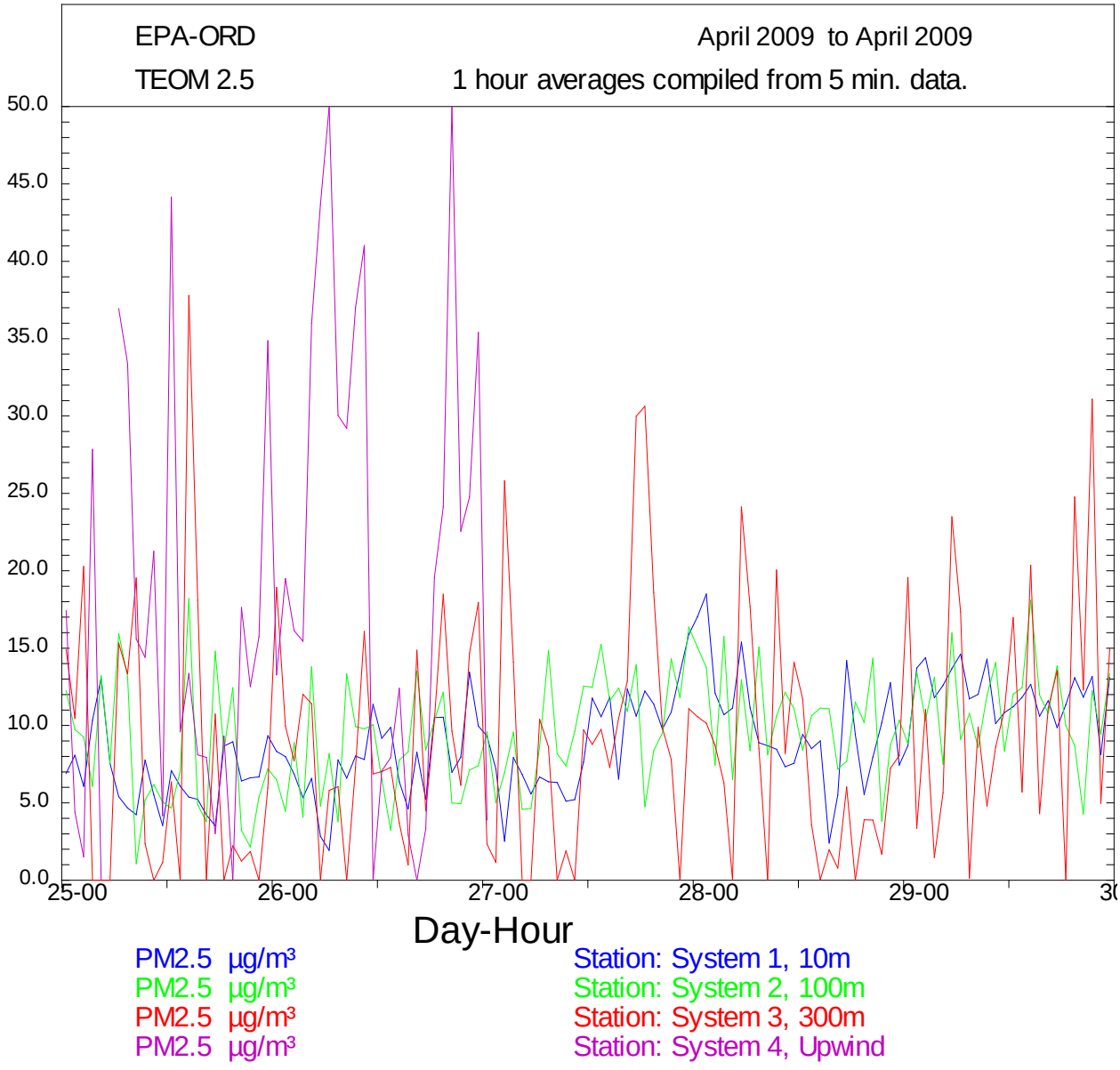

EPA-ORD
25 Apr 2009
PM2.5 Check
1 hour averages compiled from 5 min. data.
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
PM2.5 µg/m³
PM2.5 µg/m³
PM2.5 µg/m³
PM2.5 µg/m³
Station: System 1, 10m
Station: System 2, 100m
Station: System 3, 300m
Station: System 4, Upwind

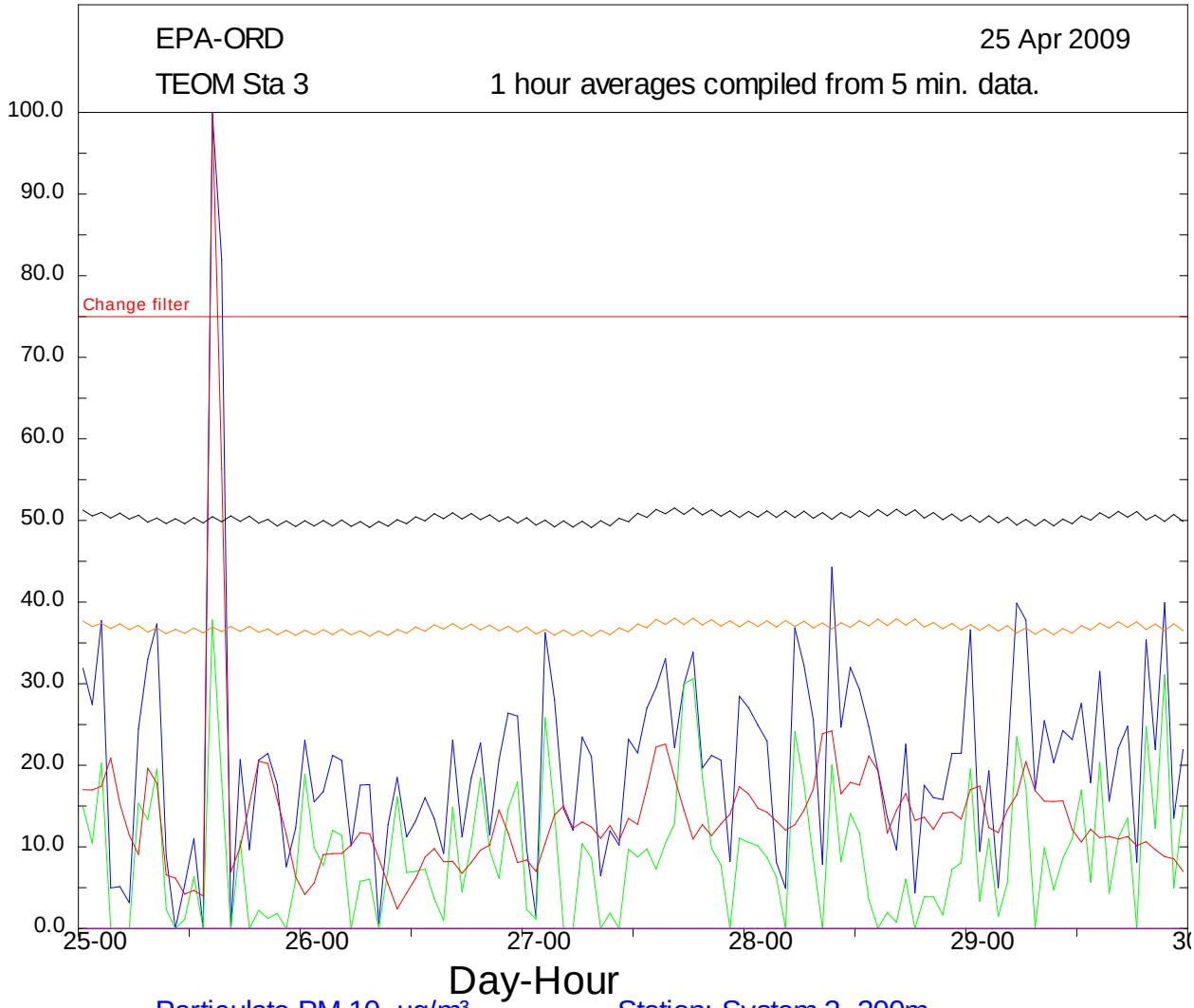

EPA-ORD
25 Apr 2009
Shelter Temperatures
5 min. averages compiled from 5 min. data.
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
RT C
Station: System 1, 10m
RT C
Station: System 2, 100m
RT C
Station: System 3, 300m
RT C
Station: System 4, Upwind

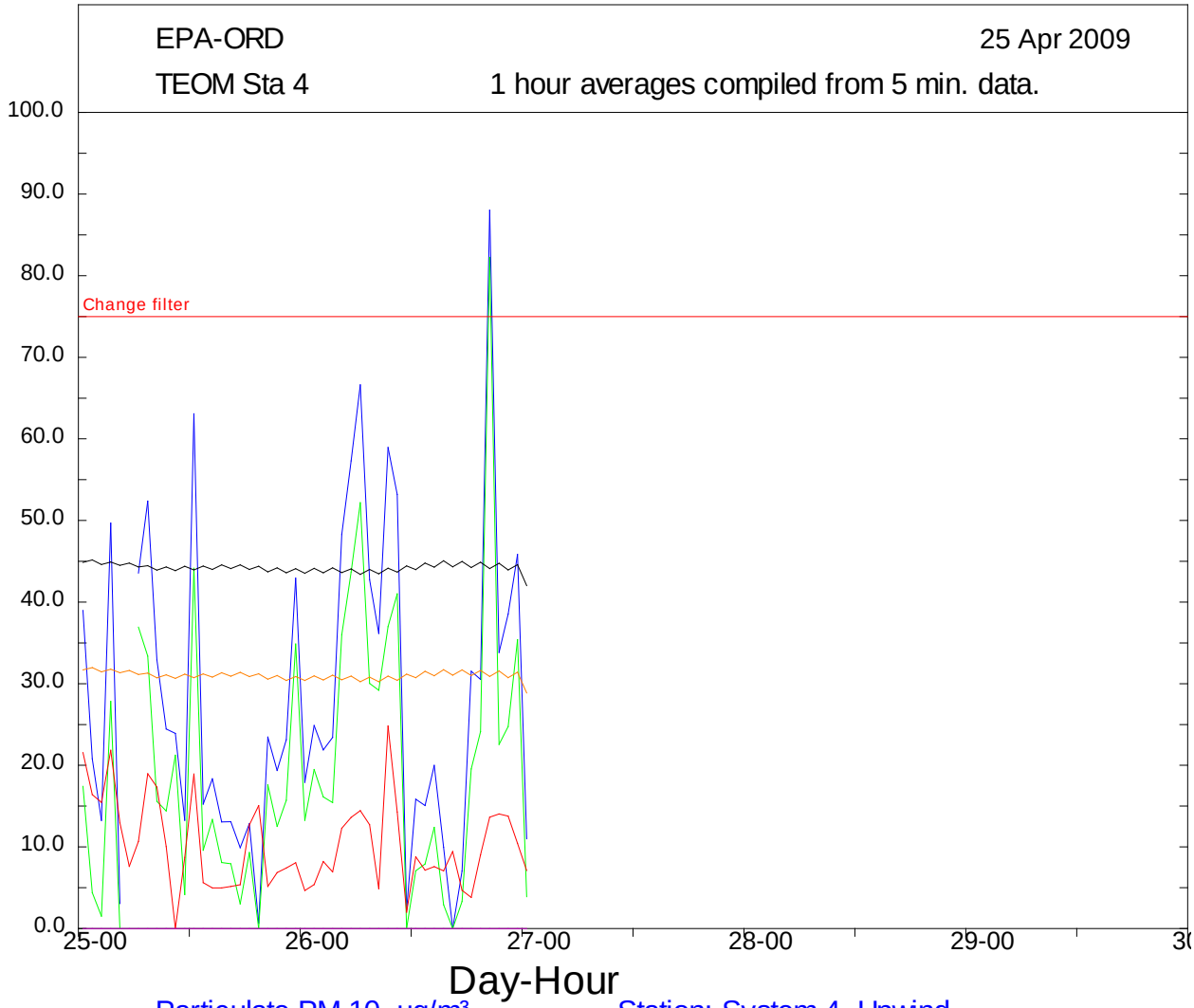

EPA-ORD
03 Sep 2009
Shelter Temps vs Ambient 1 hour averages compiled from 5 min. data.
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
3-00
4-00
5-00
6-00
7-00
8-00
9-00
Day-Hour
RT C
Station: System 1, 10m
RT C
Station: System 2, 100m
Vaisala C
Station: System 2, 100m
RT C
Station: System 3, 300m
RT C
Station: System 4, Upwind

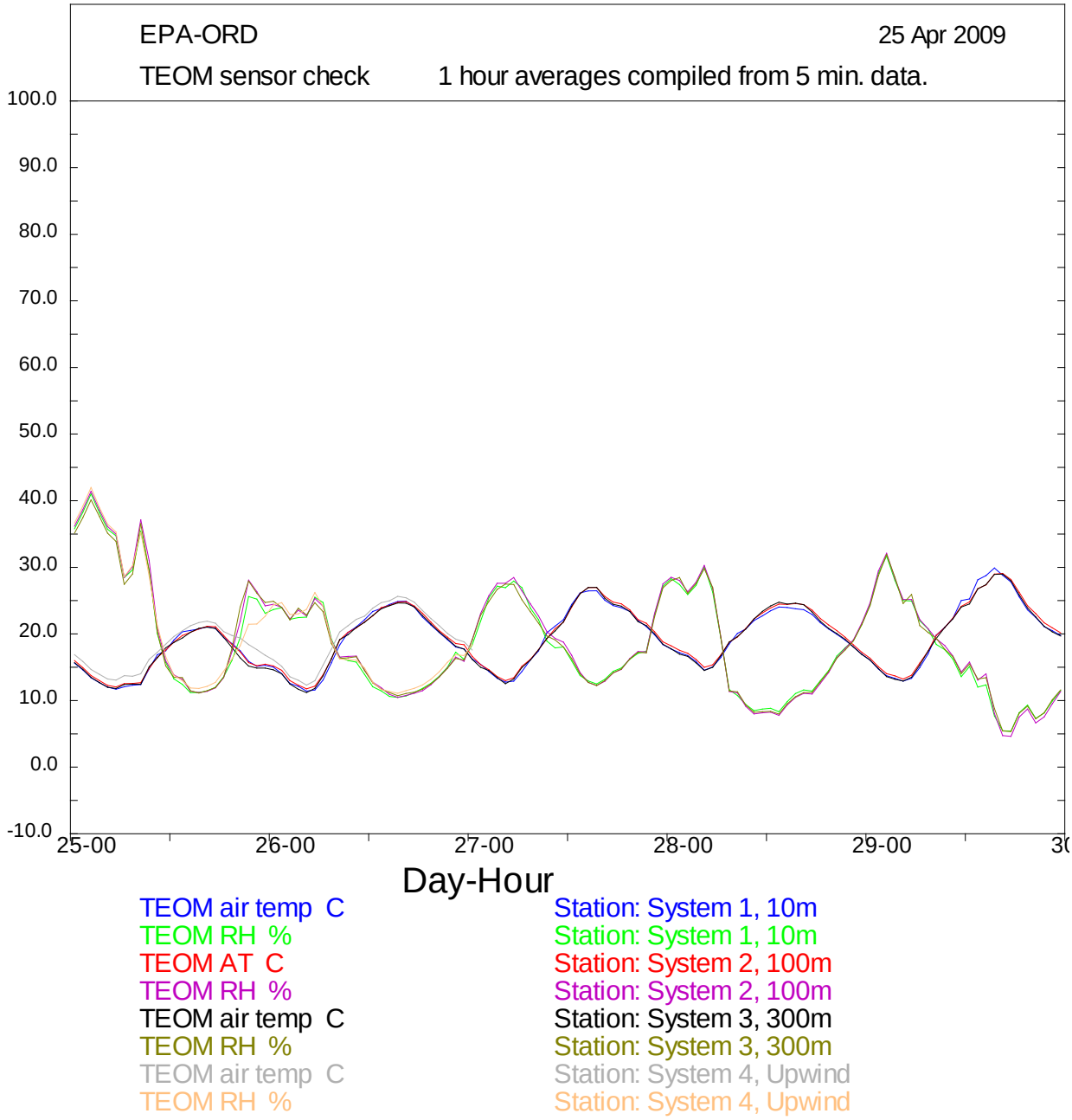

EPA-ORD
25 Apr 2009
TEOM Sta 1
1 hour averages compiled from 5 min. data.
100.0
90.0
80.0
Change filter
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
Particulate PM 10 µg/m³ Station: System 1, 10m
PM2.5 µg/m³ Station: System 1, 10m
PM Coarse µg/m³ Station: System 1, 10m
TEOM Status Status x 100 Station: System 1, 10m
FilterLoad A % Station: System 1, 10m
Filter Load B % Station: System 1, 10m

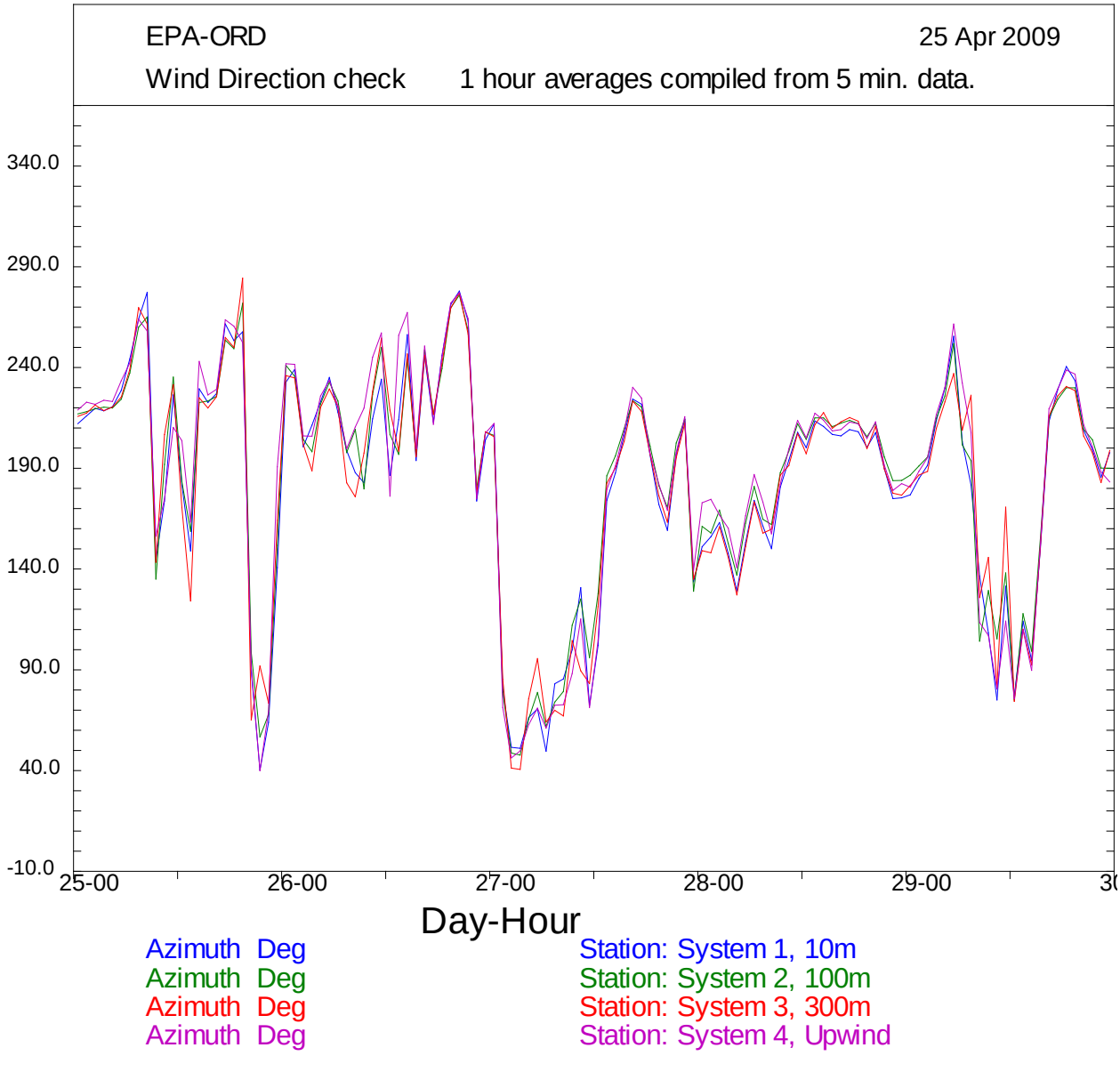

EPA-ORD
25 Apr 2009
TEOM Sta 2
1 hour averages compiled from 5 min. data.
100.0
90.0
80.0
Change filter
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
Particulate PM 10 µg/m³
Station: System 2, 100m
PM2.5 µg/m³
Station: System 2, 100m
PM Coars µg/m³
Station: System 2, 100m
TEOM Sta Status x 100
Station: System 2, 100m
Filter A %
Station: System 2, 100m
Filter B %
Station: System 2, 100m


EPA-ORD
April 2009 to April 2009
TEOM 2.5
1 hour averages compiled from 5 min. data.
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
PM2.5 µg/m³
PM2.5 µg/m³
PM2.5 µg/m³
PM2.5 µg/m³
Station: System 1, 10m
Station: System 2, 100m
Station: System 3, 300m
Station: System 4, Upwind


EPA-ORD
25 Apr 2009
TEOM Sta 3
1 hour averages compiled from 5 min. data.
100.0
90.0
80.0
Change filter
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
Particulate PM 10 µg/m³
Station: System 3, 300m
PM2.5 µg/m³
Station: System 3, 300m
PM Coarse µg/m³
Station: System 3, 300m
TEOM Status Status x 100
Station: System 3, 300m
FilterLoad A %
Station: System 3, 300m
Filter Load B %
Station: System 3, 300m


EPA-ORD
25 Apr 2009
TEOM Sta 4
1 hour averages compiled from 5 min. data.
100.0
90.0
80.0
Change filter
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
Particulate PM 10 µg/m³ Station: System 4, Upwind
PM2.5 µg/m³ Station: System 4, Upwind
PM Coarse µg/m³ Station: System 4, Upwind
TEOM Status Status x 100 Station: System 4, Upwind
FilterLoad A % Station: System 4, Upwind
Filter Load B % Station: System 4, Upwind


EPA-ORD
25 Apr 2009
TEOM sensor check
1 hour averages compiled from 5 min. data.
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
TEOM air temp C
Station: System 1, 10m
TEOM RH %
Station: System 1, 10m
TEOM AT C
Station: System 2, 100m
TEOM RH %
Station: System 2, 100m
TEOM air temp C
Station: System 3, 300m
TEOM RH %
Station: System 3, 300m
TEOM air temp C
Station: System 4, Upwind
TEOM RH %
Station: System 4, Upwind


EPA-ORD
25 Apr 2009
Wind Direction check
1 hour averages compiled from 5 min. data.
340.0
290.0
240.0
190.0
140.0
90.0
40.0
-10.0
25-00
26-00
27-00
28-00
29-00
Day-Hour
Azimuth Deg
Azimuth Deg
Azimuth Deg
Azimuth Deg
Station: System 1, 10m
Station: System 2, 100m
Station: System 3, 300m
Station: System 4, Upwind

17 Appendix -- Data Checks

Level 1

1. Check to see if all variables are listed in each file. Continuous data has all variables for all stations even if station does not have that specific instrument installed.
2. Sound data, traffic, spans, zeros, integrated ($PM_{2.5}$, 1,3-butadiene, benzene, acrolein, formaldehyde, acetaldehyde) data are either recorded in separate files or recorded and stored in separate files.

Measurements	10 Meter Roadside	100 Meter Downwind	300 Meter Downwind	100 Meter Upwind
Continuous Analyzer Data -- Data stored by Station ID – 4 separate files.				
Continuous gas monitoring (CO, NO_x)	X	X	X	X
Continuous black carbon monitoring (Aethalometer)	X	X	X	X
Continuous fine particle (TEOM)	X	X	X	X
Wind speed/wind direction	X	X	X	X
Meteorological monitoring (temp, RH, etc.)		X		
Integrated -- VOC data stored as separate file, $PM_{2.5}$ data stored as separate file.				
TO-11A Cartridge sampling	X	X	X	X
TO-15 Canister sampling	X	X	X	X
Integrated $PM_{2.5}$ (FRM)	X	X	X	X
Other Continuous – Stored as separate files by pollutant or type (sound, video, etc.)				
Video Camera	X			X
Traffic Data – Stored as a separate file				

Level 2 Check

1. Check to see if zero volt reference channel (0_Vref) is equal to zero and five volt reference channel (Vref) = 5.03. Five volt reference channel value is shelter specific. (All other records should be labeled as invalid.)
2. Check to see if continuous data are being recorded every five minutes.
3. Check to see if continuous GC data are being recorded every 30 minutes
4. Check between continuous analyzer data files to determine if time sync is correct. For example, data points are being recorded every 5 minutes. The time stamp for each file should be…. 00:05, 00:10, 00:15….23:55.
5. Check to see if traffic data contains both north bound and sound bound data.
6. Check to see if traffic data is being reported every 15 minutes (approx.).

Level 3 Check

1. Perform summary statistics and inspect for variability issues
2. Check traffic data to determine if sum of traffic volume by length bins is approximately equal to total volume count.
3. Check Outliers: Values that are 3 standard deviations from the mean
4. LowHigh: Check the lowest 5 values and the highest 5 values for all parameters.
5. Jumps: Checks to see if data quickly rises and then drops. There are macro variables that control the sensitivity (need to discuss sensitivity of the macro variables).

18 Appendix -- Data Rules/Flags

General Rules – All Stations		
Where O_Vref is ≠ 0, then mark as invalid all data from all continuous analyzers		
When NO = negative, mark NO as invalid		
When NO = negative, mark NO2 as invalid		
When NO = negative, mark NOx as invalid		
When NO = negative, mark Nox_Flow as invalid		
When NO = negative, mark Nox_Pres as invalid		
When CO = negative, mark as invalid data		
When CO = negative, CO_Flo is invalid		
When CO = negative, CO_Chass is invalid		
When TEOM_Sta ≠ 0 and TEOM_Op ≠ 4, then mark as invalid all TEOM parameters for that record		
PM10; PM2.5; PM Coars; TEOM Sta; TEOM Op; Filter A; Filter B; Mflow A; MFlow B; VFlow A; VFlow B; MFlowBy; VFlowBy; TEOM Vac; Noise A; Noise B; FreqA; FreqB; TEOM AT; TEOM RH; TEOM BP; Dew Poin		
When TEOM Filter_A or TEOM Filter_B > 75, then mark all TEOM parameters as invalid		
PM10; PM2.5; PM Coars; TEOM Sta; TEOM Op; Filter A; Filter B; Mflow A; MFlow B; VFlow A; VFlow B; MFlowBy; VFlowBy; TEOM Vac; Noise A; Noise B; FreqA; FreqB; TEOM AT; TEOM RH; TEOM BP; Dew Poin		
When Aeth < 0, then mark as invalid Aeth data		
When Aeth > 15, then mark data as outliers		
When Aeth_1 < 0, then mark as invaild Aeth_1 data		
When Aeth_2 < 0, then mark as invalid Aeth_2 data		
When Aeth_3 < 0, then mark as invalid Aeth_3 data		
When Vaisala_1 < 0, then mark all Vaisala parameters invalid (Vaisala, Vaisala_1)		

General Rules – All Stations			
When GasCal_S = 3 or 6 or 7 or 15 or 18 or 19, mark all gas analyzer parameter data invalid: NO; NO2; Nox; NOx Flow; NOx Pres; CO; CO Flow; CO Chass.			
GasCal_S	1 = zero (calibration)		
	2 = span 400 ppb NO/CO		
	3 = error		
	4 = manual zero/span activity		
	5 = span 100 ppb NO/CO (every 11 days)		
	6 = error		
	7 = error		
	8 = span 400 ppb SO2		
	11 = span 100 ppb SO2 (every 11 days)		
	14 = manual zero/span activity		
	15 = error		
	17 = manual zero/span activitiy		
	18 = error		
	19 = error		
When NO > 450, then mark as outlier (NO, NO2, NOX) for that record			
When CO > 2.25, then mark as outlier (CO) for that record			
When PM10 > 400, mark data as outliers			
When PM2_5 > 100, mark data as outliers			
When PM_Coars < 0, mark PM_Coars as invalid			
When Aeth > 15, then mark data as outliers			

19 Appendix – Data Dictionary – WinCollect

Electronic Excel File

20 Appendix – "Core Measurements" File – SAS Dataset

SAS Dataset

21 Appendix – Digital Aethalometer

SAS Dataset

22 Appendix -- Traffic

SAS Dataset

23 Appendix – Integrated Sample Data – PM Filters

SAS Dataset

The table is a summary of all of the samples collected between September 29, 2010 thru June 20, 2011.

September 29, 2010 thru June 20, 2011						
Sample Type	**# of Samples**	**% by Sample Type**	**# of Samples w/ No Sample Collection Errors/Warnings (Flag_PM = 0)**	**% of Samples w/ No Sample Collection Errors/Warnings (Flag_PM = 0)**	**# of Samples w/ Sample Collection Errors/Warnings (Flag_PM = 1,4)**	**% of Samples w/ Sample Collection Errors/Warnings (Flag_PM = 1,4)**
Field Blank	19	17	19	100	0	0
Field Duplicates	19	17	17	89	2	11
Samples	76	67	71	93	5	7
Total	114		107		7	

Note: invalid data may be due to instrument malfunction, torn filter, etc.

The following is a list of the variables in the PM2.5 data set.

id = station identification
SampleType = Sample, Field Duplicate, Field Blank,
Date = Date Sample Collected
Flag_PM = 0 or 1; 0 = valid data; 1 = invalid data
location = Upwind, 10 meter, 100 meter, 300 meter
PM2_5mg_m3 = PM2.5 in $\mu g/m^3$

24 Appendix – Integrated Sample Data – VOC (TO-15)

SAS Dataset

Variables for VOC Data (samples collected using Summa Canisters: Method TO-15).

id = station1, station2, station3, station4
location = 10 meter, 100 meter, 300 meter, Upwind
SampleType = Field Blank, Field Control, Field Duplicate, Lab Duplicate, Sample
SampleDateTime = Date and Time of Sample
Buta_ppb = 1,3-Butadiene (ppb)
Benz_ppb = Benzene (ppb)
Acrolein_ppb = Acrolein (ppb)
Flag_VOC = 0 or 1; 0 = valid data; 1 = invalid data (relates to the entire sample, across all pollutants)
Flag_Buta = 0 or 1; 0 = valid data; 1 = invalid data
Flag_Benz = 0 or 1; 0 = valid data; 1 = invalid data
Flag_Acrolein = 0 or 1; 0 = valid data; 1 = invalid data
FieldComments = text field
AnalysisComments = text field
LabComments = text field
fcom = text field

September 29, 2010 thru June 20, 2011
1,3-Butadiene

SampleType	# of Samples	% by Sample Type	# of Samples w/ No Sample Collection Errors/ Warnings (Flag_Buta = 0)	% of Samples w/ No Sample Collection Errors/Warnings (Flag_Buta = 0)	# of Samples w/ Sample Collection Errors/ Warnings (Flag_Buta = 1)	% of Samples w/ Sample Collection Errors/ Warnings (Flag_Buta = 1)
Field Blank	17	9	16	94	1	6
Field Control	10	5	0	0	10	100
Field Dup	18	10	17	94	1	6
Sample	142	76	132	93	10	7
Total	187		165		22	

Benzene

SampleType	# of Samples	% by Sample Type	# of Samples w/ No Sample Collection Errors/ Flag_Benz Warnings (Flag_Benz = 0)	% of Samples w/ No Sample Collection Errors/ Flag_Benz Warnings (Flag_Benz = 0)	# of Samples w/ Sample Collection Errors/ Warnings (Flag_Benz = 1)	% of Samples w/ Sample Collection Errors/ Warnings (Flag_Benz = 1)
Field Blank	17	9	16	94	1	6
Field Control	10	5	0	0	10	100
Field Dup	18	10	17	94	1	6
Sample	142	76	132	93	10	7
Total	187		165		22	

Acrolein

SampleType	# of Samples	% by Sample Type	# of Samples w/ No Sample Collection Errors/ AcroleinWarnings (Flag_Acrolein = 0)	% of Samples w/ No Sample Collection Errors/ Acrolein Warnings (Flag_Acrolein = 0)	# of Samples w/ Sample Collection Errors/ Warnings (Flag_ Acrolein = 1)	% of Samples w/ Sample Collection Errors/ Warnings (Flag_ Acrolein = 1)
Field Blank	17	9	16	94	1	6
Field Control	10	5	0	0	10	100
Field Dup	18	10	17	94	1	6
Sample	142	76	132	93	10	7
Total	187		165		22	

25 Appendix – Integrated Sample Data – Cartridges

SAS Dataset

September 29, 2010 thru June 20, 2011

Acetaldehyde

SampleType	# of Samples	% by Sample Type	# of Samples w/ No Sample Collection Errors/ Warnings (Flag_ Acetaldehyde = 0)	% of Samples w/ No Sample Collection Errors/ Warnings (Flag_ Acetaldehyde = 0)	# of Samples w/ Sample Collection Errors/ Warnings (Flag_ Acetaldehyde = 1)	% of Samples w/ Sample Collection Errors/ Warnings (Flag_ Acetaldehyde = 1)
Field Blank	13	8	13	100	0	0
Field Control	6	4	6	100	0	0
Field Dup	2	1	2	100	0	0
Lab Dup	0	0	0	100	0	0
Sample	144	87	130	90	14	10
Total	165		151		14	

Formaldehyde

SampleType	# of Samples	% by Sample Type	# of Samples w/ No Sample Collection Errors/ Warnings (Flag_ Formaldehyde = 0)	% of Samples w/ No Sample Collection Errors/ Warnings (Flag_ Formaldehyde = 0)	# of Samples w/ Sample Collection Errors/ Warnings (Flag_ Formaldehyde = 1)	% of Samples w/ Sample Collection Errors/ Warnings (Flag_ Formaldehyde = 1)
Field Blank	13	8	13	100	0	0
Field Control	6	4	6	100	0	0
Field Dup	2	1	2	100	0	0
Lab Dup	0	0	0	100	0	0
Sample	144	87	130	90	14	10
Total	165		151		14	

Acrolein

SampleType	# of Samples	% by Sample Type	# of Samples w/ No Sample Collection Errors/ Warnings (Flag_ Acrolein = 0)	% of Samples w/ No Sample Collection Errors/ Warnings (Flag_ Acrolein = 0)	# of Samples w/ Sample Collection Errors/ Warnings (Flag_ Acrolein = 1)	% of Samples w/ Sample Collection Errors/ Warnings (Flag_ Acrolein = 1)
Field Blank	13	8	13	100	0	0
Field Control	6	4	6	100	0	0
Field Dup	2	1	2	100	0	0
Lab Dup	0	0	0	100	0	0
Sample	144	87	130	90	14	10
Total	165		151		14	

Variables for Carbonyl Data (samples collected using cartridges: Method TO-11A).

id = station1, station2, station3, station4
location = 10 meter, 100 meter, 300 meter, Upwind
SampleType = Field Blank, Field Control, Field Duplicate, Lab Duplicate, Sample
SampleDateTime = Date and Time of Sample
Acetaldehyde = µg/m^3
Acrolein = µg/m^3
Formaldehyde = µg/m^3
BATCH = batch number of DNSH cartridge
Flag_Carbonyl = 0 or 1; 0 = valid data; 1 = invalid data (relates to the entire sample, across all pollutants)
Flag_Acetaldehyde = 0 or 1; 0 = valid data; 1 = invalid data
Flag_Acrolein = 0 or 1; 0 = valid data; 1 = invalid data
Flag_Formaldehyde = 0 or 1; 0 = valid data; 1 = invalid data
Data_Review_Comment = text field
Acetaldehyde_mdl = method detection limit for acetaldehyde (µg/m^3)
Acrolein_mdl = method detection limit for acrolein µg/m^3
Formaldehyde_mdl = method detection limit for formaldehyde (µg/m^3)
Acetaldehyde_ppb = Acetaldehyde (ppb) (uncorrected for background)
Acrolein_ppb = Acrolein (ppb) (uncorrected for background)
Formaldehyde_ppb = Formaldehyde (ppb) (uncorrected for background)
Acetaldehyde_ppb_mdl = Acetaldehyde (ppb) method detection limit
Acrolein_ppb_mdl = Acrolein (ppb) method detection limit
Formaldehyde_ppb_mdl = Formaldehyde (ppb) method detection limit
Acetaldehyde_detect = 0 or 1; 0 = method detection limit value substitution (only occurs when measured value – background = negative value); 1 = actual value
Acrolein_detect = 0 or 1; 0 = method detection limit value substitution (only occurs when measured value – background = negative value); 1 = actual value
Formaldehyde_detect = 0 or 1; 0 = method detection limit substitution; 1 = below method detection limit
Acetaldehyde_BL = Acetaldehyde (µg/m^3) background value
Acetaldehyde_ppb_BL = Acetaldehyde (ppb) background value
Acrolein_BL = Acrolein (µg/m^3) background value
Acrolein_ppb_BL = Acrolein (ppb) background value
Acetaldehyde_BLCorrected = Acetaldehyde background corrected (µg/m^3)
Acrolein_BLCorrected = Acrolein background corrected (µg/m^3)
Acetaldehyde_ppb_BLCorrected = Acetaldehyde (ppb) background corrected
Acrolein_ppb_BLCorrected = Acrolein (ppb) background corrected
fcom = text field (field comment)