WISCONSIN DEPARTMENT OF NATURAL RESOURCES
Bureau of Air Management

Development and Testing of a Mobile Monitoring Trailer for Improved VOCs and Particulate Carbon Monitoring Near Roadways

Final Report

Editor/Author

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Acknowledgments

Report Abstract

In the last 30 years, the Department of Transportation has recorded the three fold increase in the number of vehicle miles traveled in the United States. Today Americans are more dependent on vehicles for carrying out daily tasks. Residential developments are now placed closer to high traffic roadways, often to facilitate access to the roadways. The effect is that greater numbers of the population are exposed to vehicle emissions. Studies have shown that mobile source emissions now have significant health impacts, including respiratory problems and increased cancer risk.

The Wisconsin DNR purchased and developed a mobile laboratory trailer to measure air pollutants near roadways. The laboratory trailer included analytical systems to measure volatile organic compounds, particulate carbon, nitric oxide and nitrogen dioxide. Once developed, the laboratory was tested and used for a series of three sets of roadway monitoring studies. Between Fall 2009 and Fall 2010, Wisconsin DNR staff monitored pollutants for a total of 14 days at 9 different locations along high traffic roadways. Monitoring showed that pollutant concentrations were affected by traffic volume during specific monitoring days. Meteorological conditions appear to have a greater effect on pollutant concentrations when examining data between monitoring days. High concentrations were measured near a variety of high traffic roadways that included urban traffic corridors, urban expressways, and interstate highways. Measured hourly nitrogen dioxide concentrations were well below the new EPA standard of 100 ppb. No standards exist for VOCs, particulate carbon or nitric oxide. The trailer laboratory was also used for 2009 PAMS monitoring and to support other monitoring studies. The trailer was easy to move and position for studies. The trailer set-up could be accomplished by a single staff member. Future work with the trailer will depend on staffing and funding.

Project Description:
The Wisconsin DNR developed a mobile laboratory trailer designed to house and support analytical equipment for chemical measurements at remote locations. The laboratory, also called the RW trailer, is housed in a fourteen foot utility trailer configured to hold a laboratory in the forward section with a rear alcove to store support gases, pumps and other equipment. Analysis systems housed in the trailer include a gas chromatograph, particulate carbon monitor and an oxides of nitrogen analyzer. The trailer is powered either through a shoreline cable from an outlet or when necessary power is supplied by a propane fueled 10KW electrical generator. The mobile laboratory was tested in several monitoring campaigns to assess its usefulness in providing air monitoring data for use by modelers and risk assessors. The trailer provides short-term measurements necessary for studying dynamic emissions and atmospheric processes. The mobile laboratory also provides high quality measurements at multiple locations needed to assess the public's risk.

Benefits of the Project:
The project has provided the Wisconsin DNR an important tool for the collection of data to be used in model evaluations for planning and to collect data for risk assessments. The monitoring trailer was developed and tested in the field. This testing has demonstrated the usefulness of this laboratory for evaluating emissions near roadways and the diffusion of pollutants into adjoining neighborhoods. The Wisconsin DNR hopes the monitoring done to date and in the future will be used to provide data for "ground truthing" emission models and risk models. In the future, the RW trailer laboratory will be useful in evaluating shifting emission patterns that may result from changing roadways and population patterns.

The Wisconsin DNR's original proposal to develop the RW monitoring trailer included the following five goals. This final report will show that all five goals have been met.

i. Purchase and equip a trailer to function as a mobile monitoring platform. The trailer should provide an operational environment for analytical instruments.
ii. Install a Perkin Elmer Automated Ozone Precursor Analysis System on board the trailer and develop methods for operating the analyzer on-board the trailer.
iii. Install a Magee Aethalometer on board the trailer and develop operating conditions for this analyzer on-board the trailer.
iv. Field test the system and assess the utility of the monitoring trailer for various monitoring scenarios.
v. Deploy the RW Monitoring trailer in field studies and use this information to aid in validation of modeling results and make improvement in risk assessments

Original Problem Statement (from Wisconsin DNR's Proposal):

Air pollution in the urban environment has been increasingly indicated as a significant factor affecting the public health. Within urban areas, roadway emissions are thought to be very significant and sometimes the most significant source of air pollution. EPA has reported mobile source emissions may account for 50% or more of the cancer risk in urban areas (Federal Register, Vol. 71). Currently much of the work to document health risks is epidemiological. Several studies have shown increased respiratory health problems associated with traffic related air pollutants (Morgenstern et. al.,2007, Pierse, et. al.,2006). There are also studies showing relationships between traffic counts and respiratory health effects (Ciccone, et. al.,1998). While there is increasing evidence to suggest links between health effects and mobile source air pollution there is not a firm link between distance from roadway and asthma (Livingstone, et. al.,1996). While questions exist about risks in relation to one's proximity to roadways, it has been shown that exposure to mobile source emissions increases health problems including cardiovascular disease, respiratory diseases and cancers. Significant risk drivers from mobile sources include benzene and fine particulate matter. Benzene is a ubiquitous aromatic hydrocarbon that is present in gasoline and is also formed in many combustion processes. Benzene is a known human carcinogen and is considered one of the most significant risk drivers in the urban environment. Mobile source emissions make up the major source of benzene in the urban environment (Fruin et.al., 2001). Models show that the exposure from roadways is related to the distance from the roadway (Funk and Lurmann, 2001). Monitoring studies suggest that for mobile source pollutants, like benzene, the outdoor and indoor air concentration are similar and indicate ambient air is the most important exposure driver (Paynes-Struges et. al., 2004). Many questions remain about benzene in the urban environment that warrant further study. First, what are the accuracy of the current stationary source and mobile source inventories in predicting ambient benzene concentrations? How to address the relative contributions of both major roadways and the numerous minor urban roadways as sources of benzene? Are there other significant sources that also need to be addressed or that might be more easily controlled? How quickly is benzene dispersed from the roadways to the adjoining environment? What are benzene exposures in neighborhood environment? Roadways are also a major source of fine and ultra fine particulate matter. The fine particulate matter (PMfine) can enter deeply into the lungs and cause tissue damage. Diesel emissions are a major source of PMfine. The 1999 National Air Toxic Assessment (NATA) assigned 100% of the diesel PM from mobile sources. Fine particulate matter can also be linked with VOCs. The group of heavier, less reactive VOCs called "aromatics" have been associated with the formation of organic carbon (OC) fine particles (Grosjean and Seinfeld, 1989). Consequently, measurements of aromatic VOCs (e.g., toluene, benzene, xylene) would be helpful in estimating the relative impact of these precursors to OC PMfine at monitoring sites. PMfine is currently monitored by filter-based techniques and some limited real-time analytical instruments (TEOMs and Aethalometer). The passive monitoring techniques used by the WDNR to measure roadway benzene concentrations are not effective at measuring particulate matter. We believe that analytical techniques like the aethalometer will provide data that when combined with the VOC measurements will provide toxicologists and other health professionals the data necessary to assess major risk sources in the urban atmosphere. In assessing exposure, studies have shown poor correlation between self-reported traffic air pollutants exposure and modeled concentrations near roadways (Heinrich,J. et.al.). Modeling has been and will continue to be the primary tool used to show the dispersion of air pollutants from the roadways. The model concentration data can in turn be used to assess the risk of the public. Modeling efforts like RAIMI combine dispersion modeling with risk assessment to form an important assessment tool that can be used at the state, local and neighborhood levels of analysis. We expect this effort to be especially important for understanding exposure gradients in areas near roadways, which increasingly have been identified in the public health literature as being a potentially variable to consider in epidemiology. The ability to ground truth modeling data becomes very important if that data is to be used by regulators. Currently the ability to check data is limited to a few monitoring stations. The NATTS network compromises only 22 stations nationally. While these NATT sites provide the highest quality data they are very limited in the areas they reach. Assessing the impacts of benzene and other significant volatile pollutants requires the NATTS site data be supplemented with PAMS monitoring data and with local monitoring data. Even with multiple networks taken together the number of monitoring points is smaller than available data for ozone and particulate networks. Another unknown is whether kriging techniques or inverse distance weighting used with regional pollutant data can be effectively be used to interpolate toxic pollutant concentrations. Air monitoring studies focusing on roadways has been limited. Many current monitoring sites were set up to avoid direct impacts from roadways. Additional monitoring studies will be needed if we are to demonstrate the value of modeling and to better understand the causal link between roadway traffic, increased emissions, spatial and temporal exposure gradients and provide and estimate of exposure that can be potentially lined to studies of health effects. In Wisconsin, monitoring studies will be of direct benefit to DNR planning staff and to other state and local health agencies. Efforts to link epidemiological studies, modeling, monitoring, and risk assessment can be used by regulators to determine if emission reductions like those proposed for mobile sources (Federal Register, Vol. 71) can obtain the desired risk reductions.

Project Milestones:

Appendix B of this report contains a complete summary by quarter for all the work done on the project. The Wisconsin DNR's grant proposal listed six basic work tasks for the project. Those work tasks are reviewed below:

Work Task 1: Develop the guidance documents for staff to initiate and complete the monitoring project.

Wisconsin DNR staff have drafted and completed a number of guidance documents for use in project. Documents include a Quality Assurance Project Plan, a new SOP for the operation of the Aethalometer, SOPs for the operation of the meteorological sensor, the GPS antenna and the electrical generator. In addition, staff are currently drafting a SOP for the Oxides of Nitrogen analyzer. Copies of completed documents are included in Appendix C & D of this report.

Work Task 2: Procure a custom-outfitted trailer and associated components to assemble a mobile monitoring platform.

The Wisconsin DNR purchased a 14 foot Wells Cargo Utility trailer to be out fitted as a mobile laboratory. The trailer included a forward platform for two propane gas cylinders, roof supports for installing a work deck, a roof mounted air conditioner/heater, a side access door and rear cargo doors, a front enclosure to house an electrical generator, and workbench on the right side of the trailer. After delivery of the trailer, the Wisconsin DNR contracted for the installation of a 10 KW Kohler electrical generator in the trailer. Wiring was installed for electrical circuits and data transmission. A bulkhead wall was installed in the rear of the trailer to separate the gas storage area from the work area. An electrical rack was installed to support several rack mountable analyzers. Figures 1a through 1i in the next section of this report show the diagrams and photos of the trailer.

Work Task 3: Test the operation of an Aethalometer to be used in the monitoring trailer. Develop analytical procedure for routine operation of the Aethalometer by Wisconsin DNR staff.

The Wisconsin DNR purchased a Magee AE22 rack mounted dual channel Aethalometer for the project. This was the first Aethalometer purchased and used in the Wisconsin Air Monitoring program. After receiving the analyzer the unit was installed in the Madison East monitoring site for initial testing. This also provided staff an opportunity to learn how the analyzer operates. The Aethalometer was operated at the site for a period of approximately six month during which time the trailer was purchased and configured. Data from the initial operations at the Madison east site were examined to see relationships between wind direct and the black carbon concentration. PM2.5 data from the Madison East site was compared to the black carbon data. A general conclusion was that the PM2.5 and the black carbon data did not show a high degree of correlation (correlation .448, n=4054). This is consistent with theory that carbon is only one of a number of chemical compounds that make-up PM2.5. Michigan DEQ staff provided invaluable guidance in the analyzer operation based on their own extensive experience. The operation of the analyzer during this break-in period was very good.

Additional information on the value of the Aethalometer is provided in the conclusion section of this report.

Work Task 4: Installation of the Ozone Precursor Analyzer and the Aethalometer in the monitoring trailer.

After support systems were installed the analytical systems were added to the trailer. Support system included the generator, electrical and data wiring, construction of a bulkhead wall creating a storage area, installation of a cabinet, an electrical rack, installing sampling inlets and mounting a support mast for meteorological equipment.

The Perkin Ozone Precursor analyzer was mounted on the trailer work bench. Data from the analyzer was sent to the interface unit in the electrical rack. The Aethalometer was mounted in the electrical rack. A rack mount PC computer was also installed in the electrical rack. The computer collected all monitoring data. A computer monitor and keyboard was installed on the workbench. Later in the project an API 200E oxide of nitrogen analyzer was added to the trailer electrical rack. The API 200 was installed in the electrical rack and reported data through APICOM software to the trailer's computer.

A mounting bar was fabricated to hold the electronic compass in alignment with the metrological sensor. When deployed the electronic compass reported position data for the met sensors.

Work Task 5: Use the Trailer to conduct Summer PAMS Monitoring

The Wisconsin DNR's proposal envisioned the RW trailer as a platform for Summertime PAMS monitoring. The mobile trailer could then be used for additional roadway monitoring in fall and spring. In May 2009, the trailer was moved to the Milwaukee South East Region Headquarter monitoring site and was installed at the site for the summertime PAMS monitoring. Summertime intensive PAMS monitoring includes the collection of hourly VOC measurements using the Perkin Ozone Precursor analyzer. The 2009 PAMs season saw the first use of the Aethalometer in Milwaukee as an adjunct measurement for PAMS. While the operation of the trailer went very well, the Perkin Ozone Precursor analyzer, now 10 year old, showed increasingly poor performance. The analyzer was plagued by increase noise problems in the system detectors.

The Wisconsin DNR had planned to deploy the RW trailer to the Milwaukee site for the 2010 PAMS season. The trailer was used in two roadways studies in the fall 2009 and spring 2010. After the last study it was becoming apparent that the AutoGC system was failing. Cascading failures made it very difficult to maintain the analyzer's operation for an extended period such as the summer 2010 PAMS monitoring project. Plans for using the trailer for PAMS monitoring in 2010 were cancelled.

Work Task 6: Field-test the trailer for Roadway and other monitoring operations.

Following the 2009 PAMS monitoring operations, the trailer was returned to the Wisconsin DNR's Madison Science and Operations (SCIOPS) facility for maintenance. An initial roadway monitoring study was conducted in Fall 2009. This was followed by a spring study in 2010. In early 2010, with EPA Region 5 support, the Wisconsin DNR planned for the inclusion of an oxides of nitrogen analyzer in the RW trailer. The API 200E analyzer was purchased in the summer of 2010 and installed in the RW trailer in fall 2010. A Fall 2010 monitoring study looked at black carbon and oxides of nitrogen concentrations at seven roadway sites in the Madison area.

In addition to the roadway studies, the trailer was deployed to the Wisconsin DNR's Cassville monitoring site for a comparison study with an aethalometer deployed at Cassville as part of the LADCO sponsored Biomass Emission Monitoring study. While at the site the RW trailer was used to document increased ambient black carbon with trains. A second aethalometer comparison study was conducted in January 2010 on board the RW trailer when stationed at the SCIOPS location.

Roadway Monitoring Trailer

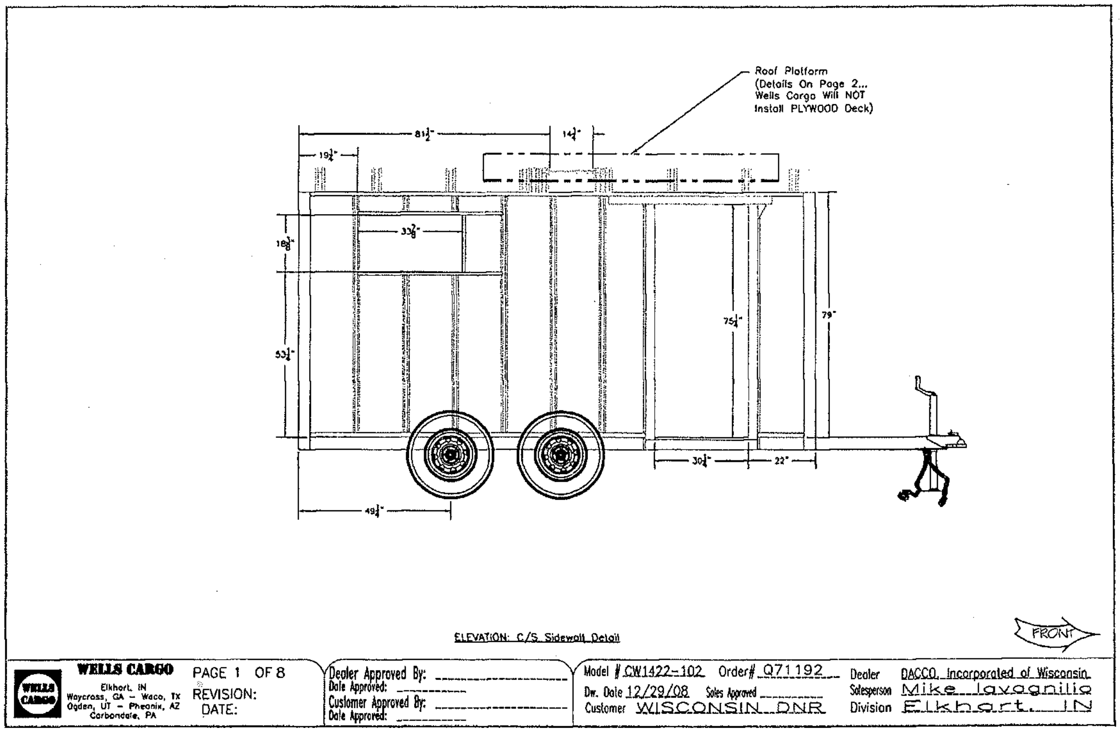


Figure 1a: Production diagram, side view of RW trailer

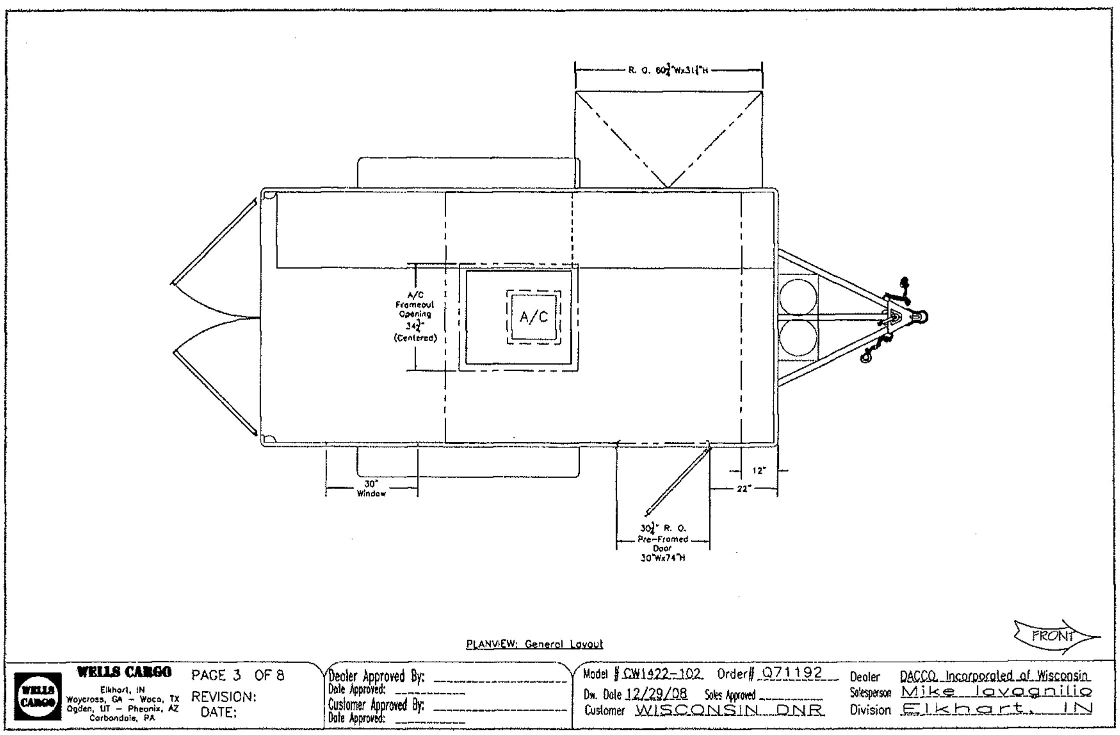


Figure 1b: Production Diagram, top view of trailer

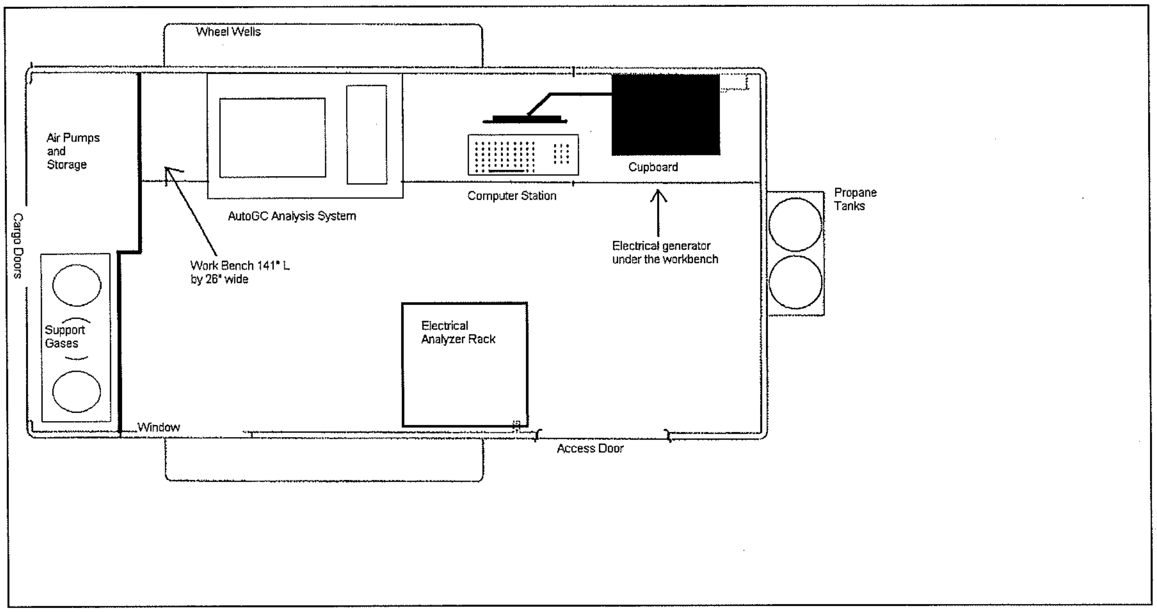


Figure 1c: Diagram of trailer after the Wisconsin DNR's configuration to a mobile laboratory. Diagram shows bulkhead wall, AutoGC secured to workbench and analyzer electrical rack.

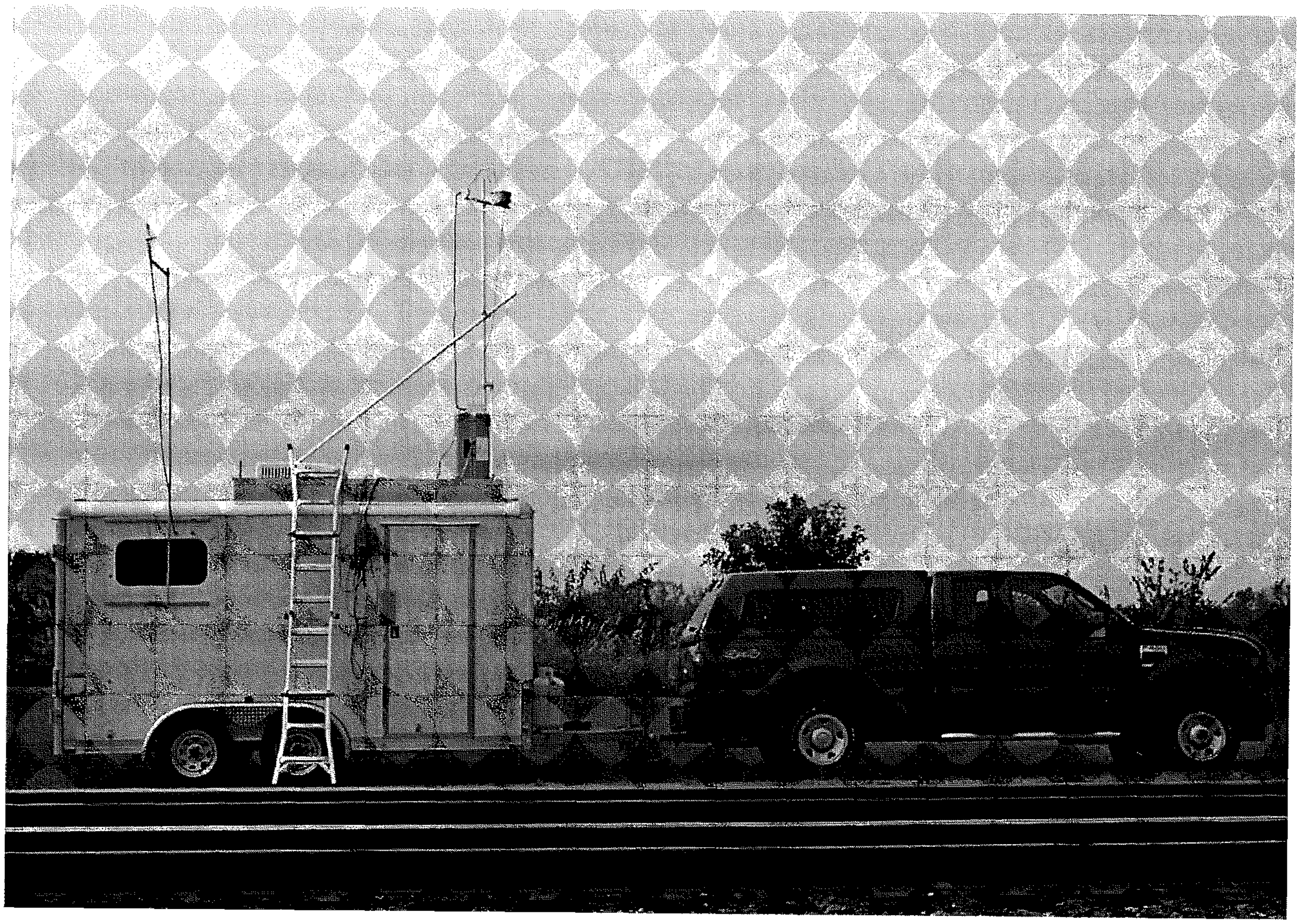


Figure 1d: Monitoring trailer is a 14 foot utility trailer configured as a mobile laboratory. Trailer is show above in a field monitoring operation.

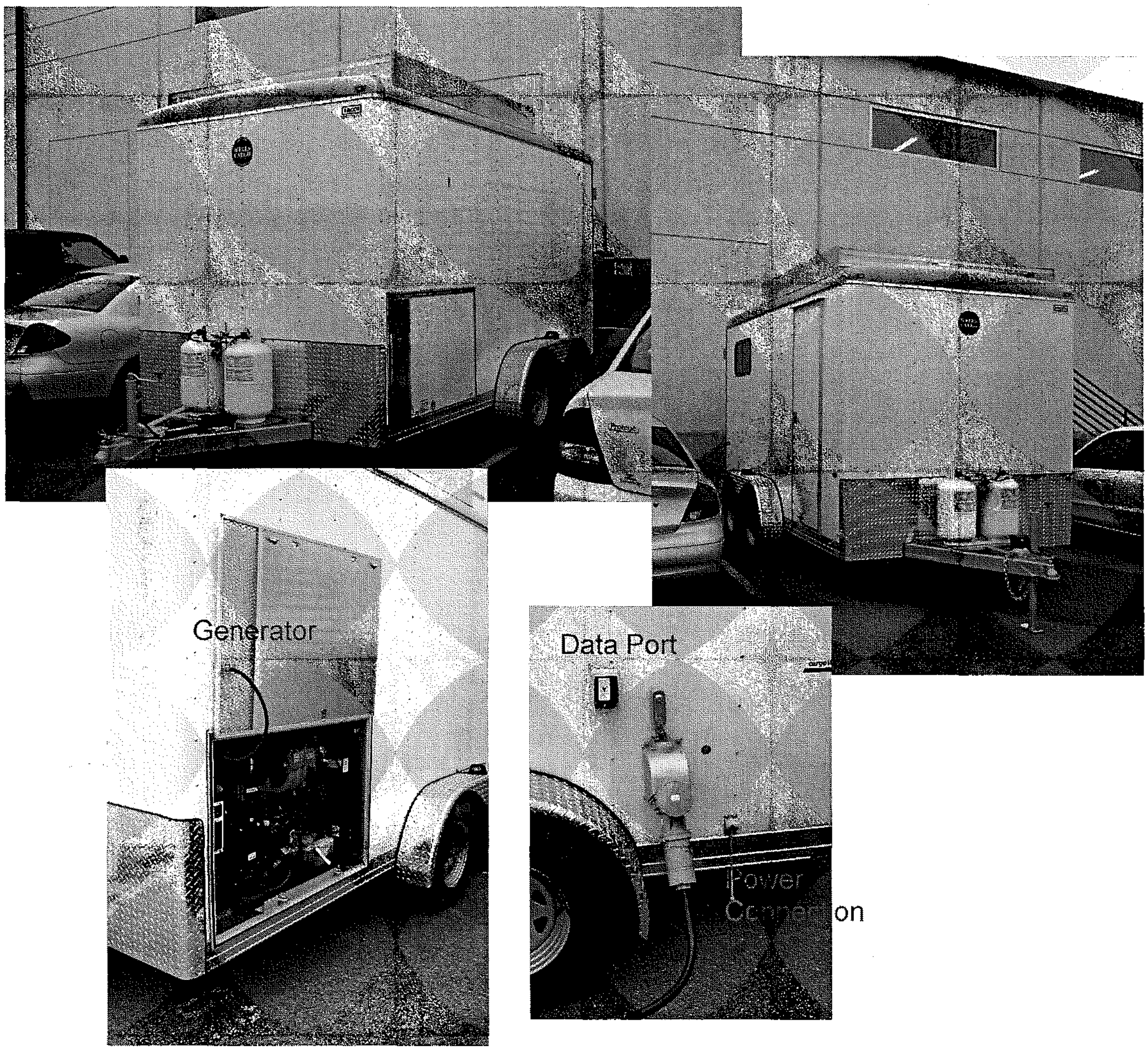
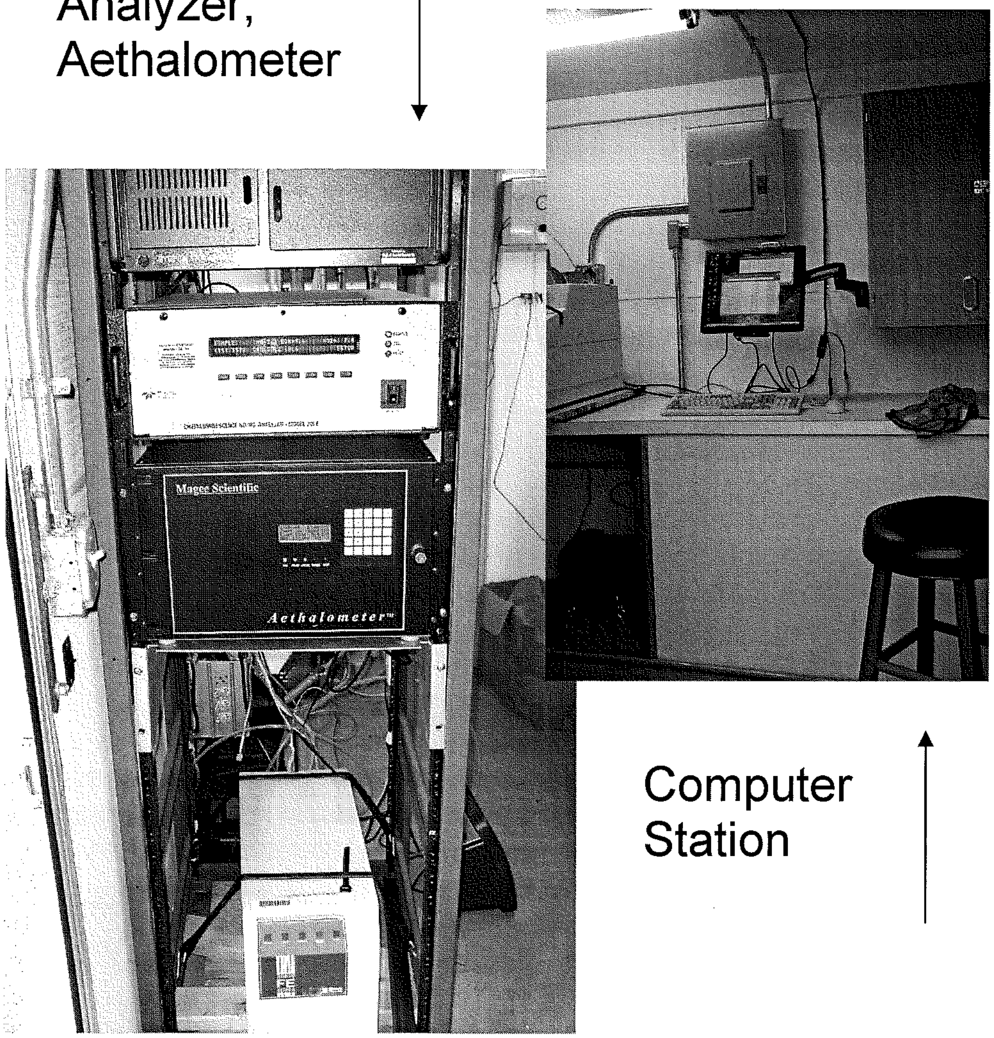


Figure 1e: Roadway trailer has a 10 KW electrical generator power by propane stored in two gas tanks. When parked, the trailer is plugged into a 50 A 220 VAC outlet. Also shown is a data port for telephone and data communications.

Instrument Rack
From top,
computer, NOx
Analyzer,
Aethalometer



Computer
Station

Figure 1f: The data computer and analyzers are mounted in an electrical rack. At the bottom of the rack is an uninterruptable power source. A computer station is located across from the rack on the workbench.

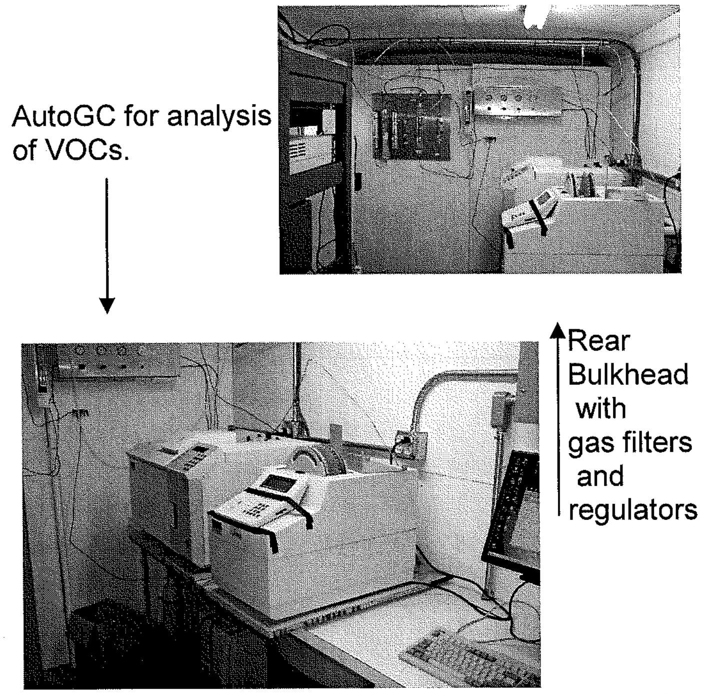


Figure 1g: The Roadway Trailer's AutoGC system is mounted on the workbench. Support gases and pumps are located behind the bulkhead wall.

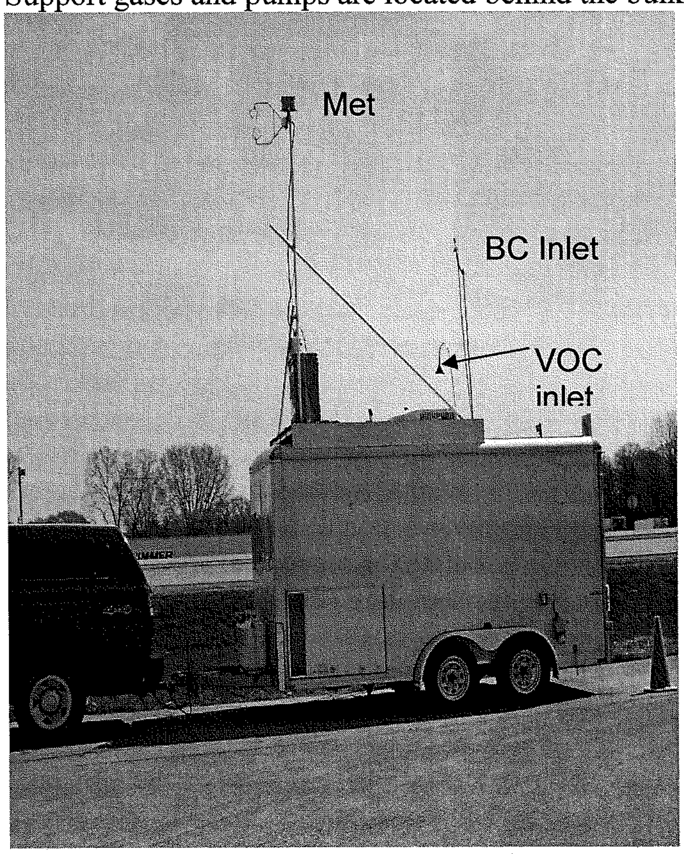


Figure 1h: Trailer set up for a field study. The meteorological sensor package, black carbon inlet and the VOC inlet are show in the photograph.

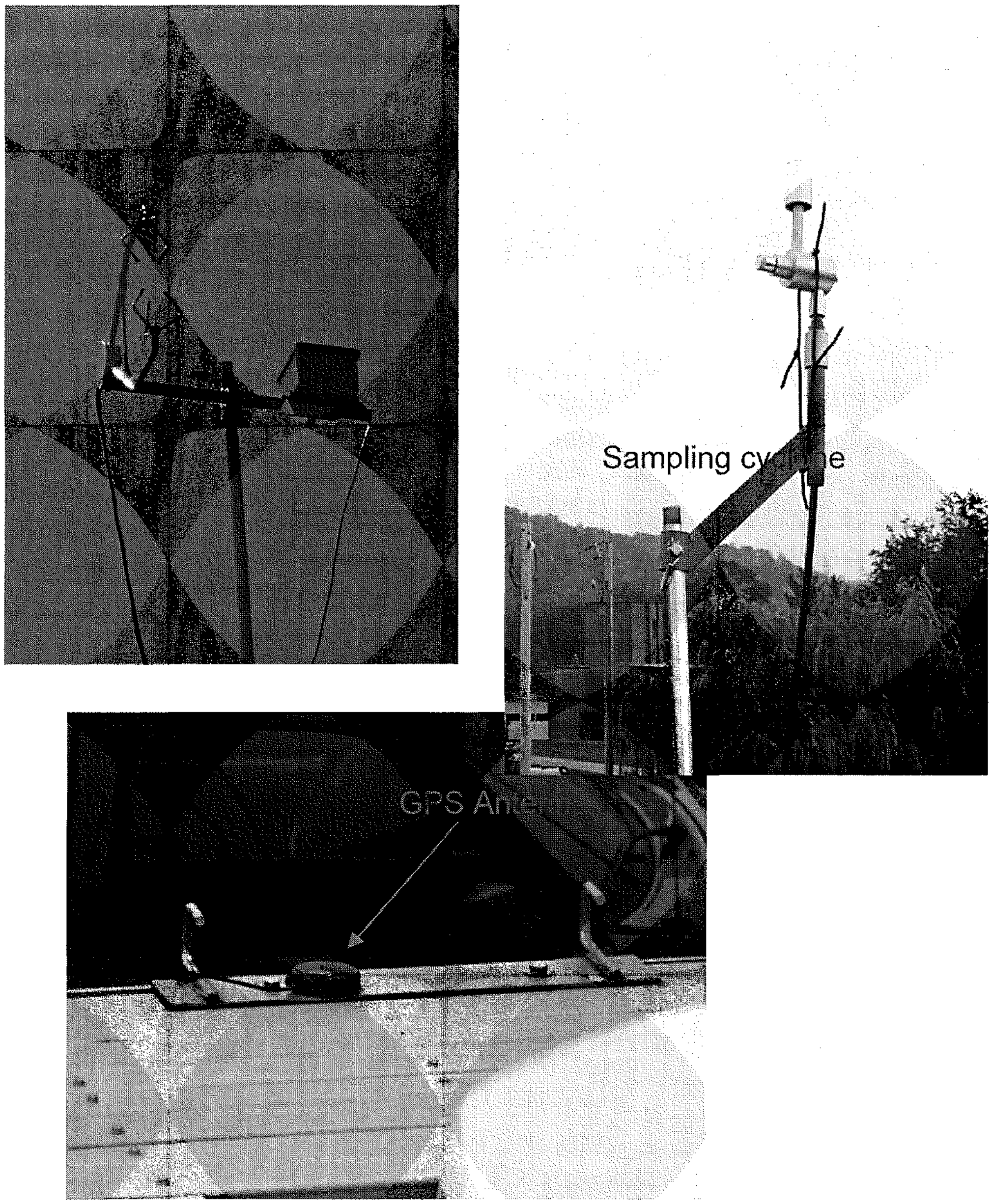


Figure 1i: Roadway Trailer auxiliary monitoring parameters include a sonic three dimensional wind sensor, an electronic compass to orientate the sensors, a GPS antenna. The aethalometer inlet uses a size selective cyclone for sampling PM2.5.

Monitoring Studies:
Monitoring studies using the RW trailer are listed in Table 1. Copies of available reports are attached as Appendix A to this report.

Table 1: RW Trailer Monitoring Studies

Dates	Description	Summary
June 2009 – August 2009	PAMS Intensive	Three month intensive study in Milwaukee. The study included hourly VOC measurements using the trailer AutoGC system. Because of the problems with the AutoGC much of the VOC data remains unreviewed.
11-19-2009 to 12/03/2009	Fall 2009 Roadway Studies	Studies included three separate days of monitoring conducted at two sites along Madison's "Beltline" expressway. Monitoring for a total of 20 hours was report. Parameters included BTEX and black carbon.
4/14/2010 to 4/28/2010	Spring 2010 Roadway Studies	Monitoring studies were conducted at two locations along Interstate Highway 39 running directly to the east of Madison. Each location was monitored on two separate days for a total of four monitoring excursions.
09/22/2010	Cassville Aethalometer Check	A single days monitoring at the Cassville site to directly compare the Cassville aethalometer with the RW trailer's aethalometer as a Quality Assurance check.
11/02/2011 to 12/08/2010	Fall 2010 Roadway Studies	Seven monitoring studies were conducted along three types of high volume roadways. No VOC measurements were made, but black carbon, nitric oxide and nitrogen dioxide were measured.
01/06/2011 to 01/18/2010	Biomass Study Aethalometer Check	A multiday study to compare two aethalometers used in Wisconsin air monitoring studies. The study looked at the bias between the analyzer and factors affecting that bias.

Budget:

Table 2 show the original line item budget provided by Wisconsin and the most update reporting on the project expenditure.

Table 2: Original Line Item Budget with Estimated Expenditures			
Line	Original Budget	June 2010 Extension	Final Expenditure
a. Personnel	$26,806	No Change	$29,186
b. Fringe Benefits	$9,228	No Change	$11,684
c. Contractual Costs	$12,999	No Change	$0
d. Travel	$808	No Change	$148
e. Equipment	$48,000	No Change	$51,771
f. Supplies	$10,900	No Change	$11,948
g. Other	$3,070	No Change	$3,641
h. Total Direct Costs	$111,811	No Change	$108,378
i. Total Indirect Costs: must include documentation of accepted indirect rate	$4,119	No Change	$4,119
j. **Total Cost**	**$115,930**	No Change	**$112,497**

Overall the Wisconsin DNR has stayed within the funds granted for the project. Fund budgeted on the contractual line were not used. The original project plan had call for contracting to have the AutoGC system serviced and for support of the AutoGC measurements. When the AutoGC failed these plans were dropped. Some of the unused funds went into labor and supplies in attempts for fix the AutoGC system. Funds were also used to support other areas of the project, including the purchase of an oxides of nitrogen analyzer to more thoroughly assess vehicular roadway emissions in real-time. The purchase of the oxides of nitrogen analyzer was approved by the Region 5 EPA. Several other lines of the budget were also greater than originally planned. Salary costs were increased because staff shortages required that an employee at a higher pay range complete some of the project work. Equipment and supplies costs increased with the addition of the oxides of nitrogen analyzer.

Conclusion and Continuing Operations

Trailer Operation

The utility trailer platform used for the mobile laboratory operated above expectation. The trailer proved easy to tow and to position for the monitoring operations. The trailer provided adequate space for the analytical systems and for the operator to work. Set-up of the sampling inlet probes was straight forward. The set-up of the meteorological sensor mast with the electronic compass to assist in positioning worked above expectations.

The electrical power system performed well, several problems were noted and some of these were addressed and minimized during operations. The on-board generator functioned very well and met expectation. There was sufficient power for all operations. Gas cylinders were weighted before and after being refilled. Data from these weights suggest that on average the generator us approximately 1.8 kg/ hour of operation. Predictions based on the cylinder size of 30 pounds (13.6 kg) estimated the generator could operate for 12 hours using 80% of fuel with a 20% reserve. This prediction was confirmed during the September 2010 Cassville monitoring study when the generator operated continuously for over 13 hours. The power transitions from shoreline to generator power were accomplished above expectations. The trailers analytical systems are either microprocessor or computer controlled and there were concerns that the microprocessor\computer controls would reset during the power transfers. A reset would necessitate reinitializing the analyses. The power transitions for shore line power to generator power work above expectation. All systems made the transition without incidents or problem. This is important because it allowed systems to be operating and in calibration mode during the transition as the trailer is prepared for operation. The back transition from generator to shore power also went well. The single exception during this transition was the AutoGC's Automatic Thermal Desorber which failed during the transition and had to be recycled (off - on) to reset.

One problem requiring a special note is the generator fuel line freeze-up. The large generator consumes the fuel quickly allowing the unused gas to expand in volume. The expansion is endothermic and results in cooling the gas tanks. During a number of operations, the operator noted the buildup of an ice layer on the exterior tanks walls. The freeze-up problem did, at some times, result in the generator being starved of fuel resulting in a shut down. When the generator shuts down, the resulted in a loss of power causes all analytical systems to shut down, requiring a restart. The propane tanks are fed through an automatic valve that should switch from an empty to full fuel tank. This did not happen when freeze-up occurred. To minimize the freeze-up problem the operator is advised to periodically (approximately each hour) flipped the supply tank to prevent excessive freeze-up. While this tanks switching minimizes the freeze-up problem, the problem did continue and cause a premature ending of the last roadway monitoring study (12/08/2010).

One related problem that has not yet been solved is the Uninterruptable Power Supply (UPS) failure. In theory, the UPS will condition the electrical line power and provide brief back up power. The UPS unit failed to accept the power supplied by the generator and switched to its back-up function, which quickly failed. An attempt was made to adjust the UPS to accept generator power, but this failed to correct the problem. This remains a problem to be addressed in future operations of the trailer.

Monitoring Analyzers:

<u>Ozone Precursor Analytical system</u>
The Ozone Precursor Analytical system, also called the AutoGC, was purchased from the Perkin-Elmer company in May 1998. The system was used from summer 1999 to summer 2009 for continuous monitoring of ozone precursors in Milwaukee. The analytical system was also used for the analysis of passive samplers in the Milwaukee Roadway Study 2006-2007 and Waupaca Benzene Study 2008. In spring 2009 the system was moved into RW trailer, a mobile laboratory trailer, to be used for near Roadway studies. The system operated in the trailer for the PAMS 2009 season and for roadways studies in fall 2009 and spring 2010

In the fall 2009 roadway studies, the AutoGC functioned well throughout the first two test days while the third day's data was affected by a noisy detector. The overall operation of the AutoGC system went well and over the three test days and the system collected 20 hours of VOC data. The report noted the AutoGC system tolerated the transition from shore to generator power and the transition back. The only lose of data during these studies was related to power failures in the trailer.

The report on the spring 2010 roadway monitoring studies noted the AutoGC system functioned only marginally. Deteriorating performance of the system's detector was noticeable. The report noted the detector was particularly affected by noise.

The AutoGC system operated well for most of the PAMS seasons from 1999 to 2008. Detector noise problems began to occur in 2007 and one detector failed after the 2009 PAMS season. After the Spring 2010 Roadway Monitoring studies the analytical system was began experiencing cascading failures. The term "cascading" referred to the condition where as quickly as one problem can be fixed a new problem occurs that precludes the operation of the system. A summary of the system problems included.

- The Zero Air Source unit was not supplying the enough air for continuous operation. The system could be operated for short periods with cylinder air as back-up but it can not be used for continuous operations.
- The ATD Concentrator unit began experiencing repeated "Triac" failures. The failure appears to shift from one part of the unit to another part. With the unit reporting the Triac failures "front arm", "back arm", and "line". The shifting nature of this failure suggests the problems in not in the Triac but rather in some electronic supporting or monitoring the units Triac points. Several attempts to clear the error failed. These attempts included testing alternate boards supplied by IEPA.

- The gas chromatograph oven cooling fan stopped functioning. The fan itself operates and the problem appears to be in the fan control electronics. Without the cooling fan the system can not reset within the time frame necessary to make hourly measurements.
- The Flame Ionization Detector (FID) 1 appears to have an electrical short. The short results in the detector current reading as a negative voltage. The electronics interpret the negative voltage as an unlit detector and will not proceed unless the detector is turned off.
- FID 2 will operated but was experiencing both a loss of sensitivity and an increase in detector noise. In addition to the basic increase in noise, a second noise problem was noted to develop as a function of the time the system was operating. This second noise problem suggests an internal problem perhaps in the power supply, which may be heating during operation and the heating may have allowed the leakage of or creation of stray voltage.

The analytical system is over 10 years old. Perkins Elmer no longer supports this analytical system and there is no one to immediately call for repairs. Parts replacements for the system is unreliable, are based on existing Perkin Elmer supplies, and the company has no plans to provide parts when the supplies are exhausted. Despite consulting a number of manuals, including technical manuals for the system, staff were unable to make effective repairs. In September 2010, the Wisconsin DNR reported to EPA that it would no longer operate the AutoGC system.

Despite problems with the AutoGC analysis system this project did demonstrate the validity of the concept of including a VOC analyzer in a mobile laboratory. Volatile organic pollutants measurements will continue to be important. The Wisconsin DNR will continue to look for funding for a replacement analytical system. The Wisconsin DNR is currently looking at the SyntecSpectras GC955 Series 600 BTEX Analyzer as a possible replacement analyzer. The Syntec system is estimated to cost approximately $37,000.

Aethalometer

The Magee AE22 Aethalometer operated as expected during the all monitoring operations. Initially, the main concern with the Aethalometer is the treatment of the data and the effects of the site to site transitions. The Aethalometer appears to need a significant amount of time to stabilize after a shut down. Because of the analyzer's stabilization time, the WDNR operator tried several transition techniques during the initial shakedown studies. These techniques included allowing the analyzer to run while moving to the site and stopping the analyzer during the transition. Eventually it was decide to allow the analyzer to run while in route to the monitoring site. No data during the transition was reported in any study. A second concern with the Aethalometer is the lack of external standardization, which limits any verification of the analyzer's operations. The comparison studies run were one attempt to check individual analyzers against each other as means of assuring confidence in the analyzer's measurement. The only notable operation problem was that the aethalometer did experienced several filter tape problems, but all the problems were corrected without affecting any planned operations.

The value of the aethalometer measurements is shown in the data in Figure 2a and 2b. Figure 2a is a graph of measured black carbon plotted by the wind direction at the time of the measurement. Figure 2b show the modeled results of Roadway Diesel Cancer Risk for the area near the monitoring site. An empirical analysis suggests that the highest black carbon concentrations were measured along wind directions crossing the area of highest diesel risk. For a more quantitative comparison, the modeled concentration value at the receptor closest to the monitor is 0.42 micrograms per cubic meter. The Wisconsin DNR staff monitored at the Madison East Site for approximately 6 months (4261 hours or 0.49 year). Over that time period the average black carbon measured 0.57 ug/m3. The actual measured average concentration was 137% of the modeled concentration. This analysis supports the modeled risk information and confirms the value of the aethalometer in confirming modeling results.

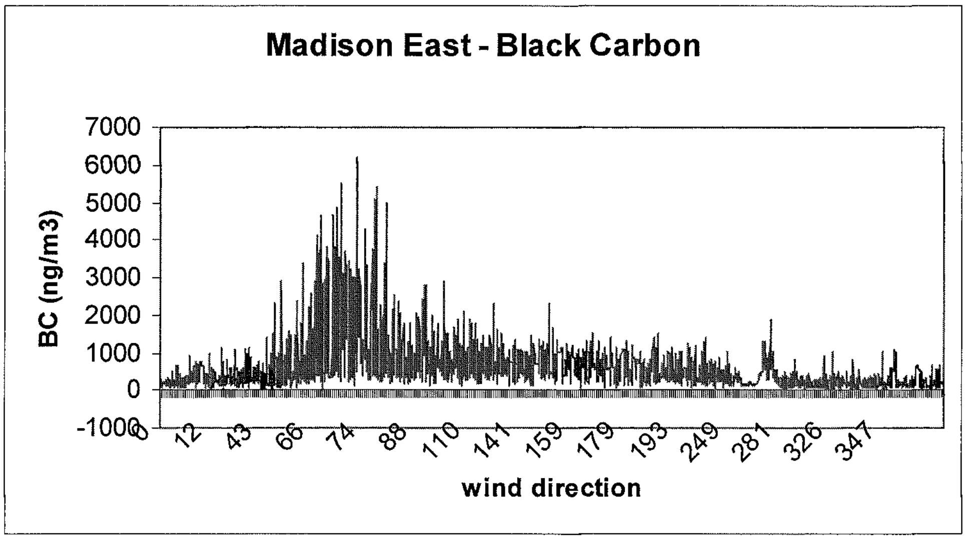


Figure 2a: Black carbon measurements plotted by wind direction.

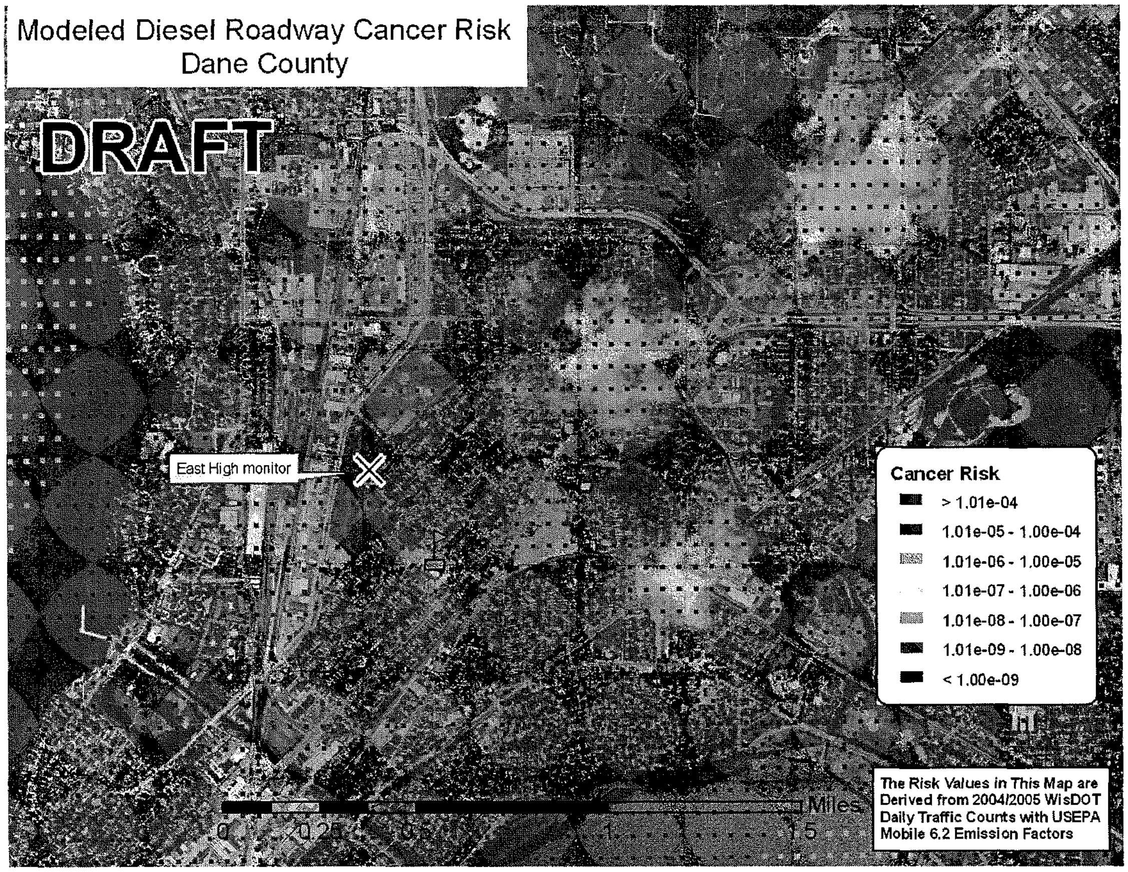


Figure 2b: Graphical results for risk modeling in the area near the Madison East High monitoring site.

<u>API 200E Oxides of Nitrogen Analyzer</u>

The API 200E was operated in a manner consistent with the manufactures instructions. Overall, the oxides of nitrogen analyzer operated as expected. There was a small amount of data lost, but this was due to generator failures and not to any problems with the analyzers. Multipoint verifications of the analyzer calibration were preformed before and after the studies.

Photochemical Assessment Monitoring Station (PAMS):

A major goal of this project was to move the PAMS operation from a permanent fixed site to a mobile laboratory. In past years, the PAMS monitoring equipment was used during the summer and then left idle during other times of the year. The project plan envisioned that the mobile laboratory would be operated from a fixed location during the summertime PAMS intensive studies. The laboratory could then be used at various locations at other times of the year.

The usefulness of the mobile laboratory was proved in concept, but the more practical use of the system remains to be seen. The major set back was the failure of the AutoGC analysis system. The AutoGC system was originally purchased by the Wisconsin DNR in 1998 and has been in used since the 1999 PAMS monitoring program. At the time, the Wisconsin DNR's proposal was submitted the system appeared to be operating as expected. The funding of the proposal was delayed and the system continued to age. From the time the system was installed in the trailer, to the time of failure was approximately one year.

Wisconsin is not alone in experiencing operational problems with the AutoGC system. A number of states have reported that aging AutoGC system are failing or have failed. LADCO has developed a proposal to replace the AutoGC system with less complex and less costly analyzers that measure Total VOCs or analyzers that measure BTEXs. Wisconsin has asked to be a test site for the proposed BTEX analyzers. If funding does become available for the BTEX analyzers Wisconsin will replace the AutoGC with the BTEX analyzer. Wisconsin would then resume the original project idea to use the RW trailer for summertime intensive PAMS monitoring.

Roadways:

The RW trailer has proven to be a useful tool for studying air quality near roadways. The trailer laboratory provides a platform to bring analyzers for VOC, black carbon, nitric oxide and nitrogen dioxide to the monitoring location near roadways of interest. The onboard generator and the trailer's environmental systems provide support for the measurement systems. The generator provided power at locations that could not be readily accessed with power drops. The mobile laboratory also allows sampling at locations where the Wisconsin DNR can get short term access for monitoring, but where permission for long term access is doubtful.

Roadways continue to be evaluated as major sources of criteria and air toxics. Modeling of roadways and risk assessments continue to show that roadways must be considered in plans to reduce exposure. EPA's recently revised NAAQS for nitrogen dioxide targeted roadways as one important source of the pollutant. Monitoring will be needed to support efforts to evaluate and address mobile source pollutants. The three series of roadway studies and the two other studies have demonstrated the usefulness of the mobile laboratory.

Staffing:

This project could not have been completed without the Wisconsin DNR's dedicated staff. The monitoring section's engineering staff provided important advice in planning the RW trailer laboratory. Shop staff configured the trailer for use as a laboratory and installed monitoring equipment.

The mobile laboratory proved to be very efficient and typically could be towed into place and set up for studies by a single staff member. A decreasing number of staff did slow the project and it was necessary to extend the project to complete all the work originally planned.

Future operations of the mobile monitoring trailer will rely on having sufficient numbers of trained staff. The current climate for the state and federal budgets will limit funding to hire and train staff. This may well limit the use of the trailer in the future.

Appendices

Appendix A: Monitoring Reports

Appendix B: Detailed Project Timeline

Appendix C: QAPP

Appendix D: Equipment SOPs

Roadway Trailer Final Report

Appendix A: Monitoring Reports

DATE: Monday, January 25, 2010 FILE REF: AT2010

TO: Bart Sponseller – AM/7

FROM: Mark K. Allen – AM/7

SUBJECT: Shakedown Tests of Roadway Trailer

The Roadway Monitoring and PAMS trailer, hereafter RWM\PAMS trailer, was developed in the spring of 2009. The trailer was purchased and delivered to the Wisconsin DNR in early 2009. After delivery the trailer was transferred to a contractor for installation of the electrical generator system. In April and May, the trailer was configured into a laboratory and the analytical systems were installed. In the summer of 2009 the trailer was stationed at the Wisconsin DNR's Milwaukee Headquarter building. The RWM/PAMS trailer was used for PAMS measurements during the summer of 2009. The PAMS season ended in September 2009 and I had planned to do some initial tests of roadway monitoring in Milwaukee. However, at the end of the PAMS monitoring season the trailer's analytical systems had several problems that precluded immediate use for roadway work. The trailer was therefore returned to Madison for additional repair work on the analytical systems.

Status of the AutoGC Analytical System Prior to the Initial Roadway Studies:
At the end of the PAMS monitoring season, the AutoGC system has several operational problems. The first problem is a failure of one of two FIDs used to detect compounds. This problem could not be corrected, but because roadway work focuses on higher molecular weight compounds I decided to operate the AutoGC in a signal column mode using the DP-1 column as the analytical column. Operating in this mode allows the analysis of target compounds from C6 to C12. The second problem was the deteriorating condition of the system's zero air source. The air source appears to be leaking air and this failure has resulted in an increase demand on the system's air compressors. The demand on the compressors resulted in the failure of both the primary compressor and a back-up compressor. The AutoGC system when operating in a continuous mode requires large volumes of zero air. While the compressor is required for continuous operation, the system can be operated for short times using the back-up cylinder of zero air. For shakedown tests, I elected to operate using only zero air supplied by gas cylinders.

In summary for the shakedown tests of the RWM\PAMS trailer the AutoGC was operated in a single column mode using a cylinder supplied zero air.

The shakedown tests were conducted in Madison in late November and early December. A total of three test runs were made. Testing ended for the year after the first significant snowfall occurred and it was felt that moving the trailer after the snow fall would be difficult. The purpose of this report is to document the results of the shakedown runs and assess needs for future work with the RWM\PAMS trailer.

Test location:

The primary test location was the Madison's south commuter expressway, referred to locally as the "Beltline". Specific locations and details of the monitoring operations used for the study are listed in Table 1:

Table 1: Location and Time Data for the Shakedown Roadway Tests.						
Date	Location	Start Time	End Time	Elevation (ft)	Lat	Long
11/19/2009	Beltline North side - WDR Parking lot	7:00	15:40	859	43.02518	89.22498
11/23/2009	Beltline North side - WDR Parking lot	15:30	20:30	858	43.02517	89.2251
12/03/2009	Beltline Southside - Between Fish Hatchery & Park Street	6:00	13:40	875	43.02049	89.2409

Testing protocols:
Test runs typically followed a set protocol including the follow elements. Prior to leaving SCIOPS a test standard was started on the AutoGC. The on-board electrical generator was started and when running the power was transferred from the shoreline to the generator. All outside sampling probes were removed. The trailer was hitched to the tow vehicle and after a safety check the trailer was towed to the test locations. Because the test sites were close to SCIOPS travel was less than 30 minutes. At the test site, the sampling probes were quickly set-up. On site sampling was started at the start of the hour. Secondary analysis systems like the anemometer were set-up after the AutoGC and Aethalometer were started.

During the testing, the operator monitored all analytical systems and the trailer support systems. The operator periodically made manual traffic counts to assess the amount of vehicular traffic.

At the conclusion of the test run the operator would start a test standard on the AutoGC. Outside sampling probes were removed and stored. A safety check was made of the trailer and the trailer was then towed back to SCIOPS and parked. The trailer power was transferred back from the electrical generator to the shoreline power. When all systems were back on shoreline power the generator was turned off. The operator then reviewed all data to insure records were complete and completed the trip log. Analytical systems were turned off.

Results:
Chromatographic data was captured and processed by TotalChrom software. Data was then exported to a ACCESS database as hourly data. Aetholometer data was capture by the Tekran capture software and stored on the main computer as 5 minute increments. The data was exported to an ACCESS data base and five minute measurements were combined to an hourly average. The hourly average was taken from reading report at 5 minute after the hour until the reading from the next hour. While most readings are positive the manufacturer of the Aethalometer reports that negative values may occur. The manufacturer recommend including the negative values to arrive at a true hourly average.

No direct meteorological measurements were made from the trailer due to problems described later in this report. Wind speed and wind direction data reported are taken from the Wisconsin DNR's monitoring site at East High School (55-027-0041).

Analytical results for the AutoGC (BETXs), Aethalometer (black carbon) and wind speed/wind direction system are summarized as hourly values in Data Tables 1, 2, and 3 at the end of this report.

Manual traffic counts were also made periodically as time permitted. The traffic count was made by counting the cars passing a point, here a sign post, during a fixed time period. Counts are reported on the data tables under the hour in which the count was made. Counts are reported for both the West Bound(WB) and East Bound (EB) lanes. I would generally say that traffic was moving well on all days when monitoring was down. The count therefore is an accurate reflection of volume.

Equipment performance during Shakedown

The utility trailer platform used for the mobile laboratory operated as expected. The trailer proved easy to tow and to position for the monitoring operations. Set-up of the sampling probes and the meteorological sensor mast worked as expected.

Electrical power system performed well, but several problems were noted and these should be addressed in future operations. The on the on-board generator functioned very well and met expectation. There was sufficient power for all operations. Gas cylinders were weighted before and after being refill. Data from these weights suggest that on average the generator us approximately 1.8 kg/ hour of operation. Based on cylinder size of 30 pounds (13.6 kg) I believe that we could operate on generator power for 12 hours using 80% of fuel with a 20% reserve. The power transitions from shore to generator power were accomplished above expectations. The trailers analytical systems are either microprocessor or computer controlled and I had concerns the microprocessor\computer controls would reset during the power transfers. A reset would necessitate reinitializing the analyses. The power transitions for shore line power to generator power work above expectation. All systems made the transition without incidents or problem. This means that system can be operating and in calibration mode during the transition as the trailer is prepared for operation. The back transition from generator to shore power also went well. The single exception during this transition was the ATD which failed during the transition and had to be recycled (off - on) to reset. The operator is therefore advised to be sure all ATD operations are completed before making the generator to shoreline power transition. One problem I noted with the generator was fuel line freeze-up. The large generator consumes the fuel quickly allowing the unused gas to expand in volume. The expansion is endothermic cooling the gas tanks. During operations, I noted the buildup of an ice layer on the exterior tanks walls. The freeze-up problem can results in the generator being starved of fuel resulting in a shut down. I experience this shutdown once while operating at SCIOPS and a second time near the end of the 11/23 sampling run. The generator shutdown, this resulted in a loss of power and all analytical systems had to be restarted. The tanks are fed through an automatic valve that should switch from an empty fuel tank to a full tanks. This did not happen when freeze-up occurred. While operating, I periodical (approximately each hour) flipped the supply tank to prevent excessive freeze-up. A final problem was the UPS failure. The UPS failed to function when the trailer was operating on generator power.

Analytical systems

The AutoGC functioned well throughout the first two test days while the third day's data was affected by a noisy detector. The overall operation of the AutoGC system went well and over the three test days I collected 20 hours of VOC data. The AutoGC system tolerated the transition from shore to generator power and the transition back. Sampling during first day included the collection of 6 hours, one partial hour of data plus a Retention Time standard. During the 07:00 hour of collection the datalogger and computer went down when the UPS battery failed. The datalogger and computer were restarted and a part of the missing data was recovered manually. During the second day I collected 5 hours of data. Near the end of the work day the generator stopped due to a fuel line freeze-up. The analytical systems were reset and I ran the system span gas after the restart. The third sampling day I collected 8 hours of data. The system operated well but I did note increasing noise in the detector.

The Aetholometer had experienced a tape problem prior to the start of the shakedown runs, but the problem was corrected without affecting any planned operations. The Aetholometer operated as expected during the shakedown run. The main concern with the Aetholmeter is the treatment of the data and the effects of the site to site transitions. I tried several transition techniques during the shakedown include allowing the analyzer to run while moving to the site and stopping the analyzer during the transition. There was a great deal of variation in the data during the initial transition runs and I am unable to explain what technique will work best for the transitions.

The third analytical system is the 3 dimensional anemometer designed to collect a complex data array of the wind profile during sampling. Unfortunately the anemometer was not operational during the shakedown. The system was set-up during the first sampling day but when the data was examined it was found that the system had recorded no useable data. The investigation of the system later found the data communication lines severed in one of the connectors. The cable was fixed but not in time for this study. The deployment of the sensor and sensor mast was useful because it confirmed the need for a positioning sensor to assist in aligning the CSAT sensor. Manual alignment of the CSAT on the trailer is very difficult and alignment questionable.

Recommendations:

The shakedown monitoring runs conducted with the RWM\PAMS trailer have shown the utility of the mobile laboratory for measuring air quality near roadways. The recommendations provided should help improve the operation of the trailer for future monitoring projects.

- Adjust the UPS unit to have it accept power supplied by the generator. If adjustments are not possible replace the UPS.

- Correct current operating problems with the AutoGC system. Purchase a new zero air source and return both FIDs to operations.
- Determine and implement a standard procedure for the Aethalometer to provide reliable data when the trailer is moved.
- Improve operation of the on-board meteorological monitoring system

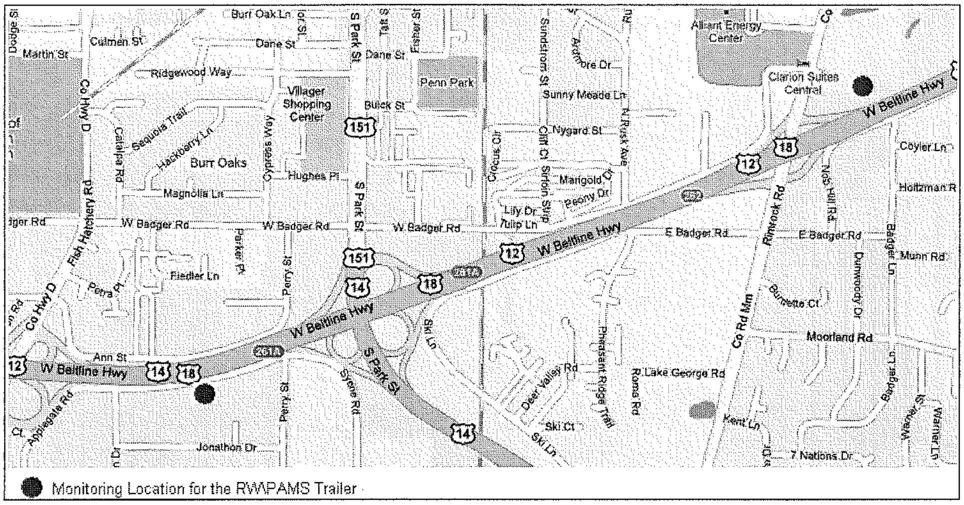
I am currently working to implement all of these recommendations.

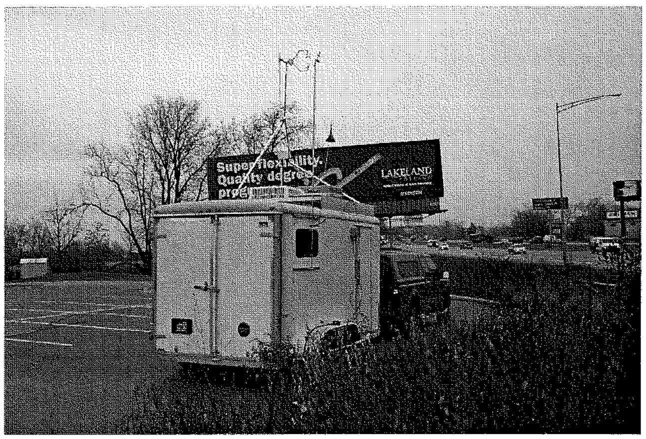
Data Table 1: Roadway Monitoring Summary for 11/19/2009							
	Sampling Hour						
Parameter Name	0700	0800	0900	1000	1100	1200	1300
Benzene (ppbV)	2.930	2.305	2.177	2.021	2.604	2.266	2.668
Ethylbenzene (ppbV)		0.965	0.835	1.174	0.844	0.659	0.803
Toluene (ppbV)	7.713	5.806	4.68	6.459	5.317	4.222	3.561
M/P-Xylene (ppbV)		2.701	2.216	3.098	1.852	1.745	1.517
O-Xylene (ppbV)		1.034	1.172	1.371	0.467	0.985	2.721
Wind Direct (deg)	70	69	81	130	111	281	278
Wind Speed (mph)	1.4	1	3.3	3.8	3.8	4.5	5.6
Black Carbon (ng/m3)	1426	1117	957	1200	887	614	-9644
WB (vehicles/min)			62	53	55	55	50
EB (vehicles/min)			57	48	55	65	60

Data Table 2: Roadway Monitoring Summary for 11/23/2009						
	Sampling Hour					
Parameter Name	1500	1600	1700	1800	1900	2000
Benzene (ppbV)	1.801	3.177	2.669	1.377	1.862	------ (*)
Ethylbenzene (ppbV)	1.051	0.779	0.729	0.561	0.393	------
Toluene (ppbV)	5.261	5.339	4.034	3.603	3.097	------
M/P-Xylene (ppbV)	1.938	2.67	1.949	1.067	0.876	------
O-Xylene (ppbV)	0.721	0.889	1.746	0.501	0.398	------
Wind Direct (deg)	91	90	97	89	97	99
Wind Speed (mph)	3.4	3.5	3.6	3.5	4.2	3.6
Black Carbon (ng/m3)	566	329	547	521	170	278
WB (vehicles/min)		81	62	38		
EB (vehicles/min)		100	85	50		
(*) – VOC data was lost when generator stopped. System restarted and a close-out standard was run.						

Data Table3: Roadway Monitoring Summary for 12/03/2009								
Parameter Name	Sampling Hour							
	0600	0700	0800	0900	1000	1100	1200	1300
Benzene (ppbV)	1.434	1.634	2.183	1.623	1.34	1.013	1.345	Noise
Ethylbenzene (ppbV)	0.915	0.636	0.544	0.552	0.822	0.463	1.021	1.473
Toluene (ppbV)	1.926	2.405	2.384	2.369	2.054	2.238	3.806	3.489
M/P-Xylene (ppbV)	1.566	1.49	1.513	1.752	1.163	1.625	2.279	4.379
O-Xylene (ppbV)	0.56	0.573	0.427	0.564	0.776	0.477	0.781	1.029
Wind Direct (deg)	346	327	343	342	344	350	358	354
Wind Speed (mph)	5.8	7.4	6.7	6.5	6.5	6.9	5.3	5.6
Black Carbon (ng/m3)	-243	350	589	454	492	628	620	-2148
WB (vehicles/min)	42	91	102	62	49			
EB (vehicles/min)	29	72	76	55	48			

Appendix 1: Map of monitoring sites





Trailer north side of Beltline in Wisconsin Department of Revenue parking lot.

Trailer south side of Beltline in between Park Street and Fish Hatchery Road.

DATE: Wednesday, August 25, 2010 FILE REF: AT2010

TO: Bart Sponseller – AM/7

FROM: Mark K. Allen – AM/7

SUBJECT: Spring 2010 Roadway Monitoring near Madison, WI.

The Roadway Monitoring and PAMS trailer, hereafter RWM\PAMS trailer, was developed in the spring of 2009 for use in a Wisconsin Community Assessment Monitoring program. The trailer was developed as a mobile laboratory that could be used for both long and short term air monitoring projects. The PWM\PAMS trailer was used for PAMS monitoring in the summer of 2009 and in the fall of 2009 for several days of air monitoring. The test location for the fall studies was the Madison's south commuter expressway, referred to locally as the "Beltline". The results of the fall roadway studies were reported in January 2010.

Status of the Trailer's Analytical Systems Prior to the Spring Roadway Studies:
In my report detailing fall 2009 roadway testing I noted on the AutoGC system the failure of one of two FIDs used to detect compounds. This problem could not be corrected and continued in the spring 2010 monitoring work. Because roadway work focuses on higher molecular weight compounds, I decided to continue to operate the AutoGC in a signal column mode using the DP-1 column as the analytical column. Operating in this mode allows the analysis of target compounds from C6 to C12. A second problem was the deteriorating condition of the system's zero air source, also continued from the fall. The air source appears to be leaking air and this failure has resulted in an increase demand on the system's air compressors. The demand on the compressors resulted in the failure of both the primary compressor and a back-up compressor. The AutoGC system when operating in a continuous mode requires large volumes of zero air. While the compressor is required for continuous operation, the system can be operated for short times using the back-up cylinder of zero air. Operating in the same manner used for the fall monitoring work, I elected in the spring studies to operate using zero air supplied by gas cylinders. I will note that a new zero air source was installed after these tests and that that system has functioned well.

In summary for the spring studies like the fall shakedown tests of the RWM\PAMS trailer the AutoGC was operated in a single column mode using a cylinder supplied zero air.

During the fall 2009 test the meteorological sensors where not operating due to broken cables. This problem was corrected and the spring monitoring included on site measurements of wind speed and wind direction. The monitoring system used was a Campbell CSAT sonic anemometer. The CSAT system measure wind speed and wind direction in three orthogonal directions. The data is reported as vector in the x, y, and z direction. To align the CSAT system the sensor is mount to a cross beam in a parallel arrangement to an OceanServer electronic compass. At the monitoring location, the meteorological tower is raised and the position of the sensor adjusted until the compass is aligned north within 4 degrees and the sensor pitch and yawl are within 2 degrees of zero (horizontal). Data processing is described in the results section.

One final analytical device added to the trailer was a GPS antenna. This antenna can be queried by the trailer computer using the HyperTerminal software.

Test location:
Specific locations and details of the spring 2010 monitoring operations used for the study are listed in Table 1:

Table 1: Location and Time Data for the Spring 2010 Roadway Tests.

Date	Location	Start Time (CST)	End Time (CST)	Elevation (m)	Lat	Long
04/14/2010	Madison, WI - NE side of city, at NW corner of I90/94/39 and Highway 51 Exit. Near dead end of Metro Road in town of Burke North of abandon truck stop at 6155 Highway 51.	06:00	17:00	268	43 07.256	89 18.819
04/20/2010	Madison, WI – At west side of Badger interchange. Between N & S bound lanes of I39/90/94. In WDOT/Dane County Highway Service Area with access from County T.	06:00	16:45	310	4306.633	8917.117
04/27/2010	Madison, WI – At west side of Badger interchange. Between N & S bound lanes of I39/90/94. In WDOT/Dane County Highway Service Area with access from County T.	06:30	17:00	315	4306.641	8917.121
04/28/2010	Madison, WI - NE side of city, at NW corner of I90/94/39 and Highway 51 Exit. Near dead end of Metro Road in town of Burke North of abandon truck stop at 6155 Highway 51.	09:00	17:00	266	4311.103	8919.475

Testing protocols:

Test runs typically followed a set protocol including the follow elements. The trailer base station for these studies was the Wisconsin DNR's Science and Operations Center (SCIOPS) located on the southeast side of Madison. Prior to leaving SCIOPS a test standard was started on the AutoGC. The on-board electrical generator was started and when running the power was transferred from the shoreline to the generator. All outside sampling probes were removed. The trailer was hitched to the tow vehicle and after a safety check the trailer was towed to the test locations. Because the test sites were close to SCIOPS travel was less than 30 minutes. At the test site, the sampling probes were quickly set-up. On site sampling was started at the top of the hour. Secondary analysis systems like the anemometer were set-up after the AutoGC was started.

During the testing, the operator monitored all analytical systems and the trailer support systems. Manual traffic counts taken in the fall 2009 monitoring were replaced with WDOT reports from sensor in roadway.

At the conclusion of the test run the operator would start a test standard on the AutoGC. Outside sampling probes were removed and stored. A safety check was made of the trailer and the trailer was then towed back to SCIOPS and parked. The trailer power was transferred back from the electrical generator to the shoreline power. When all systems were back on shoreline power the generator was turned off. The operator then reviewed all data to insure records were complete and completed the trip log. Analytical systems were turned off.

Results:

Chromatographic data was captured and processed by TotalChrom software. Data was then exported to an ACCESS database as hourly data. Aetholometer data was capture by the Tekran capture software and stored on the main computer as 5 minute increments. The data was exported to an ACCESS data base and five minute measurements were combined to an hourly average. The hourly average was taken from reading report at 5 minute after the hour until the reading from the next hour. While most readings are positive the manufacturer of the Aethalometer reports that negative values may occur. The manufacturer recommend including the negative values to arrive at a true hourly average.

Meteorological measurements were made using a Campbell CSAT sonic anemometer and are logged on a Campbell data logger. The CSAT's primary use is to measure the turbulent fluctuations of horizontal and vertical wind. Three dimensional wind measurements made using the CSAT are collected as three orthogonal vectors Ux, Uy, and Uz. Where Ux is the north south axis of the horizontal wind, Uy is the east west axis, and Uz is the axis transectioning the horizontal plane.

Vector data is converted to spherical coordinates of *Rho* (speed), *Theta* (azimuth), and *Chi* (elevation). A diagram of the spherical coordinates is shown in Figure 1. Conventions for the three vectors are given in Table 2.

Table 2: Conventions for Orthogonal Wind Vectors
Ux >0 when wind originates from the north and <0 when wind originates from the south.
Uy >0 when wind originates from the west and <0 when wind originates from the east.
Uz>0 when wind originates from the above and <0 when wind originates from the below

Wind is conventionally measured as speed and direction. Wind direction is defined by a compass circle placed on a horizontal plane. Winds measured in three directions are reported as speed and two spherically define coordinates. The speed is designated as *Rho*, and is reported in meters/second. The azimuth or *Theta* angle is the conventional planar circle. The elevation or *Chi* is the angle of the wind from the horizontal plane. Conventions for naming wind use the direction of travel. Thus a two dimensional wind of 45 degree is designated a "northeast wind". The *Theta* angle for the wind is treated similarly. The *Chi* angle also is name by the direction of travel. A *Chi* of >90 degrees is said to be a downward wind and a wind of <90 degrees is said to be an upward wind.

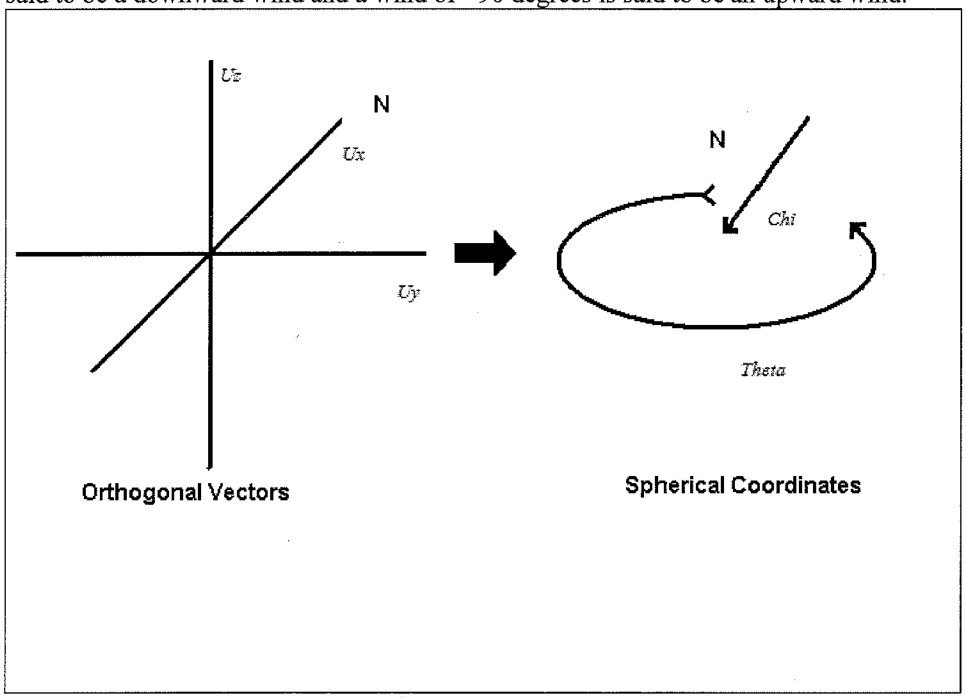


Figure 1. The transformation of orthogonal coordinates to spherical coordinates.

Analytical results for the AutoGC (BETXs), Aethalometer (black carbon) and wind speed/wind direction system are summarized as hourly values in Data Tables 3 through 6 at the end of this report.

Manual traffic counts were replaced with data from the Wisconsin DOT roadway sensors. The WDOT provided reports of hourly traffic data organized by week. Hourly data used is reported as positive, negative and total. WDOT conventions for report data are NB/EB are positive and SB/WB are negative. When multiple highways fall on the same route the lowest number and highest classification wins. For the spring studies the reference highway is Interstate 39. North and west bound traffic is reported as positive. South and east bound traffic is reported as negative. The two sites for data provided by the WDOT are Site 130259, located on Interstate 39/90/94 North OF Highway 51 at Hoepker Rd, and Site 130004 located on Interstate 39/90/94 south of the Badger interchange at CTH BB (Cottage Grove Road).

Equipment performance during studies

The utility trailer platform used for the mobile laboratory operated as expected. The trailer proved easy to tow and to position for the monitoring operations. Set-up of the sampling probes and the meteorological sensor mast worked as expected. The electronic compass proved very useful in getting an optimum alignment of the CSAT meteorological sensor.

Electrical power systems performed well and the on the on-board generator functioned very well and met expectation. There was sufficient power for all operations. Gas cylinders were weighted before and after being refill. Data from these cylinder weights measured in the fall 2009 study suggested that I could operate on generator power for up to 12 hours using 80% of fuel with a 20% reserve. I did operate for longer periods during the spring study proving there was sufficient fuel supplied by the two cylinders. During the fall 2009 studies I reported generator fuel line freeze-up. While I noted some ice build up on the gas cylinder the amount was never sufficient to block the fuel line and stop the generator. While I thought the problem with the trailers UPS was corrected this was not the case and the again UPS failed to function when the trailer was operating on generator power. Monitoring systems were therefore plugged directly into the trailer power for the monitoring operations.

Analytical systems

The AutoGC functioned only marginally. Deteriorating performance of the system's detector was noticeable. The detector was particularly affected by noise. The noise presented a challenge and all data was reviewed and where necessary the peaks were manually integrated to get the best possible estimate of the ambient concentrations. I have presented the VOC data I have but also caution the user that all data collected in the four measurements is suspect. I believe that I will need to optimize the system as best possible for it to be of any use in future studies.

The Aetholometer had functioned very well through out the studies. Based on experience gained in the fall 2009 I allowed the analyzer to run while moving to the site and discarded the data for the period when the trailer was in motion.

The 3 dimensional anemometer functioned very well. In the fall 2009 studies I reported the manual alignment of the CSAT on the trailer is very difficult and that the alignment was questionable. The addition of the electronic compass mounted with the CSAT sensor greatly improved the alignment of the sensor array. Complete data was collected for three of four monitoring days. Several hours of data were lost from 04/27/2010 when a logger problem occurred. Despite several attempts I could not retrieve the missing data.

The GPS antenna failed to operate on the 04/14/2010 sampling day due to blown fuse. A back-up hand held GPS unit was used to provide site coordinates. The GPS system did operate for the remaining three sampling days.

Recommendations:
The spring 2010 monitoring runs conducted with the RWM\PAMS trailer support the fall 2009 findings showing the utility of the mobile laboratory for measuring air quality near roadways. These additional recommendations will help improve the operation of the trailer for future monitoring projects.

- The AutoGC system used on the trailer is over 10 years old and is deteriorating rapidly. The system should be replaced soon. We should look for funding for a replacement system to measure VOCs. The replacement may come in the development of future plans PAMS monitoring.

- New nitrogen dioxide rules will require monitoring near roadways. We should consider adding a NO/NO2/NOx analyzer to the trailer to develop data to support future monitoring near roadways.

I am currently working to implement all of these recommendations.

Data Table 3: Roadway Monitoring Summary for 4/14/2010										
Parameter Name	Sampling Hour									
	700	800	900	1000	1100	1200	1300	1400	1500	1600
Benzene (ppbC)		1.27	1.59	(0.71)	1.16	1.04	(0.37)	0.26	0.81	ND
Toluene (ppbC)		1.88	2.73	3.54	1.27	1.10	1.59	0.38	(0.74)	1.93
Ethylbenzene (ppbC)		0.76	(0.39)	0.81	0.24	ND	ND	0.90	ND	ND
M/P-Xylene (ppbC)		0.82	(1.86)	0.89	0.86	0.18	(0.62)	ND	ND	0.30
O-Xylene (ppbC)		0.24	0.47	ND	0.22	ND	0.79	(0.53)	0.50	(NR)
Black Carbon (ng/m3)	693	1104	1088	971	986	1013	818	764	642	612
Rho (meters/second	3.0	3.6	3.2	3.8	3.5	3.3	3.9	4.2	4.8	4.2
Theta (degree from north	144	162	161	174	188	198	201	197	200	204
Chi (degrees from horizontal)	87	88	87	88	88	88	87	88	87	88
NB (vehicles/hour)	972	1267	1301	1240	1295	1432	1416	1463	1621	1859
SB (vehicles/hour)	1390	1964	1518	1326	1258	1321	1404	1421	1483	1663
Values in parenthesis have been estimated using manual integration of the chromatographic peak.										

Data Table 4: Roadway Monitoring Summary for 04/20/2010										
Parameter Name	Sampling Hour									
	700	800	900	1000	1100	1200	1300	1400	1500	1600
Benzene (ppbC)	1.72	(1.27)	(0.84)	1.11	(0.34)	(0.53)	(ND)	(1.77)	(N*)	(0.54)
Toluene (ppbC)	2.31	(3.18)	(2.19)	(3.11)	(1.65)	1.03	0.73	1.86	(N*)	2.12
Ethylbenzene (ppbC)	0.63	0.63	(0.26)	(0.21)	0.25	(N*)	(N*)	(N*)	(N*)	(N*)
M/P-Xylene (ppbC)	1.28	1.19	0.70	(0.95)	(0.33)	(N*)	(N*)	(N*)	(N*)	(N*)
O-Xylene (ppbC)	1.17	0.67	0.80	(0.75)	ND	(N*)	(N*)	(N*)	(N*)	(N*)
Black Carbon (ng/m3)	1553	1527	1361	1425	1173	1002	912	1455	1302	1492
Rho (meters/second)	0.6	1.0	1.2	0.8	0.8	0.9	0.7	0.9	0.9	1.3
Theta (degree from north)	247	288	321	293	342	343	357	286	269	316
Chi (degrees from horizontal)	84	88	87	85	84	88	86	90	87	87
NB (vehicles/hour)	3612	2725	1969	1958	2123	2162	2219	2488	3024	3773
SB (vehicles/hour)	3572	2654	2079	2046	2012	2166	2165	2247	3065	3615
Values in parenthesis have been estimated using manual integration of the chromatographic peak. N* values were removed because of electrical noise interferences.										

Data Table 5: Roadway Monitoring Summary for 4/27/2010										
	Sampling Hour									
Parameter Name	700	800	900	1000	1100	1200	1300	1400	1500	1600
Benzene (ppbC)	1.13	1.57	0.91	0.88	1.13	0.85	1.81	1.10	1.05	0.77
Toluene (ppbC)	0.82	0.86	(0.49)	0.96	1.15	0.89	1.39	ND	1.44	(0.43)
Ethylbenzene (ppbC)	ND	ND	(1.63)	ND	ND	0.12	1.46	1.83	0.09	0.55
M/P-Xylene (ppbC)	0.24	ND	(1.64)	ND	0.56	1.82	ND	0.37	ND	ND
O-Xylene (ppbC)	0.54	0.50	(0.31)	0.31	0.27	ND	0.80	ND	1.04	0.73
Black Carbon (ng/m3)	276	317	364	468	515	552	412	619	762	703
Rho (meters/second	4.9	4.2	3.6	3.4	3.2	NA	NA	NA	2.2	2.0
Theta (degree from north	59	50	44	54	45	NA	NA	NA	35	33
Chi (degrees from horizontal)	86	87	87	87	86	NA	NA	NA	87	86
NB (vehicles/hour)	3679	2685	1900	1919	2105	2095	2339	2510	3197	3785
SB (vehicles/hour)	3490	2529	1933	1952	1964	2098	2102	2376	2860	3724
Meteorological measurement data for 1200, 1300, and 1400 was lost due to a problem with the data logger. Values in parenthesis have been estimated using manual integration of the chromatographic peak.										

Data Table 6: Roadway Monitoring Summary for 4/28/2010										
	Sampling Hour									
Parameter Name	700	800	900	1000	1100	1200	1300	1400	1500	1600
Benzene (ppbC)	1.54	1.09	0.86	0.74	0.60	0.66	ND	(0.39)	(ND)	1.07
Toluene (ppbC)	4.96	1.85	1.48	0.57	1.10	0.89	(0.78)	(1.02)	0.26	2.06
Ethylbenzene (ppbC)	0.64	0.70	1.64	0.35	ND	2.16	0.39	(1.41)	4.29	0.11
M/P-Xylene (ppbC)	1.59	0.76	0.66	ND	0.18	3.14	0.38	ND	(ND)	0.22
O-Xylene (ppbC)	0.29	0.76	0.65	0.14	0.47	0.46	2.11	ND	ND	ND
Black Carbon (ng/m3)	595	336	377	224	299	237	284	315	355	392
Rho (meters/second		2.1	1.6	2.4	2.6	2.1	2.7	3.3	3.1	3.4
Theta (degree from north		205	214	185	209	203	203	172	179	181
Chi (degrees from horizontal)		88	87	87	88	86	87	87	88	87
NB (vehicles/hour)	1015	1364	1345	1307	1394	1467	1530	1562	1760	1897
SB (vehicles/hour)	1458	1890	1549	1464	1379	1453	1450	1443	1704	1735
Values in parenthesis have been estimated using manual integration of the chromatographic peak.										

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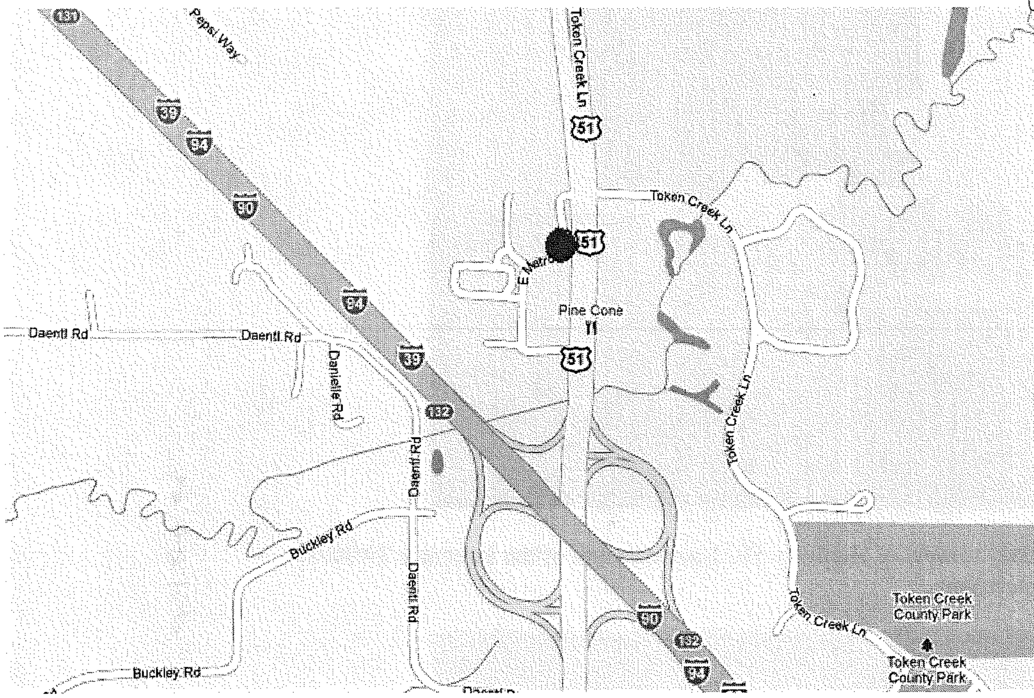
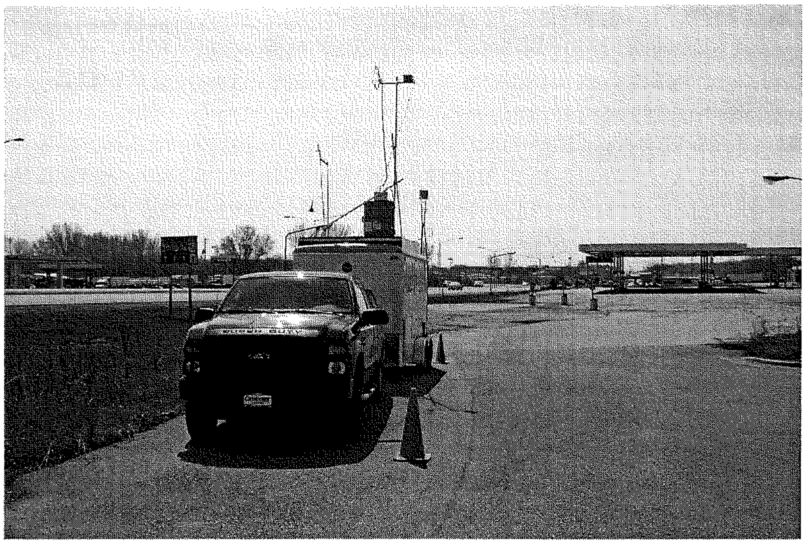
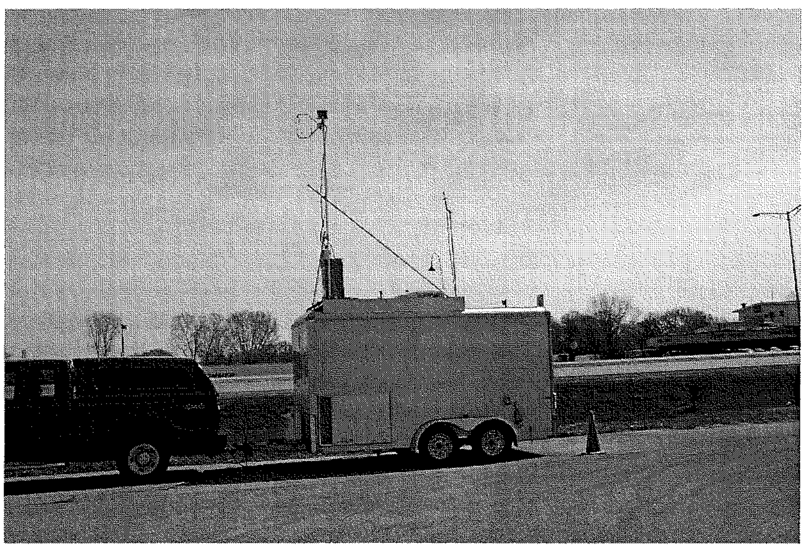
Appendix 1: Map and Photos of monitoring sites

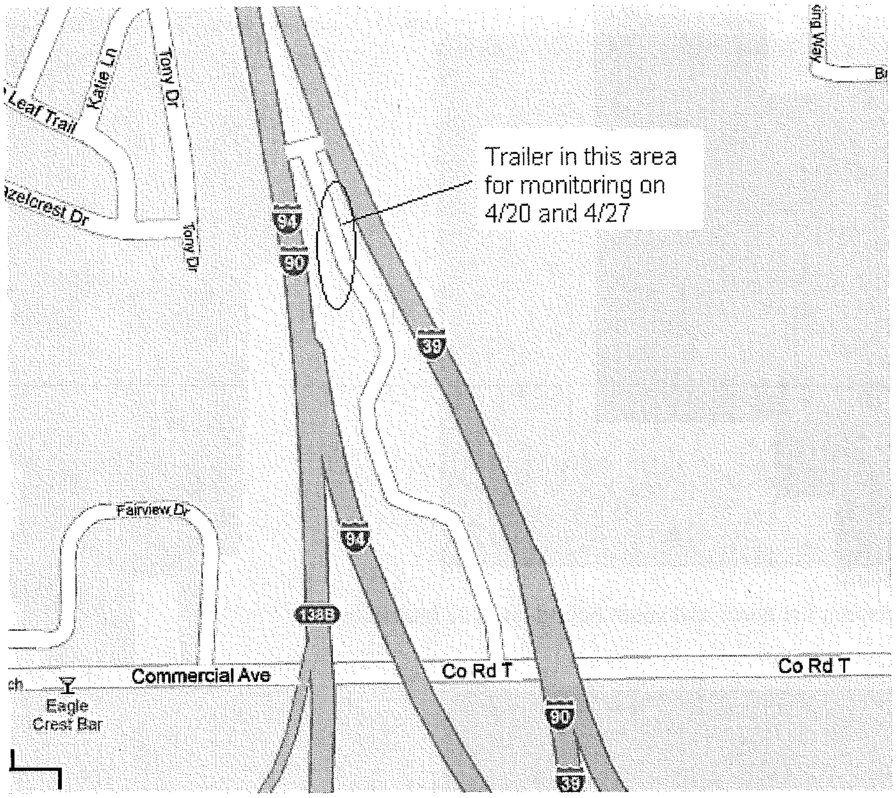


Northeast monitoring site. Red dot shows the trailer location on 4/14 and 4/28.

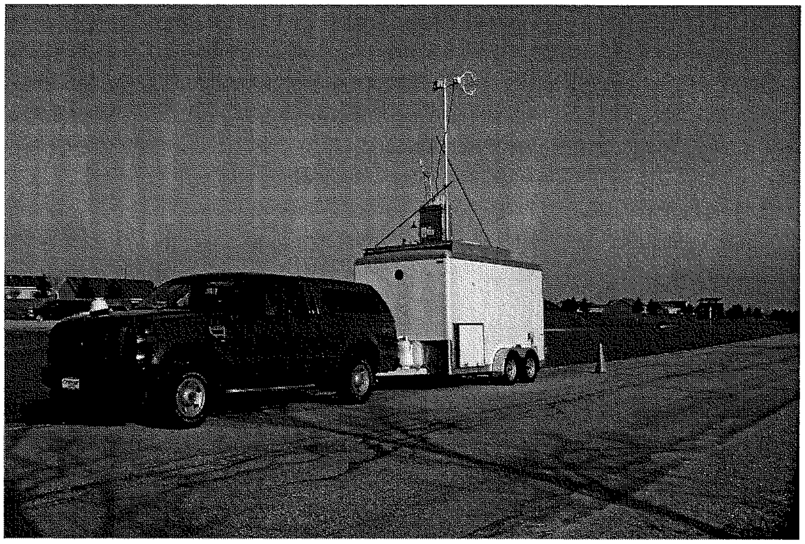


Trailer parked directly to west of Highway 51. Located south of the Interstate 39/90/94 and Highway 51 interchange.

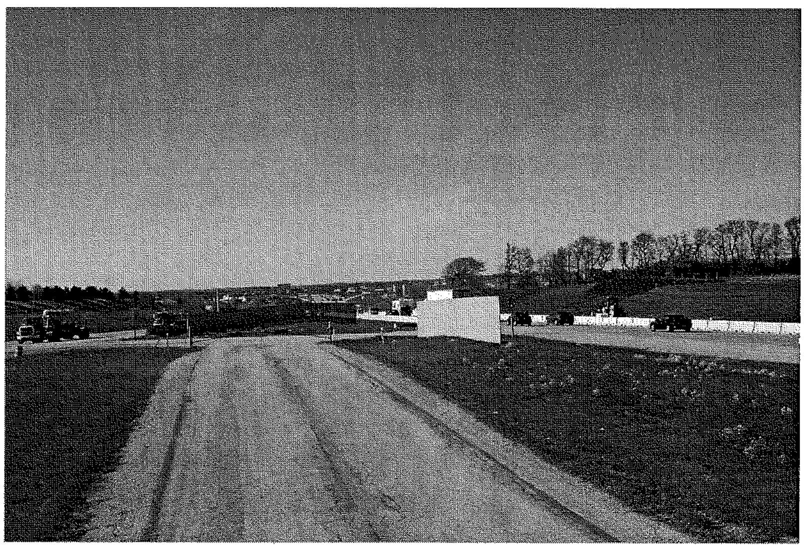




Badger Interchange parking lot. Trailer was parked in the area shown by the red circle.



Trailer parked on service road between the north and south bound lanes of Interstate 39/90/94.



Badger interchange site looking north from trailer deck. North bound traffic to right and south bound traffic on left.

DATE: Tuesday, October 12, 2010 FILE REF: AT2010

TO: Bart Sponseller – AM/7
Jason Treutel – AM/7

FROM: Mark K. Allen – AM/7

SUBJECT: Monitoring Near the Wisconsin DNR Cassville Site using the Roadway Monitoring Trailer

The Cassville monitoring site is one of two special purpose monitoring sites established to monitoring emissions from electrical power plants using biomass fuels. The site is located on the west side of the city of Cassville near the Mississippi River. To the north west of the site is the Nelson Dewey Power Plant which. continues to burn primarily coal. To the south east of the site is the Stoneman Power Plant which burns biomass fuels. Continuous parameters measured at the site include oxides of nitrogen, sulfur dioxide and PM2.5. Samplers at the site also collect ammonia. Black carbon is an experimental parameter measured with an aethalometer. The aethalometer measures black carbon using light attenuation as the particulate matter accumulated on a quartz filter tape. The aethalometer is factory calibrated and we have no direct means to verify the quality of the aethalometer measurement.

The Roadway Monitoring and PAMS trailer, hereafter RW trailer, was developed in the spring of 2009 for use in a Wisconsin Community Assessment Monitoring program. The RW trailer was developed as a mobile laboratory that could be used for both long and short term air monitoring projects. The RW trailer laboratory includes an aethalometer used to assess the diesel component of roadway particulate matter.

The primary goal of this monitoring project was to move the RW trailer near the Cassville site to compare measurements made by each of the two aethalometers.

Both aethalometers used in this study were Magee Model AE22. The Magee AE22 dual wavelength analyzer measures at two optical wavelengths. The first measure of black carbon made at an optical absorption of 880 nm. A second measure is made at 370 nm and this is designated as the 'UVPM' concentrations. The UVPM is thought to be a measure indicative of aromatic organic compounds, including biomass-burning. The two analyzer's serial numbers were 8550805 and 9300301. Analyzer 8550805 was purchased by the Wisconsin DNR in September 2008 for the roadway study. The analyzer has been used at several WDNR sites including the Madison East site and the Milwaukee Headquarter site. This analyzer has also been used in a number of roadway studies. Analyzer 9300301 was provided to the WDNR as a loan through LADCO. It was provided solely for the Biomass Study.

Test location:

Specific locations and details of the Cassville 2010 monitoring study are listed in Table 1. Maps, photos of the site and of the mobile lab are attached as appendices.

Table 1: Location and Time Data for the Cassville Site Tests.						
Date	Location	Start Time (CST)	End Time (CST)	Elevation (m)	Lat	Long
09/22/2010	Permanent site located along a frontage access road on the west edge of the city and very near the Mississippi.	NA	NA	200	42 42.716 N	90 99.5 W
9/22/2010	The mobile laboratory was parked along the same frontage road to the south of the monitoring site.	07:30	15:00	194	42 42.937 N	9059.71 W

Testing protocols:
Test runs reported here followed a set protocol including the following elements. The RW trailer's base station for these studies was the Wisconsin DNR's Science and Operations Center (SCIOPS) located on the southeast side of Madison. The aethalometer was operating prior to leaving SCIOPS. The on-board electrical generator was started and when running the power was transferred from the shoreline to the generator. All outside sampling probes were removed. The RW trailer was hitched to the tow vehicle and after a safety check the RW trailer was towed to the test locations. At the test site, the sampling probes were quickly set-up. The first probe was the aethalometer inlet. Next the meteorological sensor was set up and aligned.

During the testing, the operator monitored all analytical systems and the trailer support systems. Testing was divided into two periods. The initial period was conducted with no adjustments to the fixed site aethalometer. After the initial period the fixed site aethalometer was serviced and the operating parameters adjusted to conform to the mobile trailer's aethalometer. A second period of monitoring was then conducted. The site was located near the railroad tracks and the operator made a manual note of trains passing the site.

At the conclusion of testing, outside sampling probes were removed and stored. A safety check was made of the trailer and the trailer was then towed back to SCIOPS and parked. The trailer power was transferred back from the electrical generator to the shoreline power. When all systems were back on shoreline power, the generator was turned off. The operator then reviewed all data to insure records were complete and finally completed the trip log.

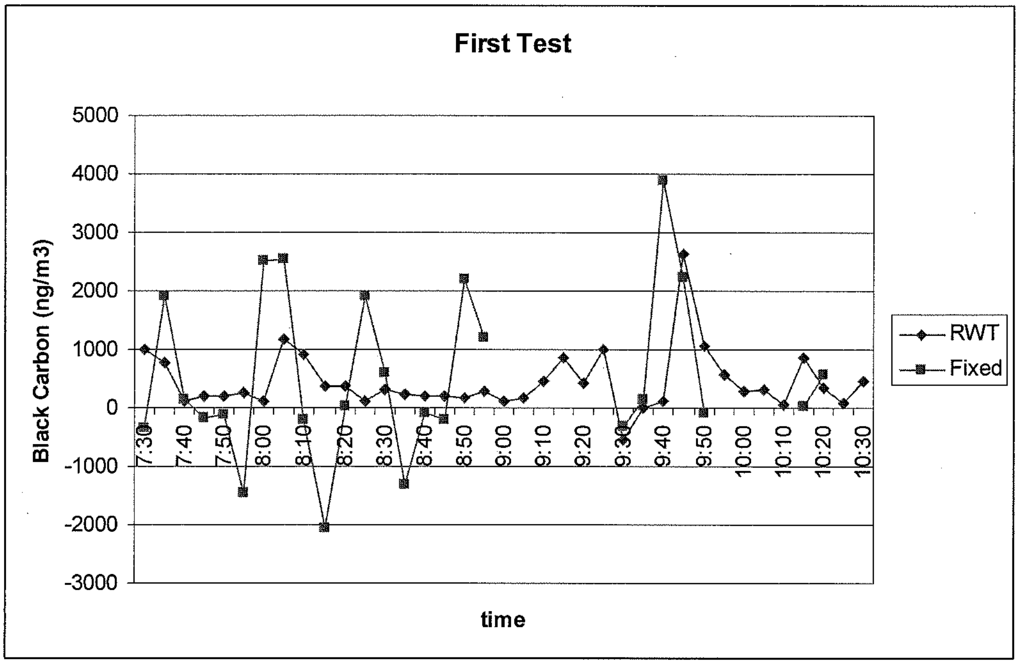
Results:
Study results are summarized in Table 2. Results reported included the average black carbon and average UVPM, the standard deviation of measurements. Also reported are the Average Absolute Difference and Average Percent Difference these are calculated values from the average of individual difference measurements. Finally reported are the

Study Absolute Difference and Study Percent Difference values calculated from the average of the study measurements.

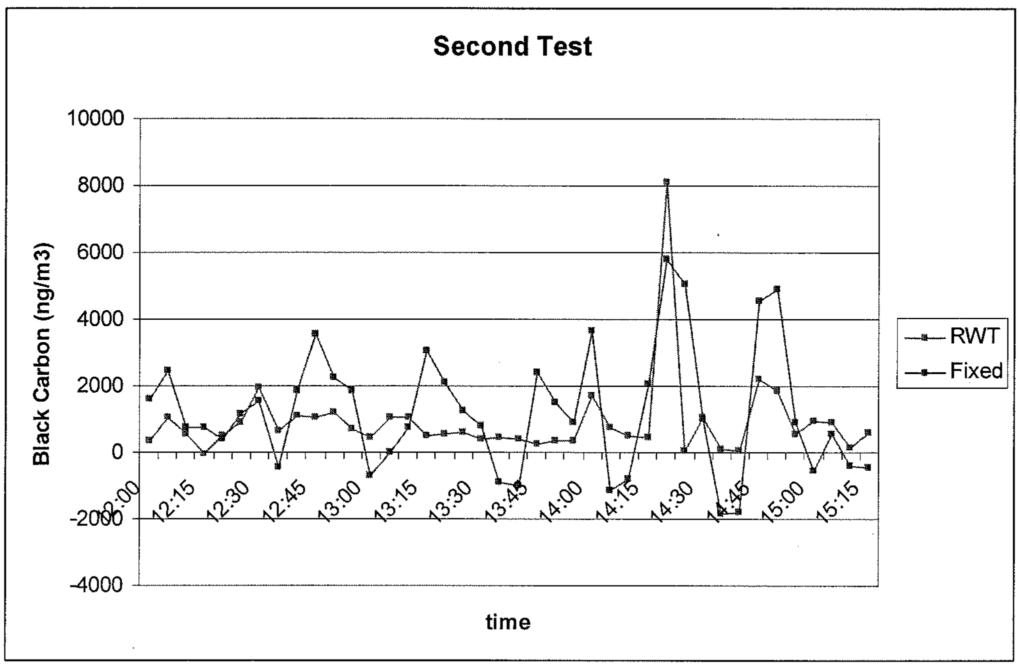
TABLE 2: Summary Data				
Start Time	7:30		12:00	
End Time	10:30		15:15	
	First Test		Second Test	
BC (ng/M3)	Fixed	RWT	Fixed	RWT
N	25.00	25.00	40.00	40.00
Average	541.436	457.212	1231.548	901.475
SD	1418.931	596.1005	1882.887	1277.86
Ave.Abs Dif	-84.224		-330.073	
Ave.Perc Dif	13.13%		-78.38%	
Study Abs Dif	-84.224		-330.073	
Study Per Dif	-16.87%		-30.95%	
UVPM (ng/M3)				
N	25	25	40.00	40.00
Average	448.92	425.26	1027.857	748.9657
SD	460.17	355.11	1518.174	1096.64
Abs Dif	-23.668		-279.005	
Perc Dif	44.11%		170.00%	
Study Abs Dif	-23.668		-278.891	
Study Per Dif	-5.41%		-31.39%	

This study's data suggests that for these two analyzers any comparison of the data would be difficult. Both the Average difference and the study difference of averages suggest significant differences in the measured data. The standard deviation data suggests a greater variation in the measured values from the fixed site aethalometer. The standard deviation increased for both samplers during the afternoon study. But again the values were greater for the fixed site analyzer. Time series plots show the two analyzers poor correlation, especially showing the greater variation in the data from analyzer 9300301.

Graphs



First Test
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
Black Carbon (ng/m3)
7:30
7:40
7:50
8:00
8:10
8:20
8:30
8:40
8:50
9:00
9:10
9:20
9:30
9:40
9:50
10:00
10:10
10:20
10:30
time
RWT
Fixed



Second Test
10000
8000
6000
4000
2000
0
-2000
-4000
Black Carbon (ng/m3)
12:15
12:30
12:45
13:00
13:15
13:30
13:45
14:00
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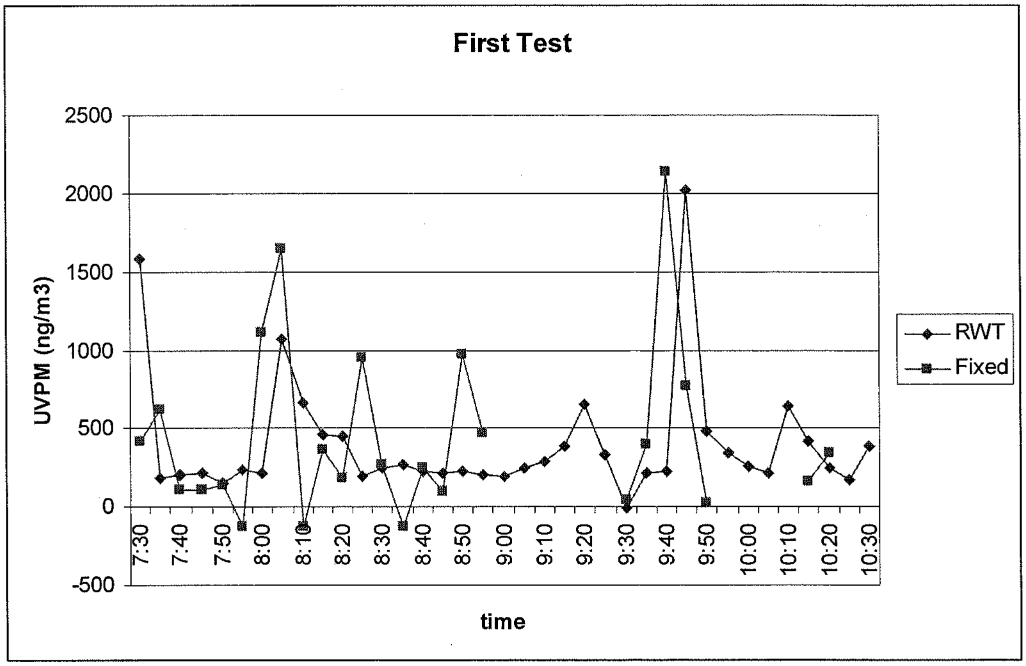
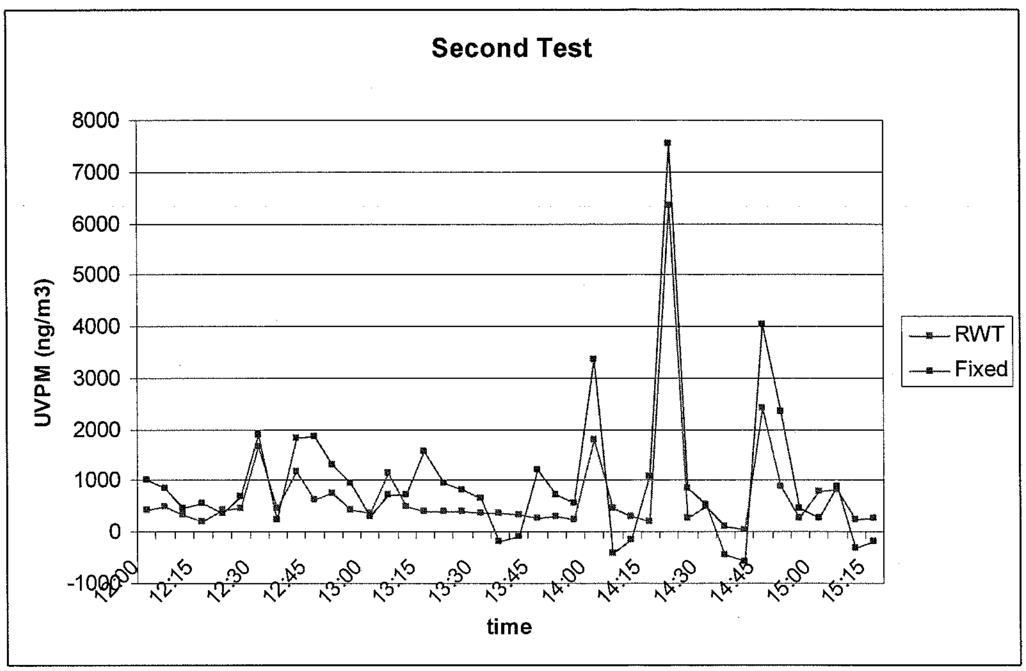
15:00
15:15
time
RWT
Fixed


First Test
2500
2000
1500
1000
500
0
-500
UVPM (ng/m3)
7:30
7:40
7:50
8:00
8:10
8:20
8:30
8:40
8:50
9:00
9:10
9:20
9:30
9:40
9:50
10:00
10:10
10:20
10:30
time
RWT
Fixed


Second Test
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
UVPM (ng/m3)
12:00
12:15
12:30
12:45
13:00
13:15
13:30
13:45
14:00
14:15
14:30
14:45
15:00
15:15
time
RWT
Fixed

Metrological measurements during the study.

Meteorological measurements were made using a Campbell CSAT sonic anemometer and are logged on a Campbell data logger. The CSAT's primary use is to measure the turbulent fluctuations of horizontal and vertical wind. Three dimensional wind measurements made using the CSAT are collected as three orthogonal vectors Ux, Uy, and Uz. Where Ux is the north south axis of the horizontal wind, Uy is the east west axis, and Uz is the axis transectioning the horizontal plane.

Vector data is converted to spherical coordinates of *Rho* (speed), *Theta* (azimuth), and *Chi* (elevation). A diagram of the spherical coordinates is shown in Figure 1. Conventions for the three vectors are given in Table 3.

Table 3: Conventions for Orthogonal Wind Vectors
Ux >0 when wind originates from the north and <0 when wind originates from the south.
Uy >0 when wind originates from the west and <0 when wind originates from the east.
Uz>0 when wind originates from above and <0 when wind originates from below

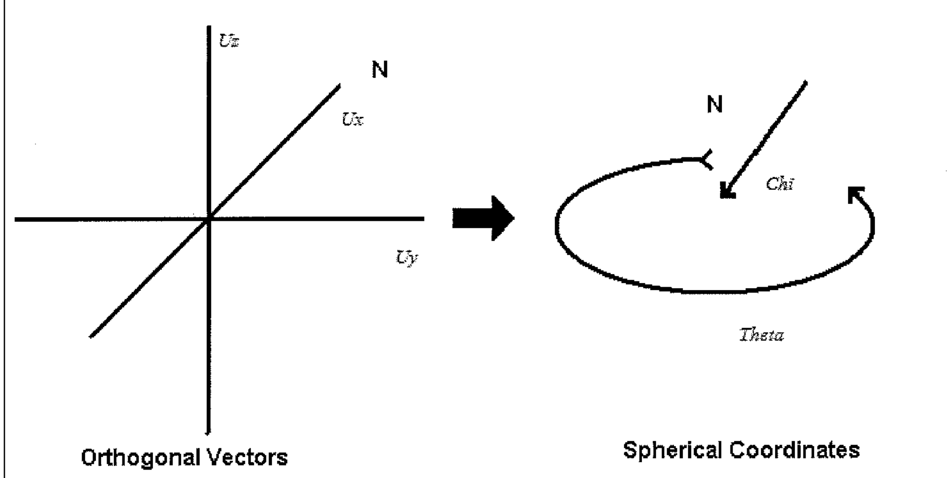


Figure 1. The transformation of orthogonal coordinates to spherical coordinates.

Comparison of Wind Measurements

Meteorological measurements of wind speed and direction are made at the Cassville site using a conventional wind vane and cup anemometer measurement system. These are compared to the RW Trailer WS/WD measurements using a three dimensional sonic anemometer which is aligned with an electronic compass. The average compass data is provided in Table 4A

A summary of hourly data from each system is compared in Table 4b. Data suggests that the two systems are making comparable measurements. This is again shown in a time series plot of the minute average data in Figure 2a and the minute wind speed in 2b. One noticeable difference is the outlier at 09:45. This is however only a single point in a total of 224. An examination of the data point found no reason for exclusion of this point. The fixed site wind speeds while similar is higher than the RW trailer wind speed. Average wind speed for the fixed site was 4.83+/-0.18 and the RW trailer average speed was 4.07+/-0.20. While comparable, there is a wind speed bias between the systems that is statistically different.

Both system reports agree that wind on the test day originated primarily from the SE, were very moderate in speeds and did not exceed 10 mph.

Table 4: Meteorology Data Summary					
Table 4a: Electronic compass for Met Alignment					
	Azimuth	Pitch	Roll	Temperature	
Average	356.5	0.47	0.93	24.49	
Min	0.1	-2.5	-1.1	22.5	
Max	359.9	2.9	3.1	27.5	
Table 4b: Hourly WD & WS Summary					
		RW Trailer		Fixed Site	
Date	Hour	WD	WS	WD	WS
09/22/2010	8	80.57	3.54	76.00	4.20
09/22/2010	9	109.36	2.62	109.00	4.10
09/22/2010	10	134.54	4.15	135.00	5.10
09/22/2010	11	121.19	4.75	117.00	5.60
09/22/2010	12	113.46	4.47	115.00	5.60

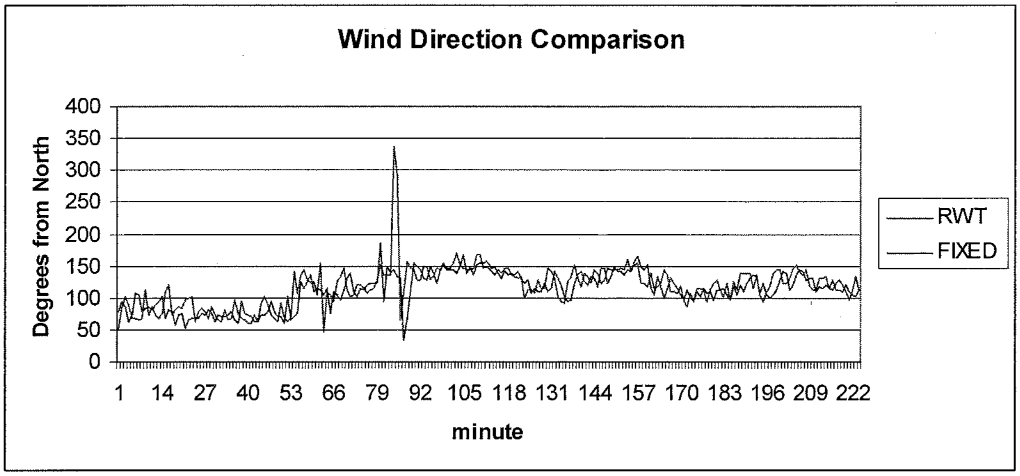


Figure 2a:

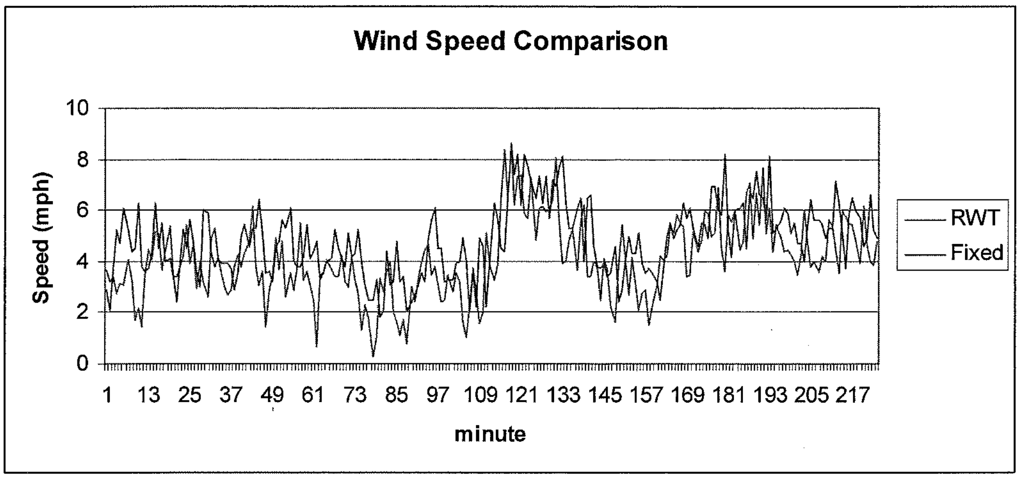


Figure 2b:

Equipment performance during studies

The utility trailer platform used for the mobile laboratory operated as expected. The trailer proved easy to tow and to position for the monitoring operations. Set-up of the sampling probes and the meteorological sensor mast worked as expected. The electronic compass proved very useful in getting an optimum alignment of the CSAT meteorological sensor.

Electrical power systems performed well and the on the on-board generator functioned very well and met expectation. There was sufficient power for all operations. Gas cylinders were weighted before and after being refill. Data from these cylinder weights, measured in the fall 2009 study, suggested that I could operate on generator power for up to 12 hours using 80% of fuel with a 20% reserve. During this study the generator supplied power continuously for 13 hours. In the fall 2009 studies, I reported generator fuel line freeze-up. While I noted some ice build up on the gas cylinder the amount was never sufficient to block the fuel line and stop the generator. I had thought the problem with the RW trailer's UPS was corrected, but this was not the case and the again UPS failed to function when the RW trailer was operating on generator power. Monitoring systems were therefore plugged directly into the trailer power for the monitoring operations.

Analytical systems

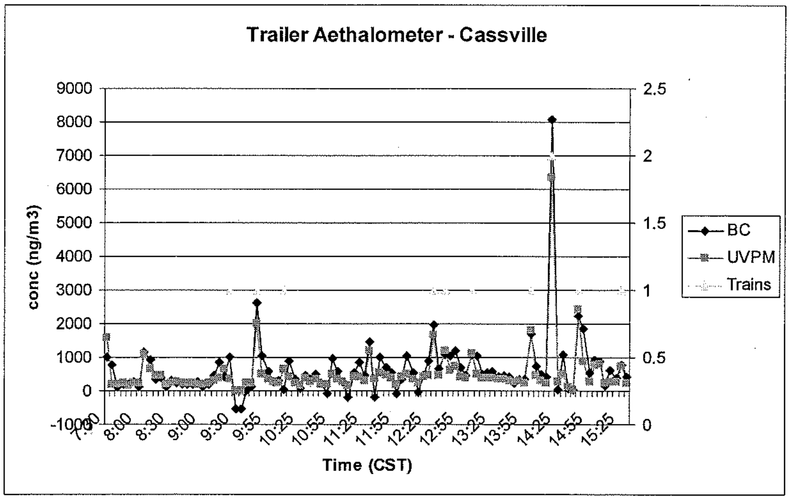
The aethalometer had functioned very well through out the studies. Based on experience gained in the fall 2009, I allowed the analyzer to run while moving to and from the site. This data was retained for study, but has not been addressed in this report.

The three dimensional anemometer functioned very well, but some data was lost when the data logger failed. The failure shows up as nonsensical data from the logger data dump. Several hours of data were lost when a logger problem occurred. This problem has happened before on earlier studies. Despite several attempts I could not retrieve the missing data.

The GPS system did operate for the study. I forgot to turn it on for the trip to the site but did log data on the return trip. I hope to match this data with the aethalometer data.

Railroad Traffic Effects.

The monitoring site is in very close proximity to the Burlington Northern Santa Fe railroad tracks. I noted during the operation an increase black carbon response when a train passed the site. I logged a number (but not all) trains that passed the site in the ten hours of monitoring at the site. A plot of the trains and the black carbon measured on the RW trailer is shown in graph 3. Data suggests there is a relationship between the trains and spike in the aethalometer data. In particular the 14:20 peak, which occurred when two trains passed the site, each train traveling in a direction opposite of the other.



Recommendations:
The result of the study suggest that the two aethalometers compared are making similar measurements, but the two analyzers show significant differences that would make it difficult to compare measurements at Cassville with black carbon measurements made in other areas of Wisconsin. Most notable is the greater standard deviation of the aethalometer 9300301. This indicates a greater variation when measuring. Because there is no direct way to challenge the aethalometers the operator has a limited numbers of indicators that the instrument is operating as expected. There is no real way to tell if one of these two analyzers is making a better measurement.

It is therefore my recommendation that we should continue to develop information on the analyzers until we can identify parameters that show an analyzer is operating optimally. A second recommendation would be to schedule additional side-by-side comparisons of the two aethalometers as permitted by the study's plans. In the interim data should be reviewed carefully.

I will continue working to implement all this recommendation and improve confidence in the aethalometer measurements.

Appendices: Monitoring location map and study photos.

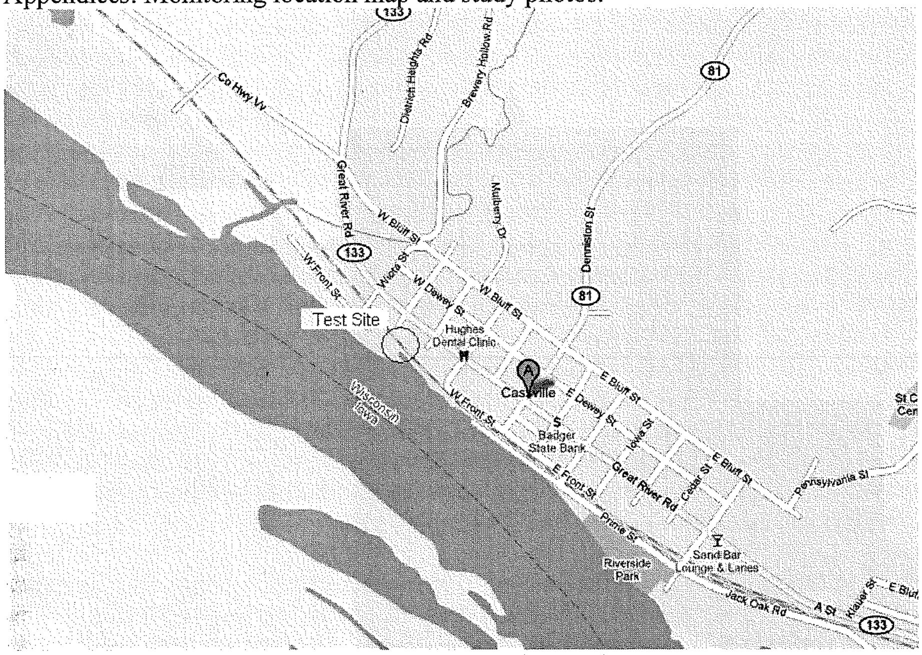


Figure A1: Red circle shows the monitoring study location.

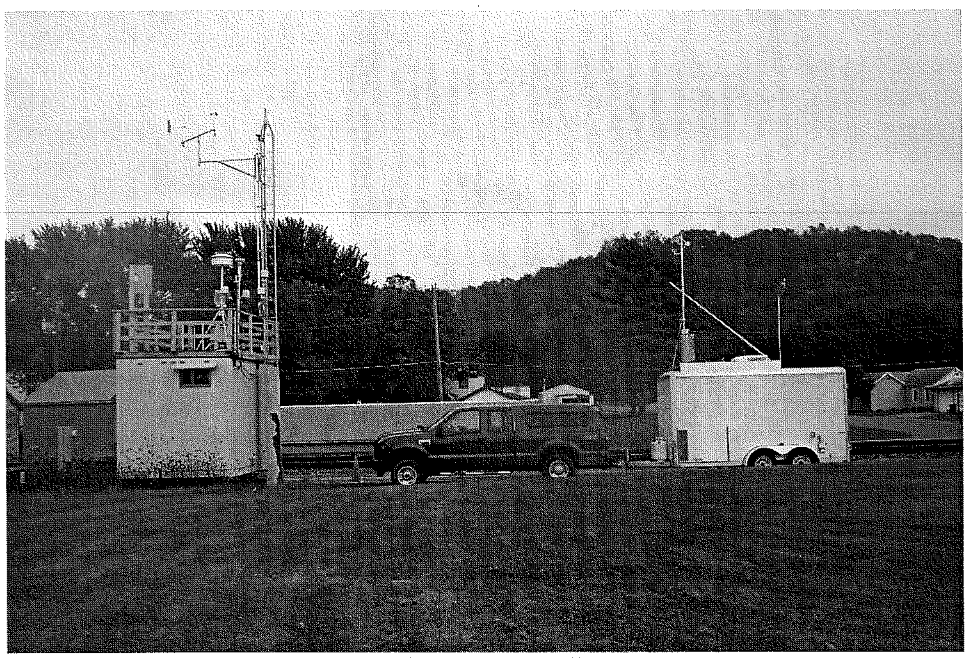


Photo 1: RW trailer and towing vehicle at the Cassville site.

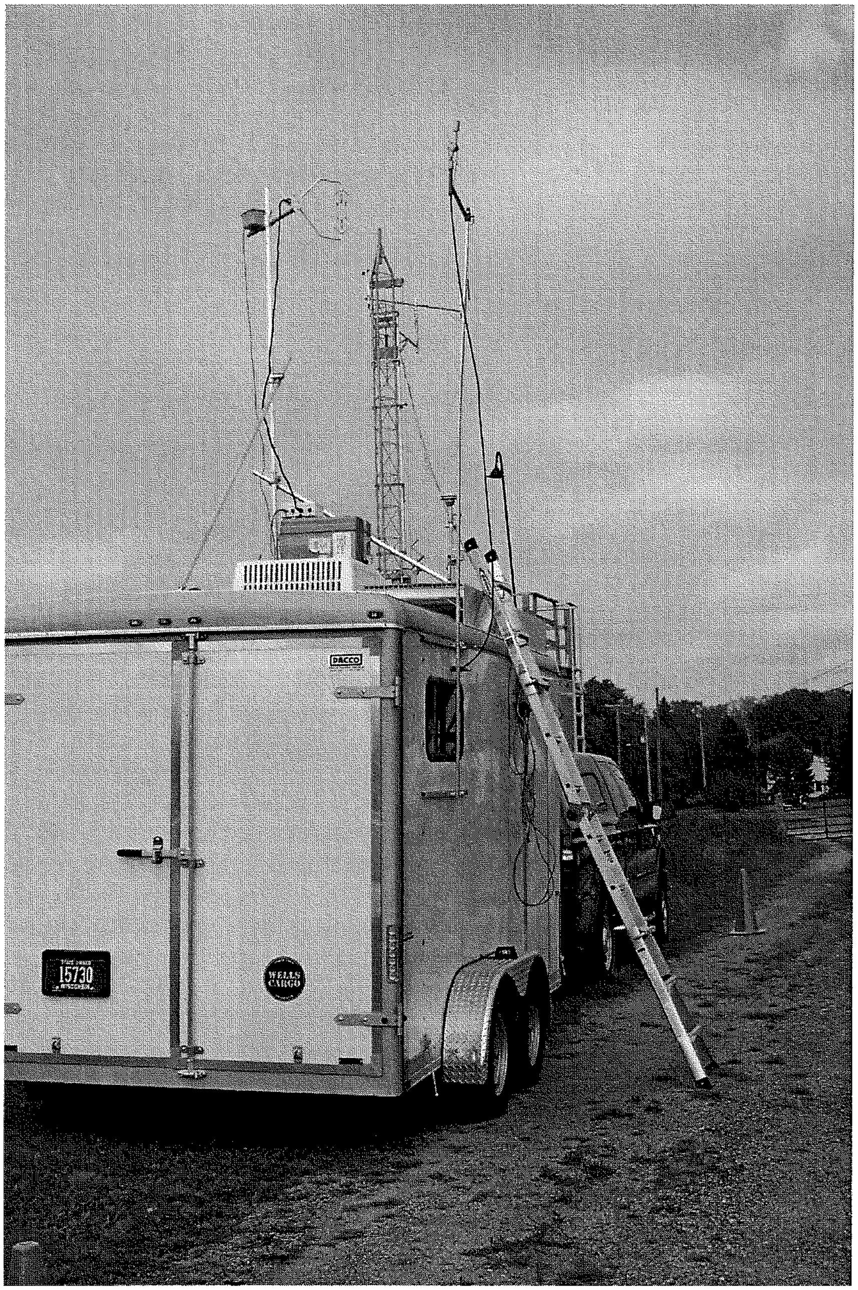
Al 

Photo 2: RW trailer with all analytical probes deployed.

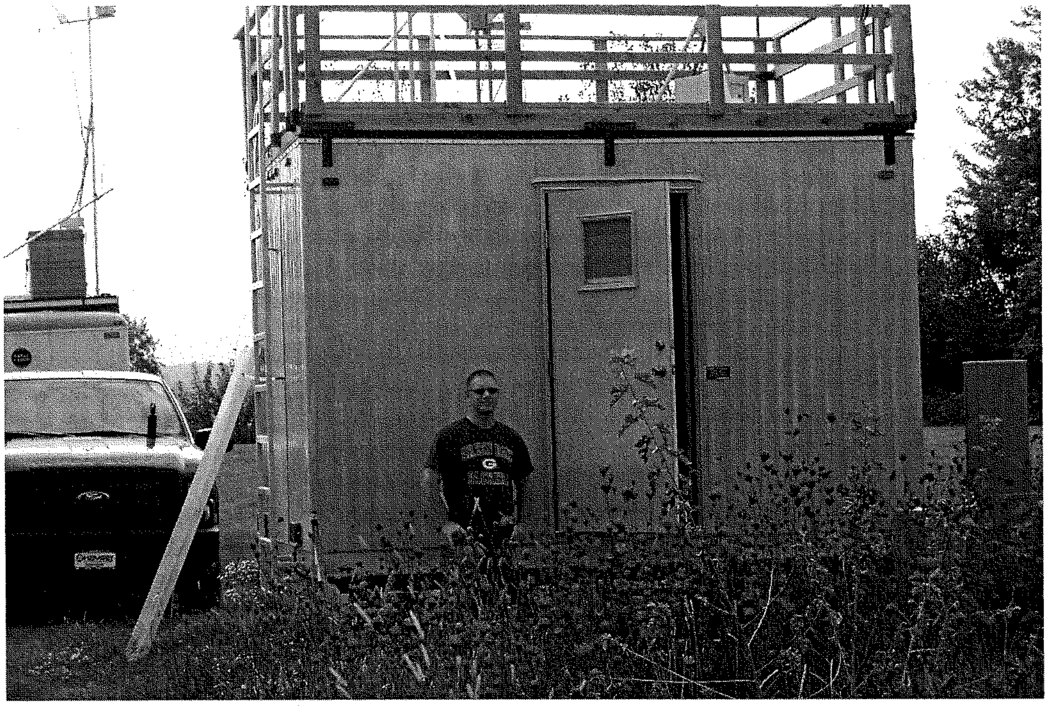


Photo 3: Cassiville site trailer.

DATE: Thursday, February 10, 2011 FILE REF: AT2010

TO: Bart Sponseller – AM/7

FROM: Mark K. Allen – AM/7

SUBJECT: Fall 2010 Roadway Monitoring Studies near Madison, WI

The Roadway Monitoring and PAMS trailer, hereafter RWM\PAMS trailer, was developed in the spring of 2009 for use in Wisconsin Community Assessment Monitoring programs. The RWM\PAMS trailer was developed as a mobile laboratory that could be used for both long and short term air monitoring projects. The PWM\PAMS trailer has been used for several deployments including the 2009 PAMS monitoring in Milwaukee, fall 2009 roadway monitoring studies, and spring 2010 roadway monitoring studies. This memorandum will report on new roadway monitoring studies conducted in fall 2010.

The objective of the fall studies was to continue investigations of pollutant concentrations near roadways. The RWM\PAMS trailer provides a mobile laboratory that can be placed in close proximity to roadways. The trailer has an on-board electrical generator to supply power. The mobile laboratory provides the flexibility to monitor for short periods at a number of different locations and to monitor at locations that would not be accessible as permanent locations. The monitoring allowed the Wisconsin DNR to assess various roadway locations to determine the impacts of the recently revised nitrogen dioxide National Ambient Air Quality Standard (NAAQS). The new nitrogen dioxide one hour standard of 100 ppb was enacted on 1/22/2011 and the EPA has targeted roadways as major emission sources.

The fall studies cover a period from 11/02/2010 to 12/08/2010. Seven individual days of monitoring were conducted at seven different locations. The locations represented three types of high traffic roadways listed below.

- Interstate Highways – these are multi-lane high speed intercity roadways with limited and controlled access. Posted speed limits for these roadways are 65 mph.
- Urban expressway – a high speed multi-lane roadway with frequent points of controlled access. Posted speed limit on this roadway is 55 mph, but speeds are typically lower during period of traffic congestion.
- Urban traffic corridor – a main traffic route in the urban area. The roadway typically has posted speed limits varying from 30 to 40 mph. Traffic is controlled with frequent traffic lights. Traffic from minor side streets are controlled with STOP signs and at major cross streets with traffic lights.

The studies reported here measured high concentrations of black carbon and nitrogen dioxide at all three types of roadways. The data suggests that on a study day at a location, the hourly traffic count was most significant in determining the highest concentration. Between studies the metrological conditions had greater significance on the measured concentrations. Data also suggest that while high nitrogen dioxide concentrations are measured, the concentrations are unlikely to exceed the 100 ppb hourly NAAQS.

Location and Local Weather Conditions:
The RWM/PAMS trailer was positioned at a down wind location and was within 50 meters of all roadways tested. Table 1 provides a summary of the study locations. A map showing six of seven locations and GPS location information is provided in Appendix 1.

Table 1: Roadway Studies Monitoring Locations						
Date	Start Time	End Time	City	Primary Roadway	Crossroad	Roadway Type
11/02/2010	6:00	17:00	Madison	Beltline	Rimrock	Urban Expressway
11/04/2010	5:00	11:00	Madison	Beltline	Southtowne	Urban Expressway
11/09/2010	13:00	19:30	Madison	Beltline	Whitney Way	Urban Expressway
11/10/2010	12:00	19:00	Madison	East Washington	First Street	Urban Traffic Corridor
11/17/2010	6:00	13:00	Lake Mills	I94	DOT Rest Stop	Interstate Highway
11/29/2010	6:00	13:00	Madison	East Washington	Stoughton Road	Urban Traffic Corridor
12/08/2010	12:15	17:30	Madison	I39	Badger Interchange	Interstate Highway

The weather conditions for the monitoring studies covered typical Wisconsin fall weather. A summary of the daytime weather conditions is provided in Table 2. The data was collected at a Wisconsin DNR's Madison East site. I have summarized for daytime hours from 06:00 to 17:00. The data is provided to give the reader baseline data for assessing monitoring conditions. Actual study wind speed and wind direct were monitored at each location and that data is provided in the summary tables, 3a through 3g. Wind speed in this report is provided in meters per second (for the reader's reference 1 mps ≈ 2 ¼ mph).

Table 2: Summary[1] of Weather Data from WDNR Madison East Site[2]						
	Temperature (degrees C)		Wind Direction (degrees)		Wind Speed (meter/second)	
	min	max	Min	Max	Min	max
11/02/2010	-0.7	10.5	50	192	0.3	2.6
11/04/2010	4.4	7.5	9	359	3.9	7.0
11/09/2010	5.7	19.9	119	337	0.4	2.7
11/10/2010	8.2	18.7	97	160	1.0	4.1

11/17/2010	3.5	5.2	309	338	2.1	3.9
11/29/2010	2.1	7.5	139	161	2.8	4.7
12/08/2010	-11.9	-5.9	16	352	0.9	2.9
1. Summary data is the daytime defined as period from 0600 to 1700 inclusive. 2. Madison East is a long term fixed monitoring site - AQS# 550250041						

Monitoring Parameters:
The studies in this report are focused on monitoring two primary pollutant parameters. The first pollutant parameter is black carbon measured with a Magee AE22 dual wavelength Aethalometer. Black carbon is present in fine particulate or graphitic carbon form. The Aethalometer provides two channels of data and includes both black carbon and a UVPM channel. The UVPM channel makes a measurement at a shorter wavelength that is thought to include black carbon and non-black carbon from organic sources. The non black carbon would include fresh diesel exhaust, but also other sources such as wood and other biomass burning. Aethalometer measurements are made over five minute durations. This report will cover the five minute measurements and these will be arithmetically averaged to hourly measurements.

The second set of pollutant parameters measured are the oxides of nitrogen, measured as nitric oxide and nitrogen dioxide. Measurements were made with an API 200E Oxides of Nitrogen analyzer. This is a chemiluminescent reaction analyzer that directly measures nitric oxide from light emissions. Nitrogen dioxide is reduced by a catalyst to nitric oxide and a second measurement of total oxides of nitrogen (NOx) is measured. The nitrogen dioxide is then calculated as the difference of the total oxides of nitrogen and nitric oxide. The analyzer makes continuous measurements which are reported as one minute average values for nitric oxide, nitrogen dioxide, and total oxides of nitrogen. For this report the one minute measurements were averaged to five minutes measurements. The five minute measurements were in turn averaged to hourly measurements.

During the studies, measurements were also made of one auxiliary set of parameters. Measurements of the wind speed and wind direction were made using a Campbell Sonic Anemometer, a three dimensional meteorological sensor system. The sonic sensor measures the wind vectors in three orthogonal directions. Ten second measurements were averaged to one minute measurements. For this report the one minute measurements were averaged to five minute measurements and the five minute measurements were also averaged to one hour measurements. All vector data was processed to conventional spherical coordinated that included wind direction, wind speed and wind angle from horizontal. These coordinates are reported as Rho (speed), Theta (azimuth), and Chi (angle from horizontal). A more extensive explanation of the wind measurements is made in Appendix B of this report.

The Wisconsin Department of Transportation operates a network of real time traffic sensors throughout Wisconsin. At the completion of the of fall studies, I requested traffic data for the seven locations monitored. Wisconsin DOT data provides hourly data for traffic in each direction and summed for total traffic. Data provided in this report is for the total traffic on the roadway.

Previous monitoring studies with the RWM/PAMS trailer have included selected VOC measurements made with a Perkin Elmer AutoGC system. This AutoGC system is over 10 years old and its operations have been increasingly erratic. Over the summer of 2010, the AutoGC system began experiencing cascading component failures and the system's use was discontinued. In September 2010, the Wisconsin DNR informed EPA Region 5 of the failure of the AutoGC system and the discontinuation of VOC measurements. There were no VOC measurements made in any of the fall 2010 studies.

Study protocols:
Monitoring studies typically followed a set of protocols including the follow elements. The trailer base station for these studies was the Wisconsin DNR's Science and Operations Center (SCIOPS) located on the southeast side of Madison. The Aethalometer and the oxides of nitrogen analyzers were running. Prior to leaving SCIOPS the on-board electrical generator was started and when running, the power was transferred from the shoreline electrical power (fixed outlet at SCIOPS) to the generator. All outside sampling probes were removed. The trailer was hitched to the tow vehicle and after a safety check the trailer was towed to the test locations. Because most test sites were close to SCIOPS, travel was generally less than 30 minutes. At the test site, the sampling probes were quickly set-up. Typically on site sampling was started at the top of the hour. Secondary analysis systems like the anemometer were set-up after primary analyzers were operating.

During the testing, the operator monitored all analytical systems and the trailer support systems. As noted manual traffic counts taken in the fall 2009 monitoring studies were replaced with WDOT reports from sensors in the roadways. The operator continued to observe relevant events such as traffic flow, approximate speeds and congestion. Pollutant and meteorological data was collected continuously. GPS location data and sensor orientation data were collected periodically. Typically the GPS and orientation data were collected for a 1 to 2 minute periods at the beginning, the middle, and the end of the monitoring study.

At the conclusion of the study, the outside sampling probes were removed and stored. A safety check was made of the trailer and the trailer was then towed back to SCIOPS and parked. The trailer power was transferred back from the electrical generator to the shoreline power. When all systems were back on shoreline power the generator was turned off. The operator then reviewed all data to insure records were complete and completed the trip log.

Study Results:
Data Management
All monitoring data was stored and managed in a single ACCESS database. Data was exported to an EXCEL spreadsheet for statistical analysis and graphing. Data was averaged using conventional EPA and Wisconsin DNR rules requiring 75% capture for

completeness. A minimum of 4 one minute averages were required for each five minute average and a minimum of nine 5 minute averages were required for each hourly average. All averages were arithmetic. Meteorological data was first arithmetically averaged as vector quantities and then converted from orthogonal coordinates to conventional spherical coordinates.

Hourly Average Data

The monitoring data is first presented as hourly average summaries in Tables 3a through 3g. The summary data includes real time traffic data provided by the Wisconsin DOT. Data was collected from WDOT monitoring sites closest to the air monitoring sites.

November 2, 2010

Monitoring conducted along the Madison Beltline at the Rimrock Road exit (Appendix 1). The winds were from the south to the south-southwest and very light under 2 mps. Monitoring started at 06:00 cover the early morning rush hour and continued through the afternoon to the start of the evening rush hour. Early morning rush hour concentrations for black carbon and oxides of nitrogen are among the highest in this series of studies. Concentrations dropped as the day progressed but began to peak again near the end of the study. Observation noted definite congestion early at 06:30 on the west bound lane. The congestion cleared by 09:30 and steady flow was reported at 12:00. Traffic congestion was again developing about 16:00. This location is directly east of an area of the Beltline undergoing construction. This was the longest study attempted; the length of the operations stressed staff and the generator fuel supply. Other studies were shorter and focused around either the morning or evening rush hour.

Table 3a: Beltline at Rimrock Road - 11/02/10											
TIME	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
BC (ng/m3)	3852	3497	1625	1041	703	661	592	513	587	748	1158
UV (ng/m3)	4139	3521	1651	1149	720	642	578	510	472	677	1353
NOX(ppb)	223.6	224.6	141.2	82.2	61.7	54.8	59.9	55.5	55.8	69.5	72.0
NO(ppb)	197.9	195.9	118.2	63.0	46.0	40.0	44.1	40.9	38.5	47.6	43.6
NO2(ppb)	25.7	28.7	23.0	19.2	15.7	14.8	15.8	14.6	17.3	21.9	28.4
Rho(mps)	0.9	0.7	0.9	0.8	1.5		1.6	1.0	0.9		1.0
Theta(degrees)	202.3	190.4	108.2	175.6	195.2		170.3	194.2	203.1		191.6
Chi (degrees)	89.8	86.9	83.9	82.6	87.2		85.5	86.9	85.4		87.9
Traffic (vehicles)	6844	9842	8228	6201	5839	6299	6636	6662	7254	8999	10090

November 4, 2010

Monitoring was conducted along the Madison Beltline at the Southtowne Road exit (Appendix 1). The winds were from the northwest and significantly higher 3 to 4 mps. Monitoring started at 05:00 to cover the early morning rush hour and was discontinued at 11:00. Traffic peaked at 0800 to 0900. Observations were that the traffic moved steadily throughout the period monitored. There was a generator stoppage at 08:20 that resulted in some loss of data. Observation also noted very light rain (sprinkling) at 09:43. Concentrations were significantly lower than measured on 11/02/2010. I believe the higher winds speeds and the location were both significant factors affecting the measured concentrations.

Table 3b: Beltline at Southtowne Road 11/04/10							
TIME	5:00	6:00	7:00	8:00	9:00	10:00	11:00
BC (ng/m3)	370	449	576		537	503	820
UV (ng/m3)	343	460	568		614	573	715
NOX(ppb)	32.27	39.07	42.06		37.66	37.77	37.67
NO(ppb)	22.08	28.48	30.48		28.77	27.36	27.91
NO2(ppb)	10.19	10.58	11.58		8.89	10.41	9.76
Rho(mps)		3.36	3.46	3.31	3.83	4.06	
Theta(degrees)		303.93	312.82	312.52	323.21	319.39	
Chi (degrees)		87.28	86.98	87.66	88.76	88.37	
Traffic (vehicles)	1005	2703	7191	9890	8043	6251	6095

November 9, 2010

Monitoring conducted along the Madison Beltline at the Whitney Way exit (Appendix 1). The winds were from the southeast, were light, and under 2 mps. Monitoring started at 13:00 to cover the afternoon rush hour and was discontinued at 20:00. Observations noted heavy but flowing traffic at 16:00. By 17:00 there was significant congestion in the eastbound lane. At 19:00 noted heavy traffic but also flowing better. Traffic peaked at 17:00 and at a lower peak volume than that measured at the other two Beltline sites. Concentration were high and among the highest measured in the fall study.

Table 3c: Beltline at Whitney Way -11/09/2010								
TIME	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00
BC (ng/m3)	754	772	989	1291	1737	1088		
UV (ng/m3)	780	829	1017	1325	2014	1438		
NOX(ppb)	66.54	68.65	121.98	132.93	133.49	86.41	83.79	244.34
NO(ppb)	31.72	43.63	87.05	88.49	87.62	56.31	51.81	201.35
NO2(ppb)	34.82	25.03	34.93	44.44	45.87	30.09	31.98	42.99
Rho(mps)		2.35	1.71	1.17	1.57			
Theta(degrees)		141.56	142.63	141.64	138.24			
Chi (degrees)		87.42	86.20	88.56	87.87			
Traffic (vehicles)	3829	3781	3994	4937	6064	4875	3567	2321

November 10, 2010

Air monitoring was conducted along the East Washington Avenue traffic corridor (Appendix 1). The location is directly west of the First Street intersection. Traffic lights at the intersection did cause traffic to back-up directly in front of the monitoring location. The winds were from the southeast, were light, decreasing and under 2 mps. Monitoring started at 13:00 to cover the afternoon rush hour and was discontinued after 19:00. Observations noted generator stoppages at 14:10 and 14:45. At 16:15 noted backup at the traffic light on east bound lane. This was again noted at 16:50. Trains passed the site at 17:05 and at 17:55 and there was a fire truck in the parking lot near the trailer at 18:00. Notes report traffic significantly less at 19:00. Traffic was significantly less than measured at the Beltline sites and peaked at 15:00. Concentrations were high and peaking at 17:00. Delta C is the difference between the UVPM channel and the black carbon. This location experienced the highest Delta C measurements, indicating greater amounts organic carbon emissions in the area.

Table 1d: East Washington Ave at First Street - 11/10/10								
TIME	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00
BC (ng/m3)	844		1038	1020	1106	1014		
UV (ng/m3)	1443		1351	1373	1404	1232		
NOX(ppb)	121.49	22.03	18.99	49.57	79.04	58.02	46.59	
NO(ppb)	99.39	8.11	8.86	21.06	39.94	33.68	29.34	
NO2(ppb)	22.10	13.92	10.13	28.52	39.11	24.34	17.25	
Rho(mps)	2.02	1.66	1.51	1.05	0.63	0.88		
Theta(degrees)	155.35	160.89	158.90	152.40	147.68	126.55		
Chi (degrees)	83.96	82.75	81.37	83.68	80.44	84.33		
Traffic (vehicles)	2589	2913	3649	3471	2740	1824	1464	1563

November 17, 2010

Air monitoring was conducted at the Wisconsin DOT Rest Area located along Interstate Highway 94 (Appendix 1). The rest area is located between the Lake Mills and Johnson Creek exits which are located approximately nine miles apart. The winds were from the northwest and were moderate measuring between 2 to 4 mps. Weather was damp, cold, with occasional light rain. Monitoring started at 07:00 to cover the morning rush hour and was discontinued after 12:00. Measured traffic was lower than that measured at the Beltline sites and peaked at 08:00 at less than 3000 vehicles per hour. Observation notes record the traffic was steady with no congestion throughout the monitoring period. Weather was cold and damp; winds were very light but increased through the study. Measured pollutant concentrations were lower than measured at either the urban expressway or the urban traffic corridor site. Concentrations peaked at 08:00.

Table 3e: Interstate Highway 94 at WDOT Rest Area - 11/17/10								
TIME	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00
BC (ng/m3)	719	739	860	819	733	624	445	
UV (ng/m3)	863	871	966	874	759	650	456	
NOX(ppb)	31.24	30.19	31.43	28.35	28.75	25.82	17.00	16.57
NO(ppb)	21.90	21.55	21.76	19.99	19.43	17.64	10.60	10.51
NO2(ppb)	9.34	8.63	9.67	8.36	9.32	8.18	6.40	6.07
Rho(mps)		2.37	2.41	3.07	3.18	3.57	4.33	
Theta(degrees)		297.73	293.74	308.08	307.27	305.85	309.45	
Chi (degrees)		89.61	89.88	88.76	88.21	87.58	87.50	
Traffic (vehicles)	1167	2247	2865	2537	2161	2027	1992	2023

<u>November 29, 2010</u>

Air monitoring was the second study conducted along the East Washington Avenue traffic corridor (Appendix 1). This location is a major intersection located on the Madison far eastside. This is a vey large urban intersection with traffic covering two plus lanes in all four directions. This includes two main traffic lanes with added lanes for turning traffic. The winds were from the south and were moderate measuring between 4 to 5 mps. Monitoring started at 06:00 to cover the morning rush hour and was discontinued after 12:00. The only traffic location monitor for this site is the Yahara River & South 113 site. This site is located at approximately 3 miles from the monitoring location, but there are numerous exits and entrances to the East Washington Avenue between the air monitoring site and the traffic monitoring site. Traffic data should be considered only an estimate. Observation noted that traffic moved through the intersection at a steady flow. There were back ups at the traffic light but with no significant delays. Generator stopped at 08:37 but was quickly restarted. Measured concentrations were lower and concentrations peaked at 07:00.

Table 3f: East Washington Street at Stoughton Road - 11/29/10								
TIME	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00
BC (ng/m3)	493	760		651	545	557	457	
UV (ng/m3)	561	783		769	642	660	564	
NOX(ppb)	24.88	45.00	33.99	31.97	22.54	28.07	29.96	57.83
NO(ppb)	10.22	24.68	18.69	15.92	13.10	14.69	18.42	36.93
NO2(ppb)	14.66	20.32	15.30	16.05	9.44	13.38	11.54	20.90
Rho(mps)		3.28	3.70	4.96	5.12	5.32	4.84	
Theta(degrees)		158.62	161.02	160.72	164.11	164.61	161.35	
Chi (degrees)		87.22	87.71	87.53	86.85	87.19	87.33	

Traffic (vehicles)	3680	3400	2566	2659	3070	3306	3307	3419

December 8, 2010

Final monitoring study in the fall 2010 studies, the air monitoring was conducted at the Wisconsin DOT Service area located between the north and south bound lanes of Interstate Highway 39 (Appendix 1). This location is within the Badger Interchange which routes traffic into Madison or to Milwaukee. This is the only north south roadway monitored during this fall study. This site is the only site with two traffic locations bracketing the monitoring location. The winds were from the northwest, were low and consistently greater than 2 mps but less than 3 mps. This was the coldest day of the fall monitoring studies. Monitoring started at 12:15 to cover the afternoon rush hour and was discontinued after 17:00 when generator problems developed. Traffic was high peaking at 16:00. Measured pollutant concentrations peaked at 16:00. Traffic was steady with noticeable slow downs during the afternoon rush period. Pollutant concentrations were higher than on other days, but not the highest measured in the studies.

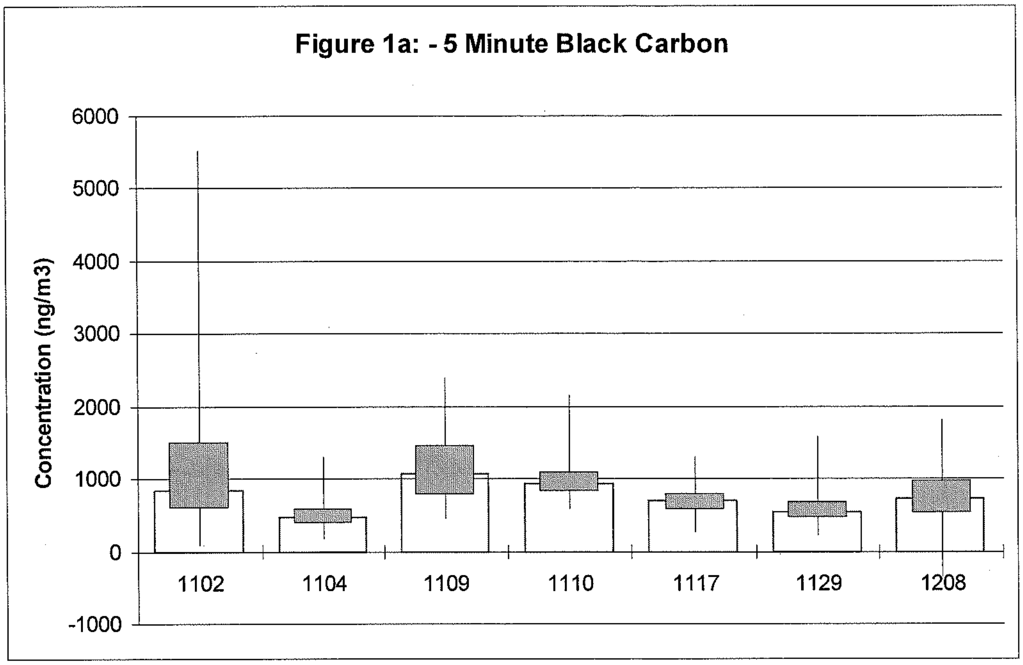
Table 3g: Interstate Highway 39 at Badger Interchange - 12/08/10

TIME	12:00	13:00	14:00	15:00	16:00	17:00	18:00
BC (ng/m3)	353	493	650	835	1082		
UV (ng/m3)	420	542	632	761	985		
NOX(ppb)	80.88	84.64	100.71	120.56	151.82		
NO(ppb)	56.96	61.61	71.73	85.51	110.36		
NO2(ppb)	23.92	23.03	28.99	35.05	41.46		
Rho(mps)		2.71	2.26	2.11	2.12	1.55	
Theta(degrees)		326.63	326.54	327.51	337.88	338.23	
Chi (degrees)		90.37	90.07	89.36	90.63	88.57	
Traffic #1 (vehicles)	4069	4438	4914	5827	7320	6436	4084
Traffic #2 (vehicles)	2730	2976	3126	3469	4133	3801	2483

Five Minute Measurements

The shortest common measurement time period for pollutants was five minutes, determined by the monitoring period for the black carbon measurements. The five minute measurements provide a more detailed view of what happened at the sites. The pollutant data is summarized in Figures 1a to 1d and is presented as box and whisker plots. The box and whisker plot provide the following data. The blue box outline the concentration range covered by the 25th to 75th percentile. The single vertical center line is the range of data from the minimum concentration to the maximum concentration. The red brackets indicate the point of the median within the 25th to 75th percentile range.

The data suggests that for the black carbon concentrations were highest in the 11/09/2010 study while the UVPM was higher on 11/10/2010. For the oxides of nitrogen the 12/08/2010 showed the highest median concentration with 11/09/2010 as a close second. Overall the 11/09/2010 study on the urban expressway showed the highest median pollutant concentrations. All three types of roadways showed studies with high concentrations.



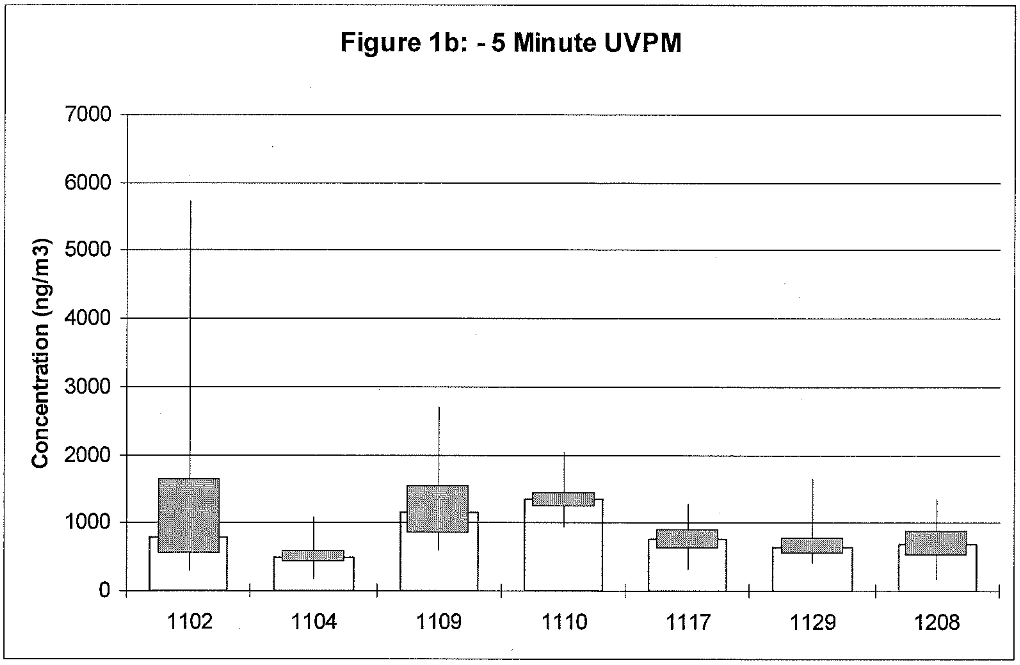


Figure 1b: - 5 Minute UVPM
Concentration (ng/m3)
7000
6000
5000
4000
3000
2000
1000
0
1102
1104
1109
1110
1117
1129
1208

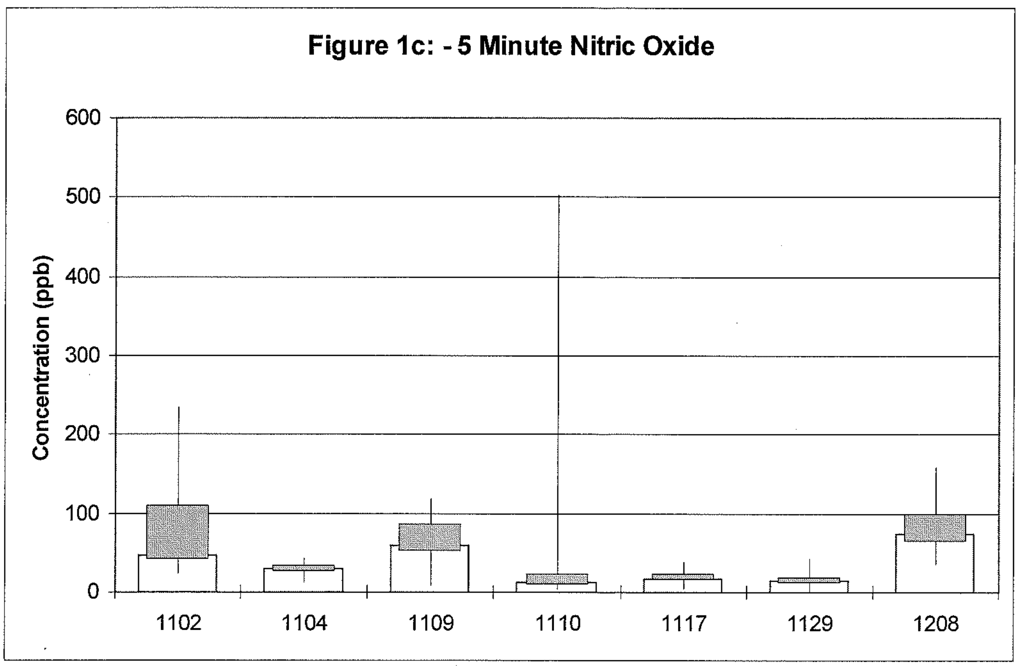
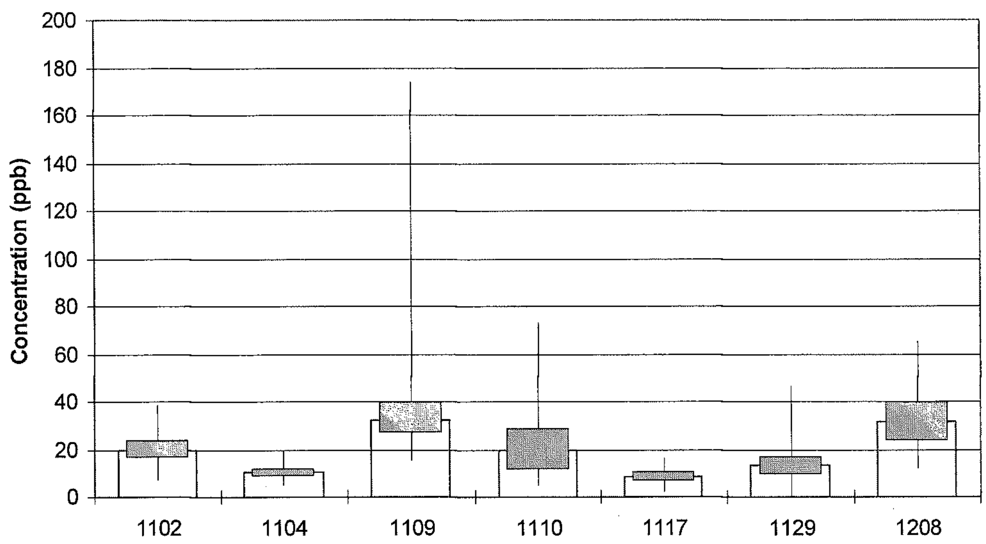


Figure 1c: - 5 Minute Nitric Oxide
Concentration (ppb)
600
500
400
300
200
100
0
1102
1104
1109
1110
1117
1129
1208

Figure 1d: - 5 Minute Nitrogen Dioxide



The next series of Figures 2a through 2g show the five minute data for the primary pollutants black carbon, nitric oxide and nitrogen dioxide plotted as a time series for each study. The "X" axis shows the 5 minute period. The figure title identifies the site, the date and the start time for the five minute periods. The reader should note that every twelve measurements on the "X" axis represents one hour. The primary and secondary Y axis has been fixed to allow the reader to compare concentrations from the different studies.

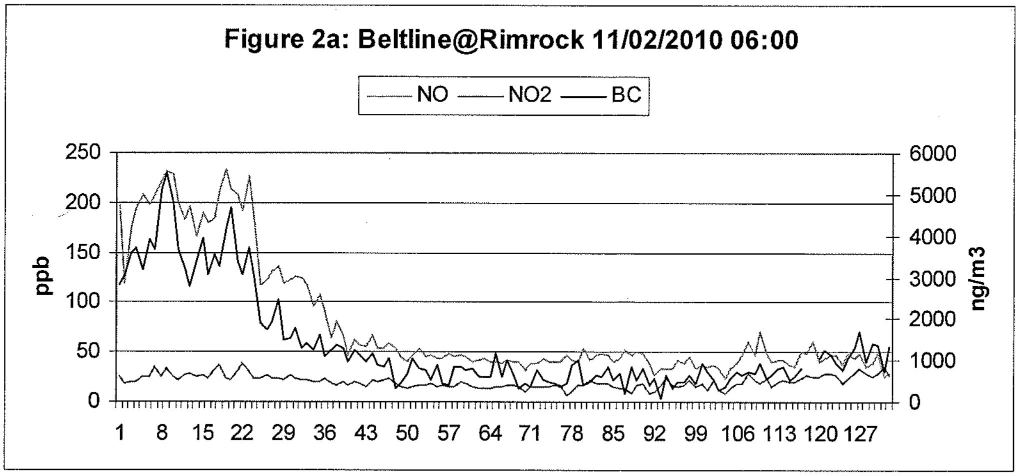


Figure 2a: Beltline@Rimrock 11/02/2010 06:00
NO
NO2
BC
ppb
ng/m3
250
200
150
100
50
0
6000
5000
4000
3000
2000
1000
0
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99 106 113 120 127

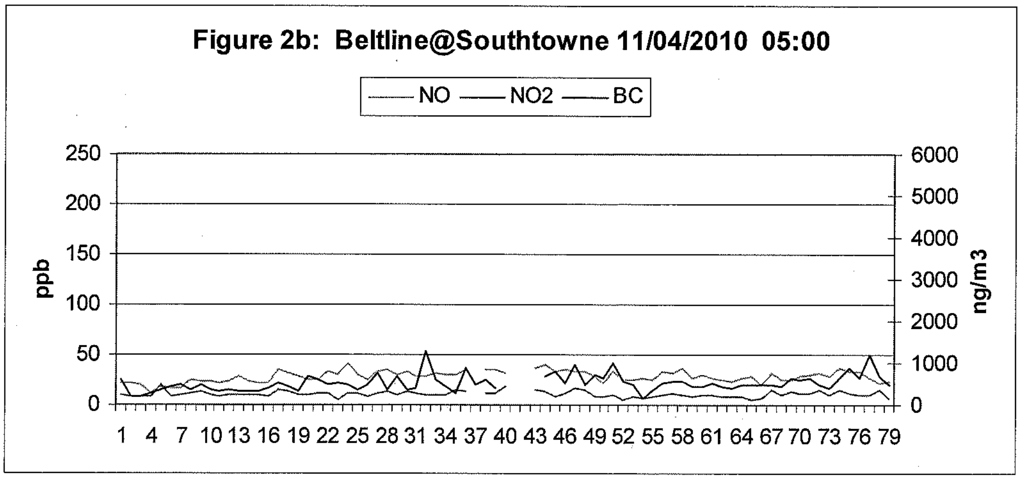


Figure 2b: Beltline@Southtowne 11/04/2010 05:00
NO
NO2
BC
ppb
ng/m3
250
200
150
100
50
0
6000
5000
4000
3000
2000
1000
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79

Figure 2c: Beltline@Whitney Way 11/09/2010 13:00

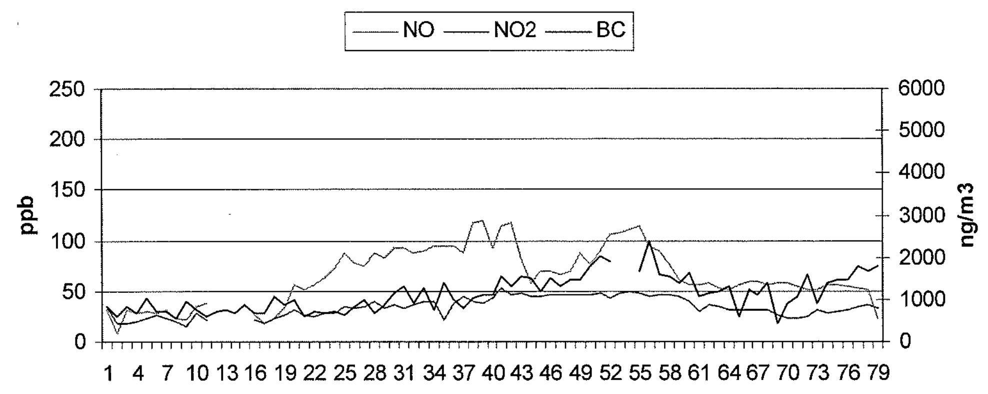


Figure 2d: E.Washington@ 1st St 11/10/2010 13:00

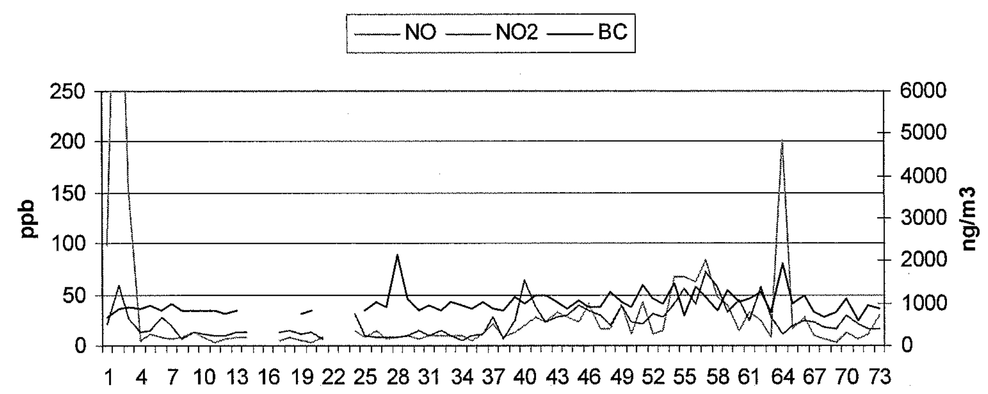


Figure 2e: I94@ DOT Rest Stop 11/17/2010 06:00

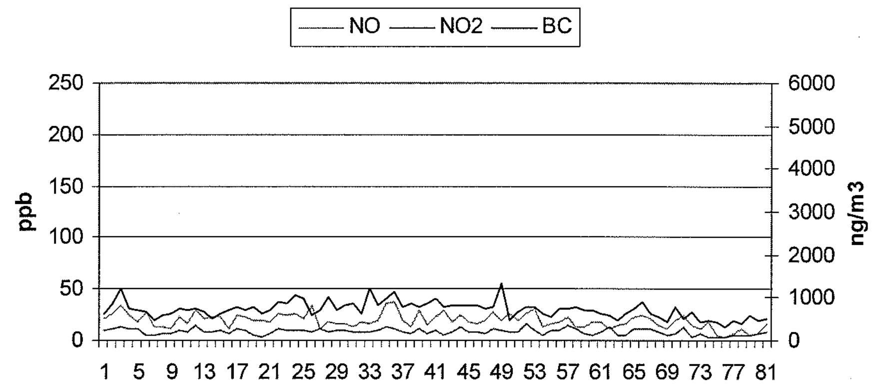
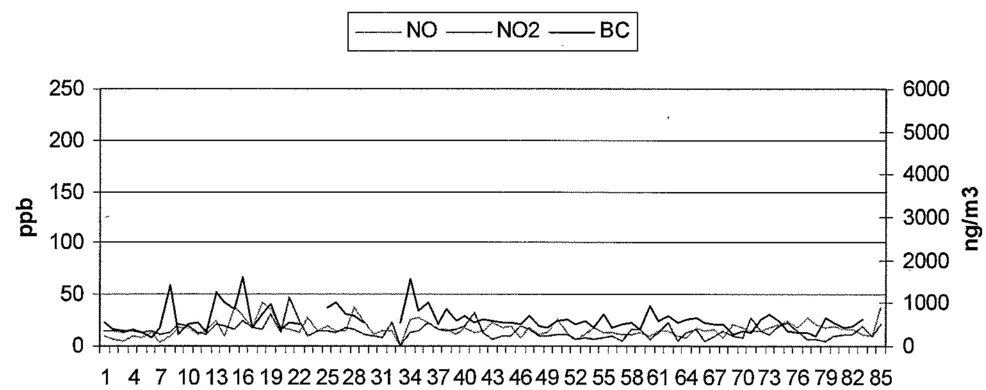
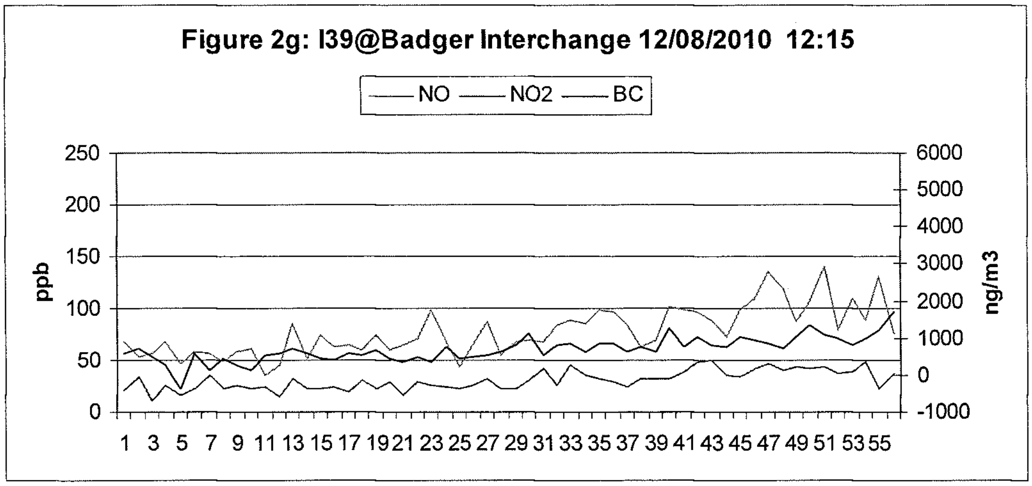


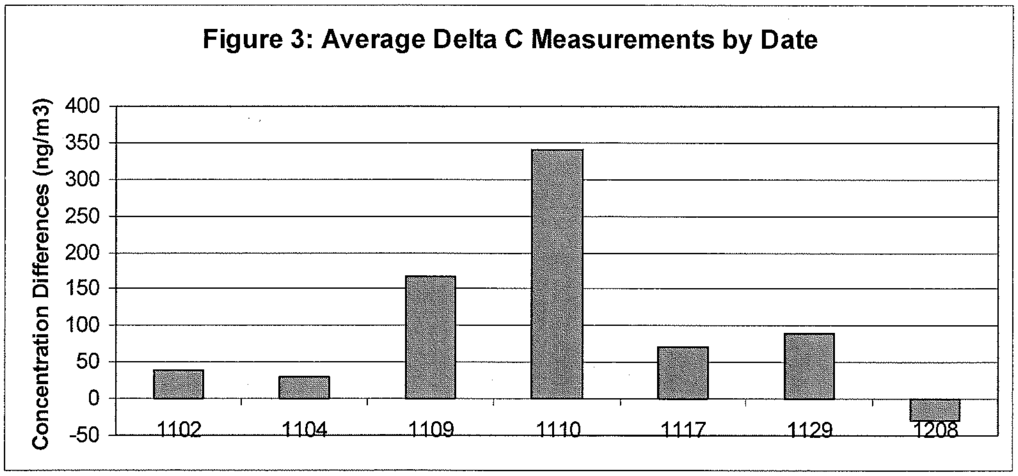
Figure 2f: E. Washington @Stoughton Rd 11/29/2010 06:00





UV PM Channel

The UVPM channel is thought to provide a measure indicative of aromatic organic carbon compounds. Examples of aromatic organic carbons include tobacco smoke, PAH mixtures, smoke from wood and other biomass-burning. In general, we expect the UVPM channel to track the elemental channel. Differences in the two channels can be indicative of additional carbon sources. The difference of the two channels of data is the assigned the name Delta C. A summary measure of Delta C shows that the highest Delta C measured on 11/10/2010. This study was on Madison's near Eastside and the presence of addition carbon sources is consistent with the multiple source location. Measurements on 12/08/2010 showed the lowest average Delta C which was actually negative indicating the BC carbon was typically higher. Sampling on 12/08/2010 was located on Interstate Highway 39 at the Badger Interchange. This is a relatively isolated location where traffic emissions would dominate. The other factor on this day was the wind direction. Wind direction for all seven sampling days was either from north or the south. Most of the roadways monitored were east-west highways and so most winds were crossing the roadways. Monitoring locations were always on the downwind side of the roadways. Interstate Highway 39 is the only roadway with a primarily north-south orientation. Monitoring on 12/08/2011 the winds were traveling parallel to the road. This may have contributed to the measured predominance of the BC channel.



Figures 4a through 4g provide time series plots examining data from the BC and UVPM channels. The reader show note that the y axis of the graph are allowed to float for the best fit. At all sites the two channels follow with the UVPM channel typically having a higher concentration. The UVPM separates noticeably from the BC channel near the end of the 11/09/2010 sampling along the Beltline and early in the 11/10/2010 monitoring at East Washington Avenue. On 11/10/2010, the channel difference drops later in the day. At the Interstate location, monitored 12/08/2010, the BC and UVPM channel track very closely, with the BC channel leads. This is the only study where BC channel was higher than the UVPM channel.

Figure 4a: Beltline@Rimrock 11/02/2010

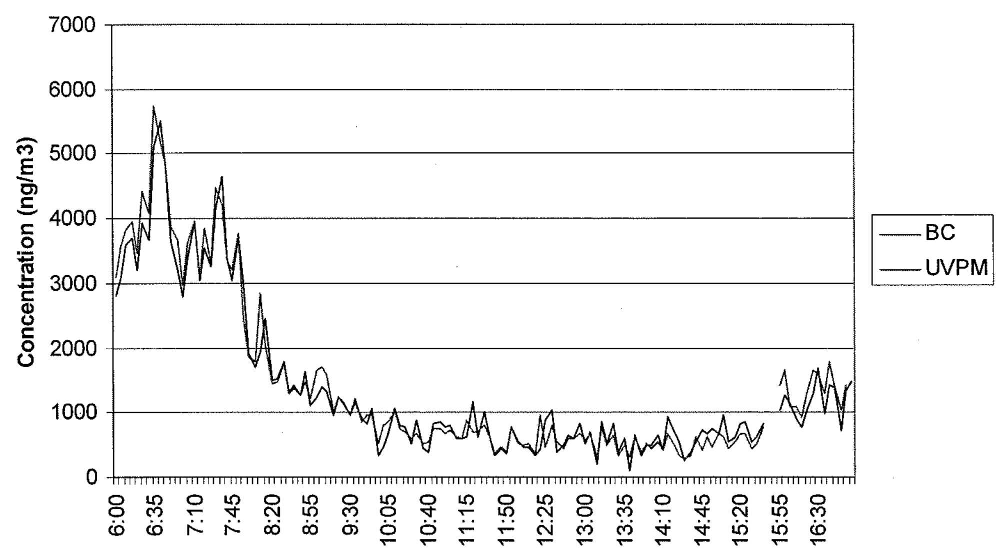
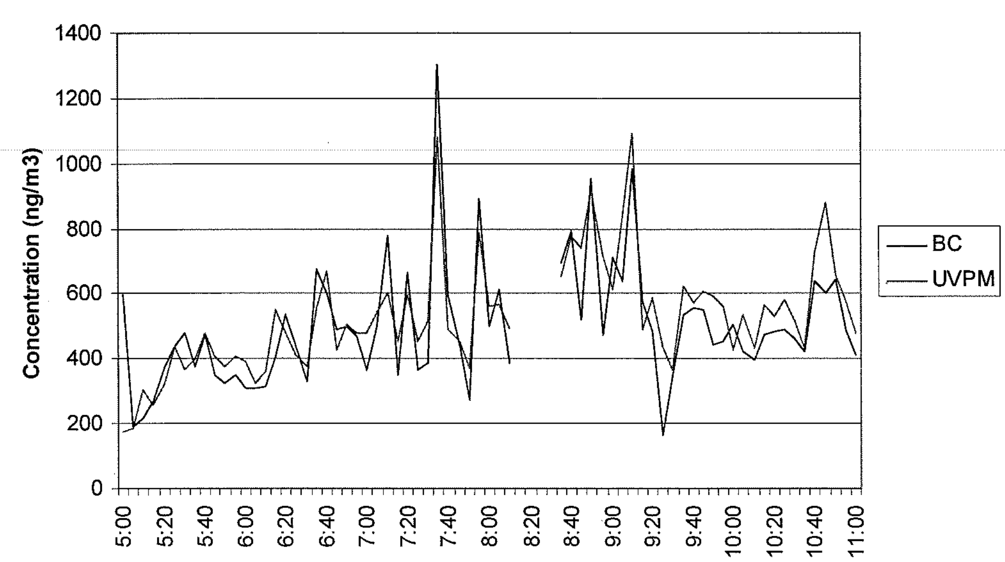


Figure 4b: Beltline@Southtowne 11/04/2010



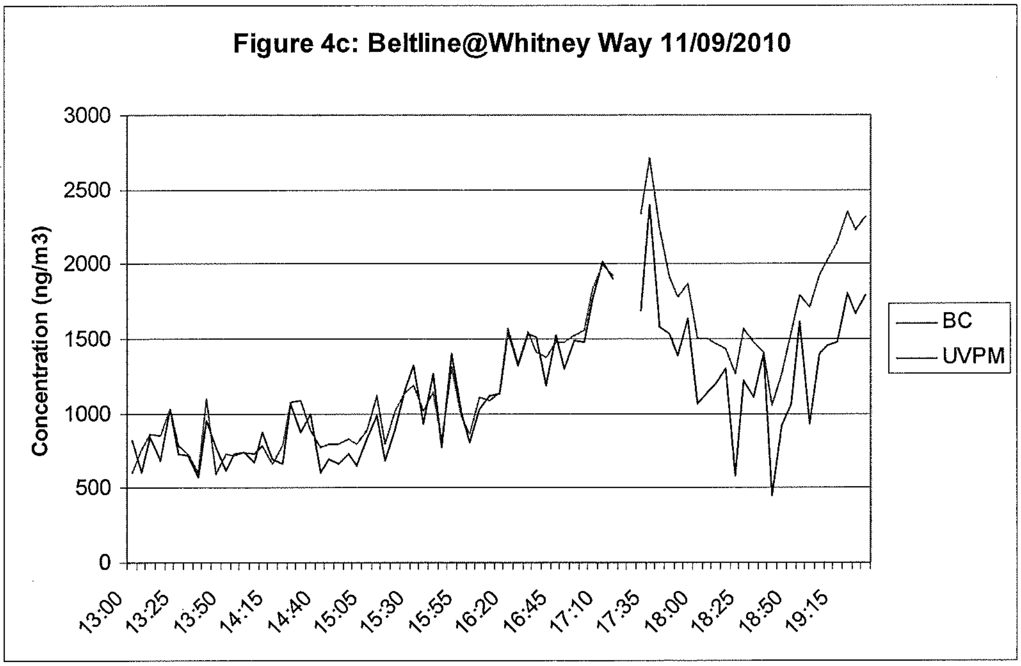


Figure 4c: Beltline@Whitney Way 11/09/2010
Concentration (ng/m3)
3000
2500
2000
1500
1000
500
0
13:00
13:25
13:50
14:15
14:40
15:05
15:30
15:55
16:20
16:45
17:10
17:35
18:00
18:25
18:50
19:15
BC
UVPM

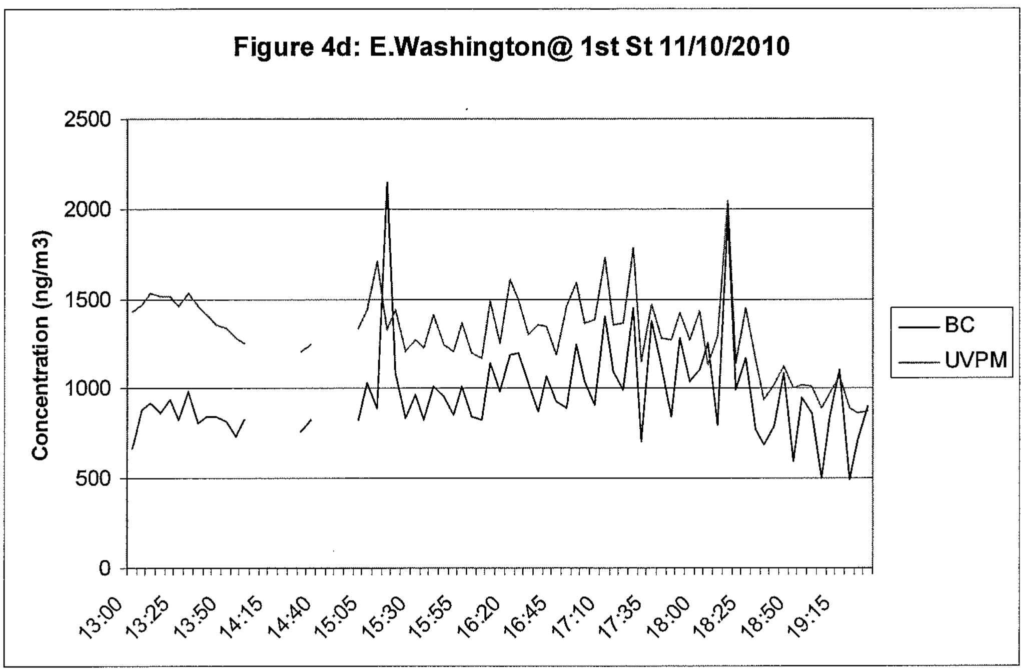


Figure 4d: E.Washington@ 1st St 11/10/2010
Concentration (ng/m3)
2500
2000
1500
1000
500
0
13:00
13:25
13:50
14:15
14:40
15:05
15:30
15:55
16:20
16:45
17:10
17:35
18:00
18:25
18:50
19:15
BC
UVPM

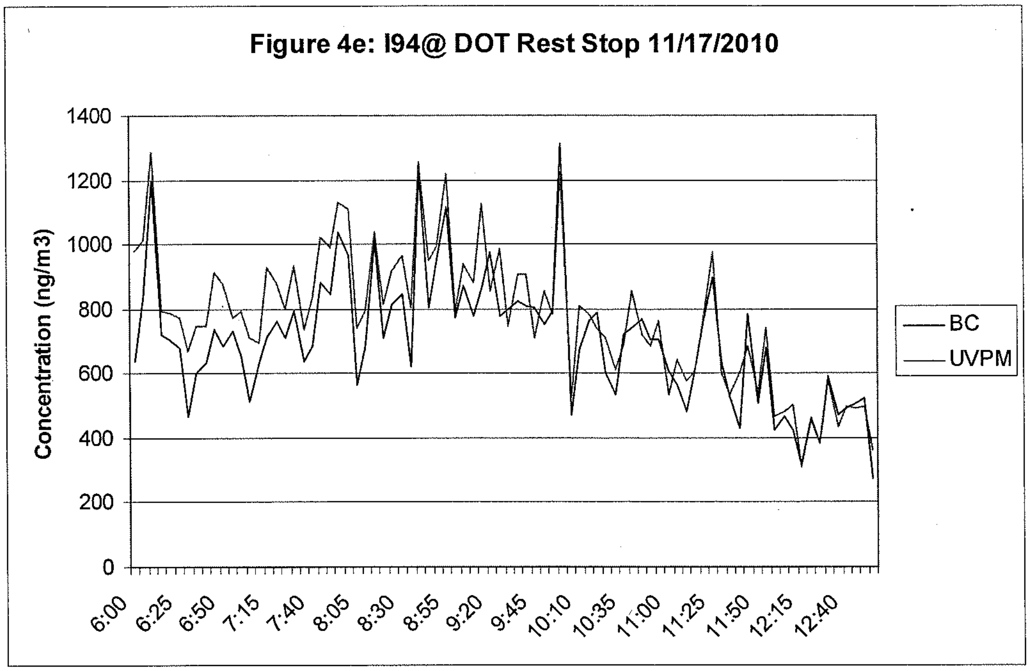


Figure 4e: I94@ DOT Rest Stop 11/17/2010
Concentration (ng/m3)
1400
1200
1000
800
600
400
200
0
6:00
6:25
6:50
7:15
7:40
8:05
8:30
8:55
9:20
9:45
10:10
10:35
11:00
11:25
11:50
12:15
12:40
BC
UVPM

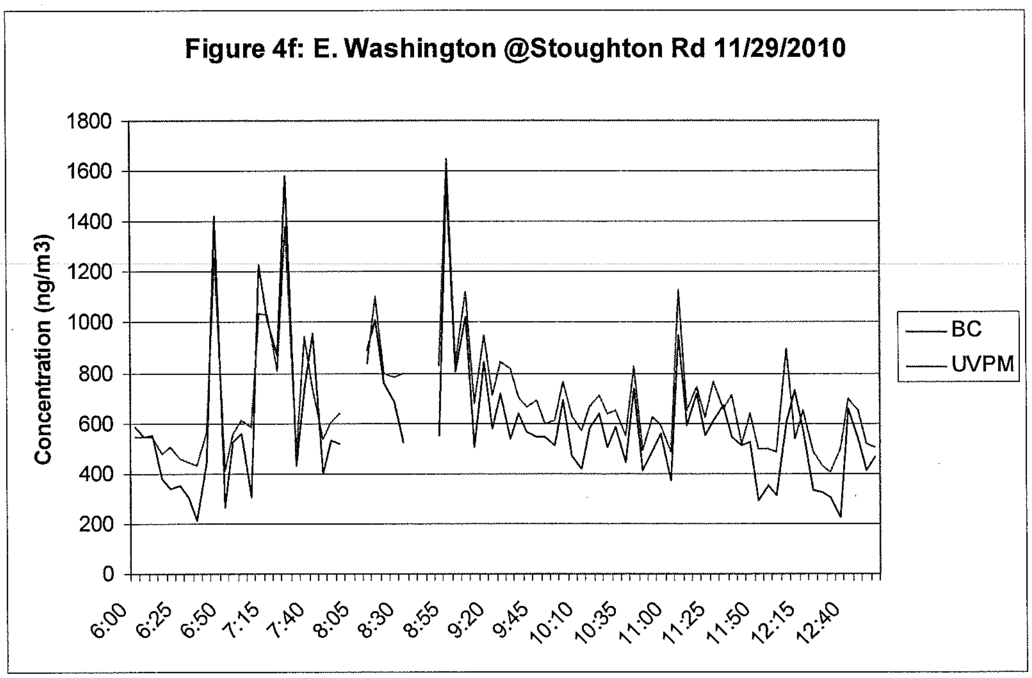
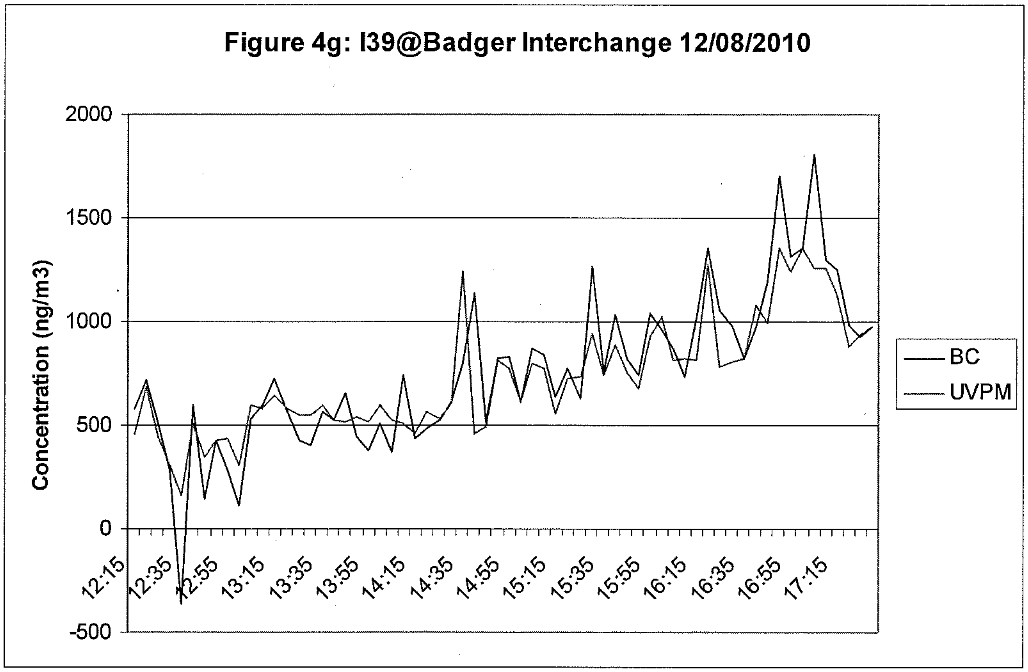


Figure 4f: E. Washington @Stoughton Rd 11/29/2010
Concentration (ng/m3)
1800
1600
1400
1200
1000
800
600
400
200
0
6:00
6:25
6:50
7:15
7:40
8:05
8:30
8:55
9:20
9:45
10:10
10:35
11:00
11:25
11:50
12:15
12:40
BC
UVPM

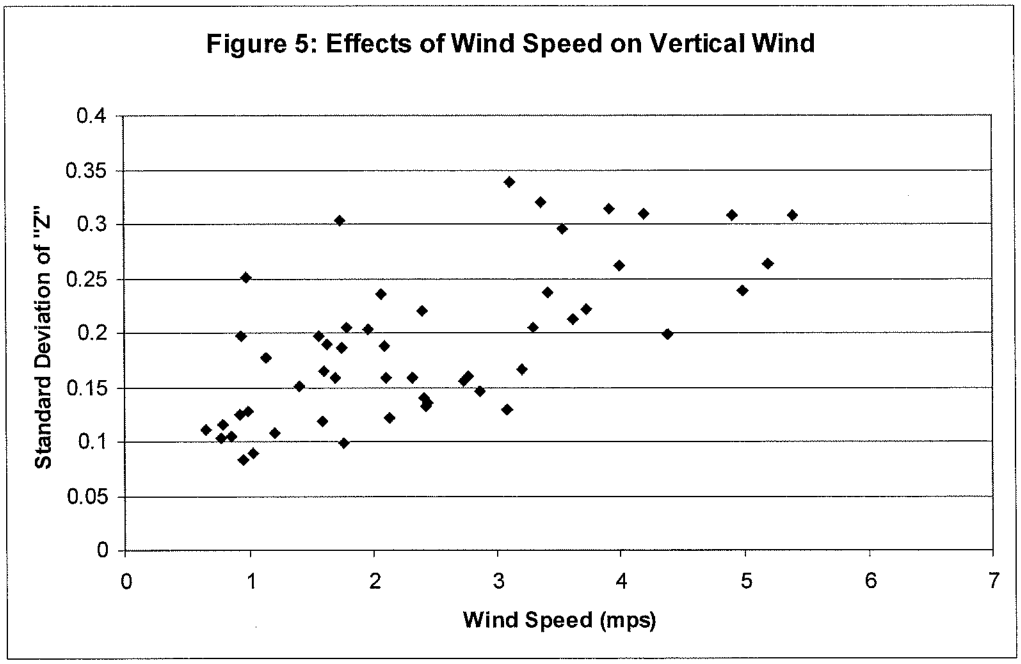


Chi Effects

The trailer is equipped with a three dimensional meteorological sensor system that allows examination of the effect of vertical winds on pollutants. The vertical component of the wind is measured along the "Z" orthogonal axis and is converted to the Chi angle. The Chi angle is the angle of attack of the wind. A true horizontal wind would strike the sensor at 90 degrees. Winds of less than 90 degrees are rising as they strike the sensor and those greater than 90 degrees are falling when striking the sensor.

The variability of the vertical wind component can be used as a measure of the air mixing that may be occurring at the monitoring location. To examine this I looked at variability of the vertical wind as the standard deviation of measurements along the "Z" axis.

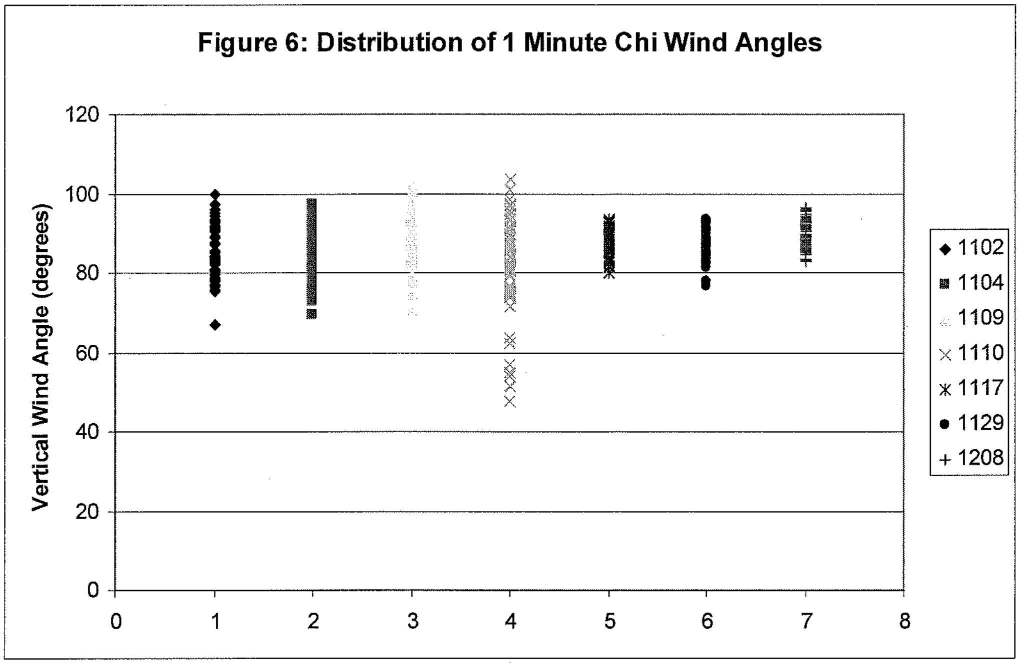
I first examined the relationship between the standard deviation and the wind speed. The hypothesis here is that the standard deviation would be inversely related to the wind speed. Higher wind speed would decrease the vertical variation in the wind. Figure 5 shows a plot of the hourly average standard deviation of the vertical wind component plotted against the hourly average wind speed. The vertical wind deviation shows no clear relationship with the horizontal wind speed. I can not accept my hypothesis and can not make any conclusions on the mixing and wind speeds.



The second analysis looks at the variability and the effect on the range of measured Chi angles. Table 4 shows the maximum standard deviation of the vertical wind component (as "Z") and in Figure 6, I have plotted the one minute Chi angles for the maximum hours on each of the study day. The hour were selected as the having the highest "Z" axis standard deviation for each day. The graph suggests the variability of the Chi angle was greatest on 1110 and smallest on 1117.

Table 4: Maximum Hourly Standard Deviation of the Vertical Wind Component

Date	Maximum Standard Deviation	Maximum Hour
11/02/2010	0.25009	15
11/04/2010	0.33804	5
11/09/2010	0.22031	14
11/10/2010	0.30298	14
11/17/2010	0.21281	11
11/29/2010	0.3084	11
12/08/2010	0.1607	12



The last effect examined is the relationship between the angle of attack and the concentration of pollutants. Five minute data was segregated into up winds (Chi less than 90 degrees) and down winds (greater than 90 degrees). The data was counted, averaged and the 95 % confidence interval calculated. Winds during most study days were dominated by up winds. Only on the 12/08/2010 date were the number of periods with up winds and with down winds approximately equal. Figure Ya through Yc look at pair data for each day comparing the up ("U") and down ("D") winds. The data indicates that with the 95% confidence interval we can not measure statically different data based on the direction of the vertical wind. The reader should be aware that for all days except 12/08/2010, the upward winds were the dominant wind. On 11/29/2010, all wind measured had Chi angles of less than 90%. Only the 12/08/2010 study had Chi angles approximately equally dispersed above and below 90 degrees.

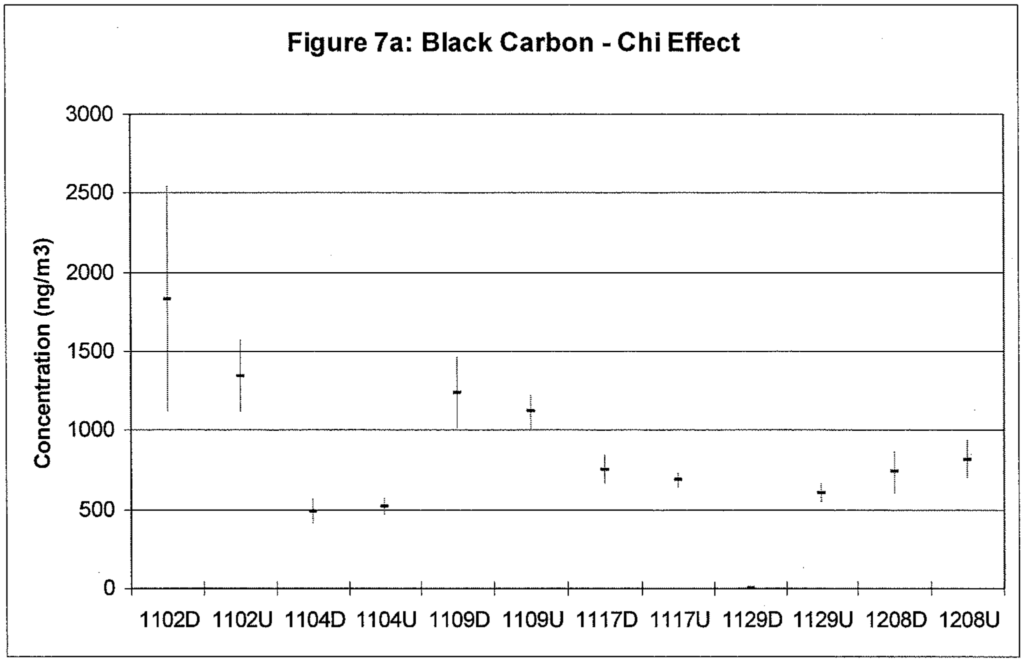


Figure 7a: Black Carbon - Chi Effect
Concentration (ng/m3)
3000
2500
2000
1500
1000
500
0
1102D
1102U
1104D
1104U
1109D
1109U
1117D
1117U
1129D
1129U
1208D
1208U

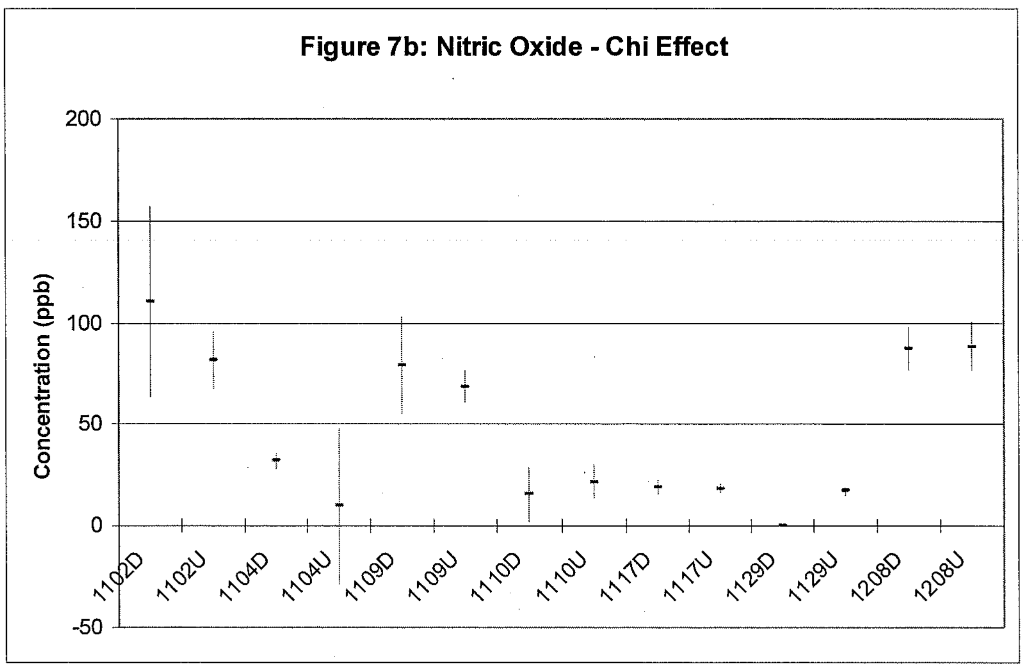
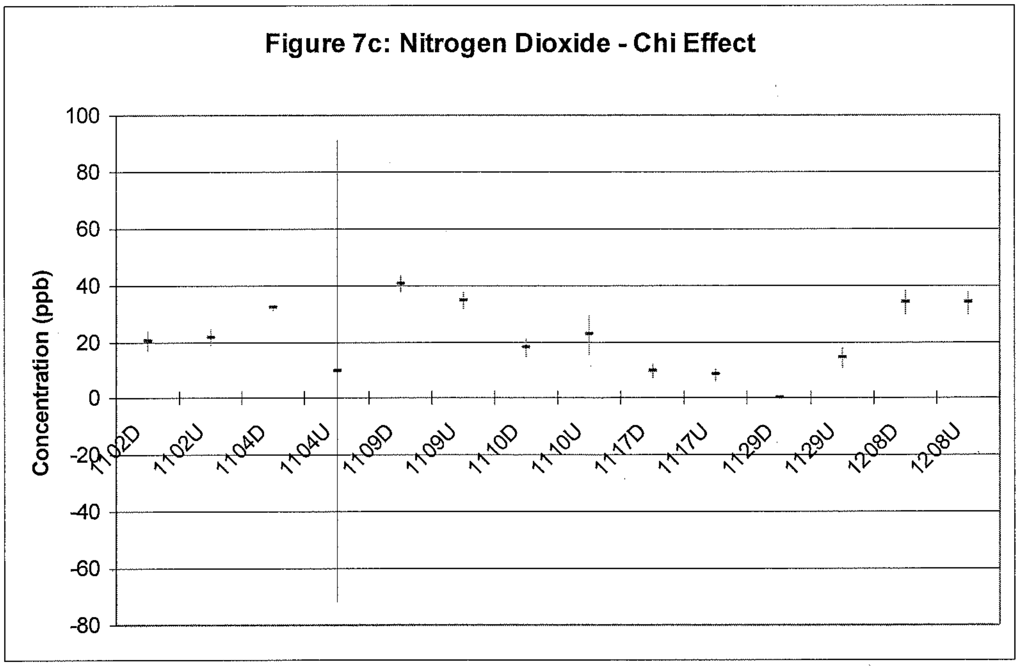


Figure 7b: Nitric Oxide - Chi Effect
Concentration (ppb)
200
150
100
50
0
-50
1102D
1102U
1104D
1104U
1109D
1109U
1110D
1110U
1117D
1117U
1129D
1129U
1208D
1208U



Operation of the Trailer's support and Analytical Systems
Both the Aethalometer and oxides of nitrogen analyzer operated as expected. There was a small amount of data lost, but this was primarily due to generator failure. The metrological sensors functioned well. Some data was lost due to data logger problems, but this was minimal. To minimize the data loss, I manually downloaded the meteorological data each hour. If a logger problem developed, I was able to quickly reset the logger to correct the problem. The GPS and electronic compass functioned very well providing location and orientation information.

The generator functioned well, but I did experience some problem with fuel freeze-up. The large generator consumes the fuel quickly allowing the unused gas to expand in volume. The expansion is endothermic cooling the gas tanks. During operations, I noted the buildup of an ice layer on the exterior tanks walls. The freeze-up problem can result in the generator being starved of fuel resulting in a shut down. I have developed a protocol of switching tanks frequently and this has minimized the problem. On the last and coldest study day, the system operated well until late in the day when the outside temperature and the fuel cooling results in repeated generator failures. I was forced to discontinue monitoring approximately one hour earlier than planned.

The trailers UPS system is expected to provide a buffer in the event of a generator failure. However, the UPS failed to function when the trailer was operating on generator power. This is a problem that has not yet been resolved in an acceptable way.

Quality Assurance and Data Processing

The Magee Aethalometer is a factory calibrated system. Prior to this study the analyzer was checked using established protocols. These protocols are detailed in the Wisconsin DNR's Standard Operating Procedure (SOP) for this analyzer.

The API 200E was operated in a manner consistent with the manufactures manual. Multipoint verifications of the analyzer calibration were performed before and after the study. In addition, a single point span check was performed during the study period. Verification data is included in Appendix D to this report.

The Campbell Sonic Anemometer Sensor is a factor calibrated system. The sensor was mounted on a mast above the trailers roof deck. The sensor was aligned using an electronic compass mount in tandem with the Campbell sensor. Criteria for the sensor was for azimuth to be +/- 4 degrees from north, pitch and yaw to be +/- 2 degree from horizontal.

All data was averaged using conventional Wisconsin DNR rules of 75% capture for completeness. A minimum of 4 one minute averages were required for each five minute average and a minimum of nine 5 minute averages were required for each hourly average. All averages were arithmetic. Meteorological data was first arithmetically averaged as vector quantities and then converted from orthogonal coordinates to conventional spherical coordinates.

Conclusion:
The RWM/PAMS trailer worked very well for investigation of black carbon and oxides of nitrogen along roadways. The utility trailer platform used for the mobile laboratory proved easy to tow and to position for the monitoring operations. I was, in all fall studies, able to position the trailer in a location very close to the target roadway. All studies were conducted well within a 50 meter distance from the roadway. Set-up of the sampling probes and the meteorological sensor mast worked as expected. The electronic compass proved very useful in getting an optimum alignment of the CSAT meteorological sensor.
The analyzers operated well and data meet operational goals. The trailing system worked well, although I did experience generator problems late in the day on the 12/08/2010 monitoring day.

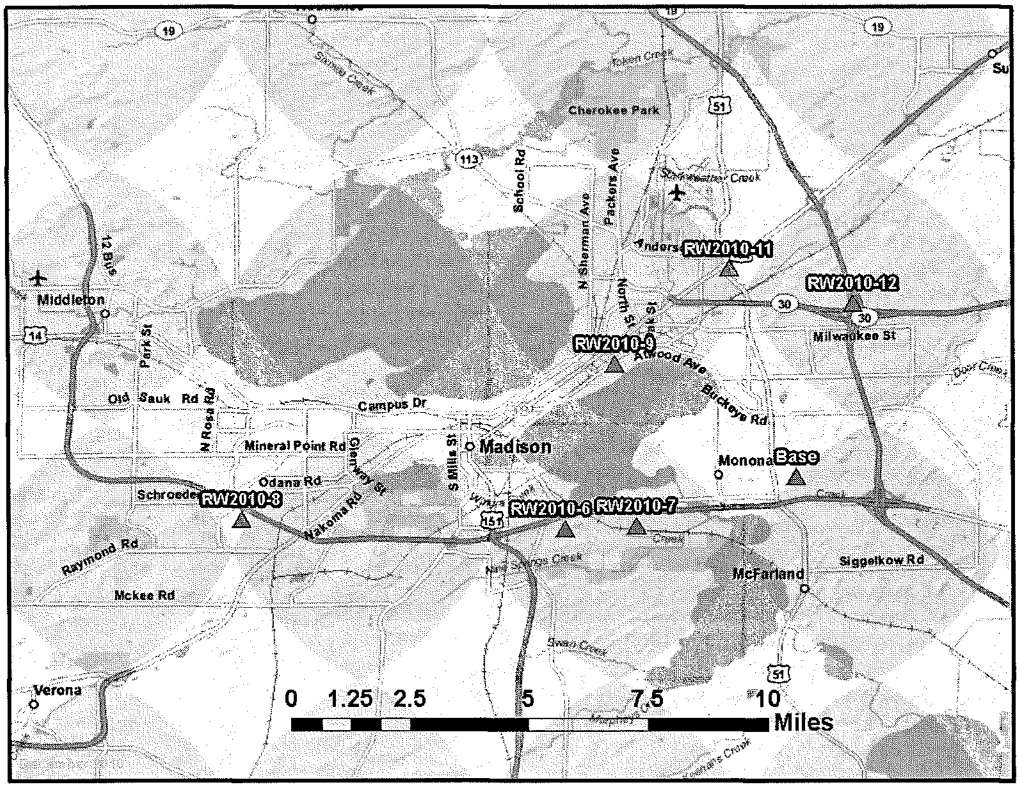
The highest concentrations were seen along the urban expressway. High concentrations were also seen at the urban traffic corridor and on the interstate roadways. The measured concentrations were influenced by the traffic count and measured concentrations were typically highest during the highest traffic period. The traffic count was not a dominant factor between locations and dates. Other factors including weather conditions and traffic flow appeared to have a greater influence on the concentrations measured between studies.

The one hour nitrogen dioxide concentrations measured were less than 50% of the new standard. While the monitoring here is limited it seems unlikely that any of the studied roadways would reach concentrations at the level of the new standard.

The UVPM channel of the Aethalometer provided some added value to the black carbon data. The measurements suggest that some sites will have multiple sources of black carbon. This seems to be especially true of sites in crowded urban sites. At the more isolated interstate highway site, the black carbon and UVPM channels showed the least difference indicating the vehicular traffic as the only source of black carbon emissions.

Analysis done in this report of the Chi angle suggests that the measurement provides little additional information. There is no indication that the angle of the wind affects concentrations measured. Or that the vertical window deviation relates to concentration measured. Wind direction and wind speed appear to be more critical parameters.

Appendix 1: Map and Photos of monitoring sites



Green triangles show the monitoring locations for these studies. Monitoring at RW2010-10 conducted on 11/17 is not shown on this map. The RW201-10 monitoring was conducted at a location approximately 33 miles east of the RW2010-12 site.

Table A1: Locations Position Information

Summary	Date	Primary Road	Cross Road	AveLat	AveLong	AveElev
RW2010-6	11/02/2010	Beltline	Rimrock Road	4302.5148	8922.5080	262
RW2010-7	11/04/2010	Beltline	Southtowne Road	4302.6010	8920.9695	268.6
RW2010-8	11/09/2010	Beltline	Whitney Way	4302.803	8928.3731	306.55
RW2010-9	11/10/2010	E.Washington Ave	First Street	4305.4837	8921.6666	262.7
RW2010-10	11/17/2010	I94	WDOT Rest Area	4305.2101	8852.4833	254.1
RW2010-11	11/29/2010	E.Washington Ave	Stoughton Road	4307.0166	8919.5053	273.2
RW2010-12	12/08/2010	I39	Badger Interchange	4306.6449	8917.1237	315.25

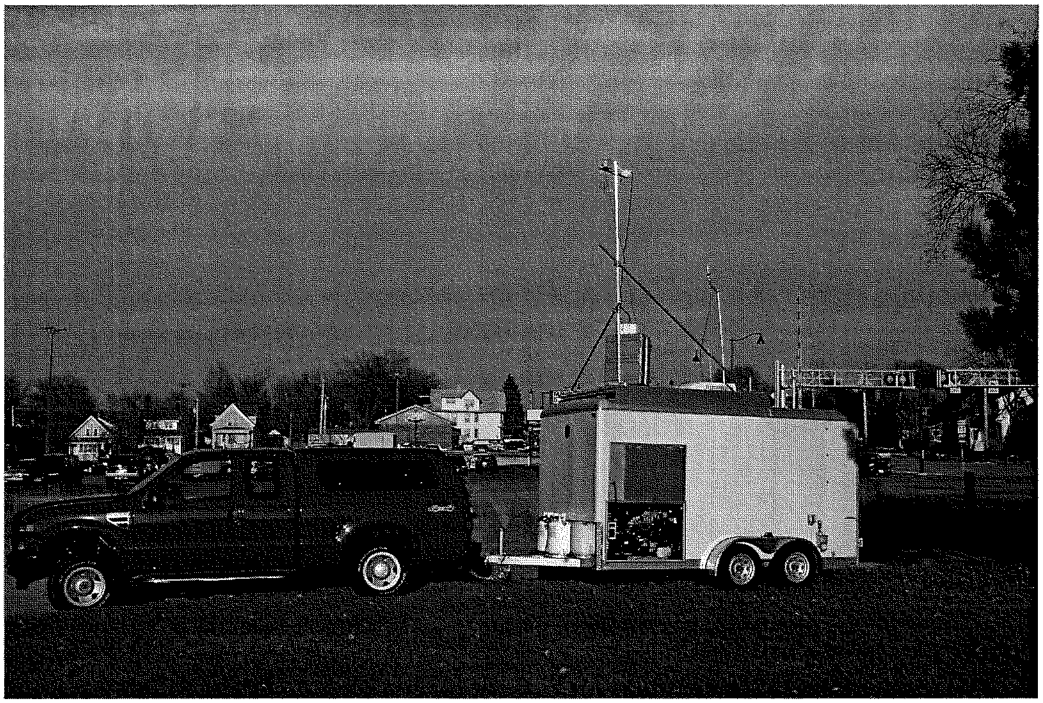


Photo of trailer at the East Washington Avenue and First Street locations. Trailer's sampling probes and meteorological sensors are deployed. Generator compartment is shown open. Roadway is shown on the right side of the photograph.

Appendix B: Meteorological Measurements

Meteorological measurements were made using a Campbell CSAT sonic anemometer and are logged on a Campbell data logger. The CSAT's primary use is to measure the turbulent fluctuations of horizontal and vertical wind. Three dimensional wind measurements made using the CSAT are collected as three orthogonal vectors Ux, Uy, and Uz. Where Ux is the north south axis of the horizontal wind, Uy is the east west axis, and Uz is the axis transectioning the horizontal plane.

Vector data is converted to spherical coordinates of *Rho* (speed), *Theta* (azimuth), and *Chi* (elevation). A diagram of the spherical coordinates is shown in Figure 1. Conventions for the three vectors are given in Table 2.

Table 2: Conventions for Orthogonal Wind Vectors
Ux >0 when wind originates from the north and <0 when wind originates from the south.
Uy >0 when wind originates from the west and <0 when wind originates from the east.
Uz>0 when wind originates from the above and <0 when wind originates from the below

Wind is conventionally measured as speed and direction. Wind direction is defined by a compass circle placed on a horizontal plane. Winds measured in three directions are reported as speed and two spherically define coordinates. The speed is designated as *Rho*, and is reported in meters/second. The azimuth or *Theta* angle is the conventional planar circle. The elevation or *Chi* is the angle of the wind from the horizontal plane. Conventions for naming wind use the direction of travel. Thus a two dimensional wind of 45 degree is designated a "northeast wind". The *Theta* angle for the wind is treated similarly. The *Chi* angle also is name by the direction of travel. A *Chi* of >90 degrees is said to be a downward wind and a wind of <90 degrees is said to be an upward wind.

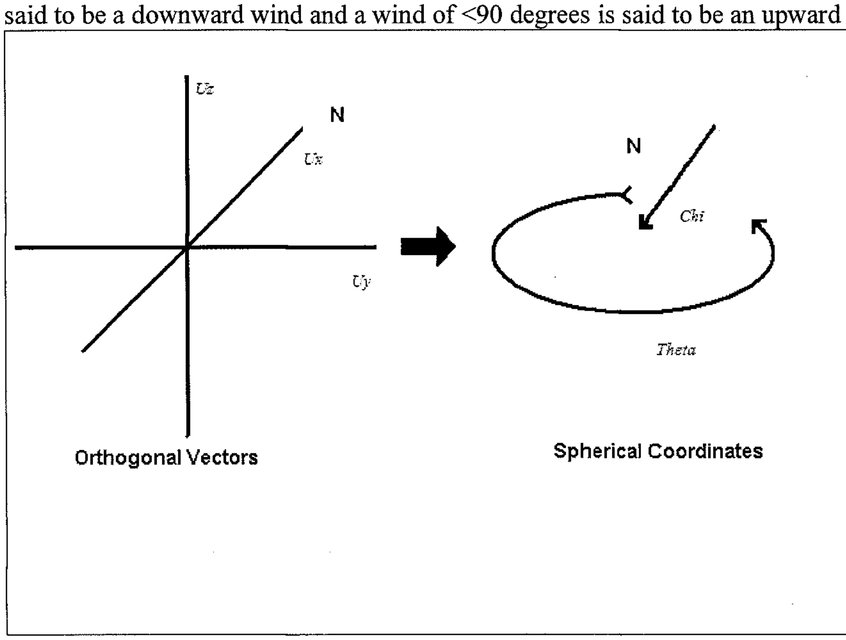


Figure B1. The transformation of orthogonal coordinates to spherical coordinates.

Appendix C: Traffic Counts Date

Hourly traffic data was obtained from the Wisconsin Department of Transportation. That hourly data is reported as positive, negative and total. WDOT conventions for report data are NB/EB are positive and SB/WB are negative. When multiple highways fall on the same route, the lowest number and highest classification wins. Site used for the Fall 2010 studies are provided in Table C1. The Wisconsin DOT was contacted for GPS coordinates for the roadway sensors, but was unable to provide the requested position data.

Table C1: WDOT Traffic Count Sites

WDOT Site	Location Description	Monitoring Link	Study Date
130004	I-39-90 - AT CTH BB N OF USH 12-18 - COTTAGE GROVE	RW2010-12	12/08/2010
130011	USH 12-18 -1.0 MI E OF CTH BW - MADISON BELTLINE	RW2010-6	11/02/2010
130032	USH 151 - BETWEEN YAHARA RIVER & STH 113 - MADISON	RW2010-9	11/10/2010
130259	I-39-90-94 N OF USH 151 - HOEPKER RD	RW2010-12	12/08/2010
130587	USH 12-14 WEST OF HIGHPOINT RD	RW2010-8	11/09/2010
670101	I-94 WEST OF STH 67 - OCONOMOWOC LAKE	RW2010-10	11/17/2010
130011	USH 12-18 -1.0 MI E OF CTH BW - MADISON BELTLINE	RW2010-7	11/04/2010
130032	USH 151 - BETWEEN YAHARA RIVER & STH 113 - MADISON	RW2010-11	11/29/2010

Appendix D: Quality Control Information

Table D1: Oxides of Nitrogen Analyzer Calibration Verification

Pre- Studies 10/21/2010 — Post Studies12/20/2010

Nitric Oxide Calibration Linearity Verification

NO exp conc (ppm)	NO observed ppm	Delta ppm	% difference	NO observed ppm	Delta ppm	% difference
0.0000	0.0011091	0.0011	NA	0.001	0.001	NA
0.4000	0.3824394	-0.0176	-4.4%	0.382	-0.018	-4.6%
0.3500	0.3342948	-0.0157	-4.5%	0.336	-0.014	-3.9%
0.2500	0.2392087	-0.0108	-4.3%	0.239	-0.011	-4.2%
0.1500	0.1445394	-0.0055	-3.6%	0.145	-0.005	-3.6%
0.0750	0.0739871	-0.0010	-1.4%	0.074	-0.001	-1.9%
Average			-3.6%			-3.6%

Total Oxides of Nitrogen Calibration Linearity Verification

NOx exp conc (ppm)	NOx obs, ppm	Delta ppm	% difference	NOx obs. ppm	Delta ppm	% difference
0.000	0.000	0.000	NA	0.000	0.000	NA
0.400	0.383	-0.017	-4.2%	0.385	-0.015	-3.8%
0.350	0.336	-0.014	-3.9%	0.338	-0.012	-3.3%
0.250	0.241	-0.009	-3.8%	0.241	-0.009	-3.6%
0.150	0.144	-0.006	-3.7%	0.146	-0.004	-2.7%
0.075	0.073	-0.002	-2.5%	0.073	-0.002	-3.0%
Average			-3.6%			-3.3%

Nitrogen Dioxide Conversion Efficiency

Lamp Setting (O3 conc)	NO2 exp.conc (x3)	NO2 observed (ppm) (y3)	NO2 delta ppm	NO2 % difference	NO2 exp.conc (x3)	NO2 observed (ppm) (y3)	NO2 de ppm
0.000	0.001	0.003	0.002	NA	0.001	0.000	
0.390	0.445	0.413	-0.033	-7.3%	0.448	0.418	
0.200	0.242	0.223	-0.018	-7.5%	0.237	0.224	
0.075	0.093	0.085	-0.008	-8.4%	0.090	0.088	
Average				-7.7%			

Table D2: Analyzer Span Check

Date:12/07/2010	Expected Concentration			Measured Concentration			% DIFF		
POINT	NOX	NO	NO2	NOX	NO	NO2	NOX	NO	NO2
1	400	400	0	387.0	382.9	4.1	-3.3%	-4.3%	
2	450	450	0	431.1	429.8	1.4	-4.2%	-4.5%	
3	450	250	200	429.9	214.6	215.3	-4.5%	-14.2%	7.7%
4	0	0	0	0.3	1.4	-1.1			

DATE: Tuesday, February 15, 2011 FILE REF: AT2011

TO: Bart Sponseller – AM/7
Jason Treutel – AM/7

FROM: Mark K. Allen – AM/7

SUBJECT: Comparison of Roadway Trailer Aethalometer with the Biomass Study Aethalometer

The Aethalometer is an analytical instrument designed for the measurement of Black Carbon (BC). Black carbon is an air pollutant produced from the combustion of carbon based fuels. Both elemental and black carbon are components of fine particulate matter (PMfine) that can enter deeply into the lungs and cause tissue damage. In the Aethalometer, the black carbon measurement is made by optical attenuation. The air sample is drawn into the analyzer and through a spot on a quartz filter tape. Particulate carbon black deposits on the filter. The analyzers light beam is passed through the spot on the filter tape and the quantity of carbon is measured by the decrease in the light energy.

The Magee AE22 dual wavelength analyzer measures at two optical wavelengths. The first measure of black carbon is made at an optical absorption of 880 nm. A second measure is made at 370 nm and this is designated as the 'UVPM' concentrations. The UVPM is thought to be a measure indicative of aromatic organic compounds. Examples of aromatic organic carbons include tobacco smoke, PAH mixtures, smoke from wood and other biomass-burning. Continuous measurements are made on a quartz filter tape as particulate matter loads. When the loading threshold is exceeded the instrument will advance the quartz tape, moving unexposed filter into place, and will then begin loading a new spot on the tape.

A summer 2010 study at the Wisconsin DNR's Cassville monitoring station concluded that two Aethalometers used by the Wisconsin DNR made similar measurements, but also concluded that the two analyzers show significant differences. The report stated that it would be difficult to compare measurements made at Cassville with black carbon measurements made in other areas of Wisconsin. The report noted that there is no direct way to challenge the Aethalometers and therefore the operators had only a limited numbers of indicators that the instrument is operating as expected. The operator could not assume one analyzer was more correct than the other.

I noted in that report that I planned to continue working to implement measures to improve confidence in all Wisconsin DNR Aethalometer measurements. This memorandum will report on a follow up study to again evaluate Wisconsin's two Aethalometers, operated as collocated analyzers.

Study Protocols:
The study was conducted on board the Roadway PAMS Monitoring trailer (RWM/PAMS). The RWM/PAMS trailer's base station is the Wisconsin DNR's Science

and Operations Center (SCIOPS) located on the southeast side of Madison. The RWM/PAMS trailer was operated at the SCIOPS facility for the entire study.

The two Wisconsin Aethalometers used in this study were serial number 8550805 and 9300301 (hereafter 805 and 301). Analyzer 805 was purchased by the Wisconsin DNR in September 2008 for the roadway studies. The analyzer has been used at several WDNR sites including the Madison East site and the Milwaukee Headquarter site. This analyzer has also been used in a number of roadway studies. Analyzer 301 was provided to the WDNR as a loan through LADCO. It was provided solely for the Biomass Study.

The two Aethalometers were installed in the RWM/PAMS trailer. Sampling lines extended from the analyzer outside the trailer and both sampling inlets were mounted on a support mast. Each sampling line had a BGI SCC 1.829 cyclone at the end of the sampling line. Aethalometer 805 had the original black plastic 3/8" sampling line. Aethalometer 301 came to the Wisconsin DNR without a sampling line and a green plastic 3/8" sampling line from a retire TEOM analyzer has been used for the analyzer's sampling line. After installation the analyzer operations were check according to protocols in the Wisconsin DNR's draft SOP.

The study was conducted from January 6, 2011 to January 18, 2011. The study was divided into three periods. In the first period the analyzers were operated as installed. In the second period, the sampling lines of the analyzer were switched. In the third period the analyzers were returned to the configuration at the original installation.

Results:
Data from the three study periods is summarized in Table 1. The data is shown graphically first in Figures 1a and Figure 1b, which show the results as the average and the upper and lower 95% confidence interval. Figure 2a, 2b, and 2c show a time series comparison of the two analyzers BC channel. Finally Figure 2a, 3b, and 3 c show a time series comparison of the two analyzers UVPM channel.

Table 1: Aethalometer Comparison Study				
Analyzer	805	805	301	301
Channel	BC	UV	BC	UV
Period A	Start 01/6/11 13:05		End 01/10/11 13:25	
Count	1149	1149	1130	1130
Average	256	447	349	532
Median	199	352	286	442
Min	-60	39	-1790	-414
Max	2954	2785	4391	3817
StdDev	226.79	370.89	291.86	443.10
Period B	Start 01/10/11 13:45		End 01/13/11 13:40	
Count	860	860	858	858
Average	374	487	353	424
Median	266	351	252	329

Min	-74	65	-149	-50
Max	4763	4541	4026	3890
StdDev	421.78	463.93	394.28	375.02
Period C	Start 01/13/11 14:05		End 01/18/11 8:05	
Count	1363	1363	1353	1353
Average	393	518	551	650
Median	357	467	514	606
Min	-174	-111	-147	-53
Max	2137	2925	3074	3185
StdDev	289.46	359.13	380.80	396.15

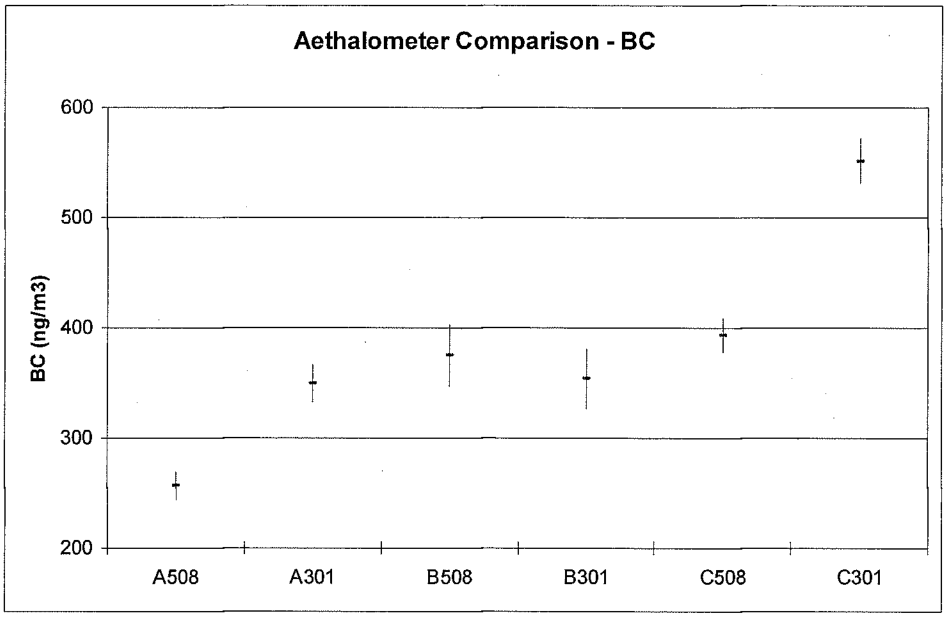


Figure 1a: Black Carbon channel summary data as mean and 95% confidence interval.

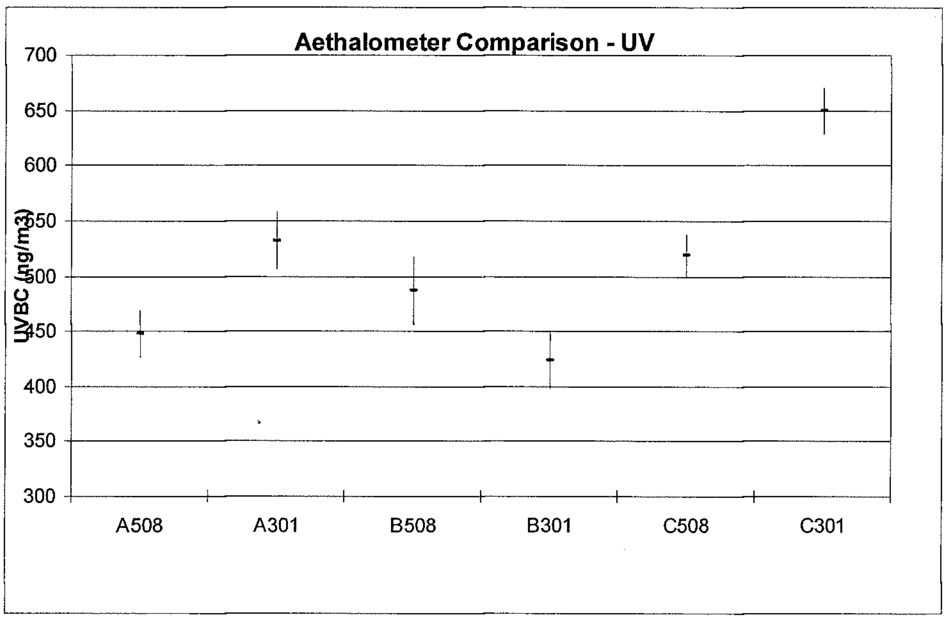


Figure 1b: UV particulate matter channel summary data as mean and 95% confidence interval.

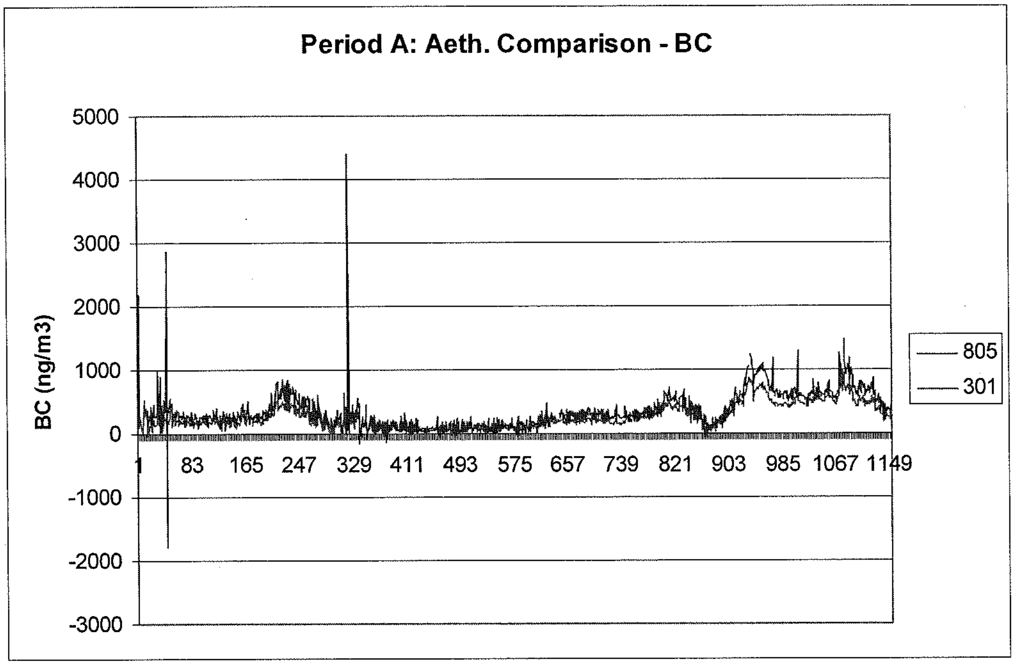


Figure 2a: Time series of analyzer response

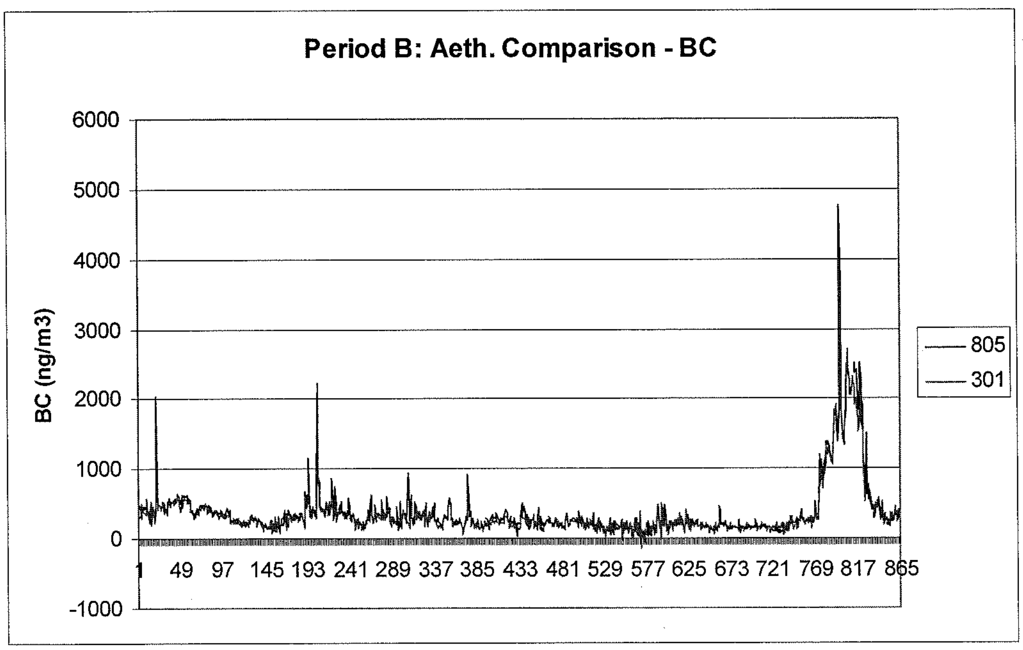


Figure 2b: Time series of analyzer response

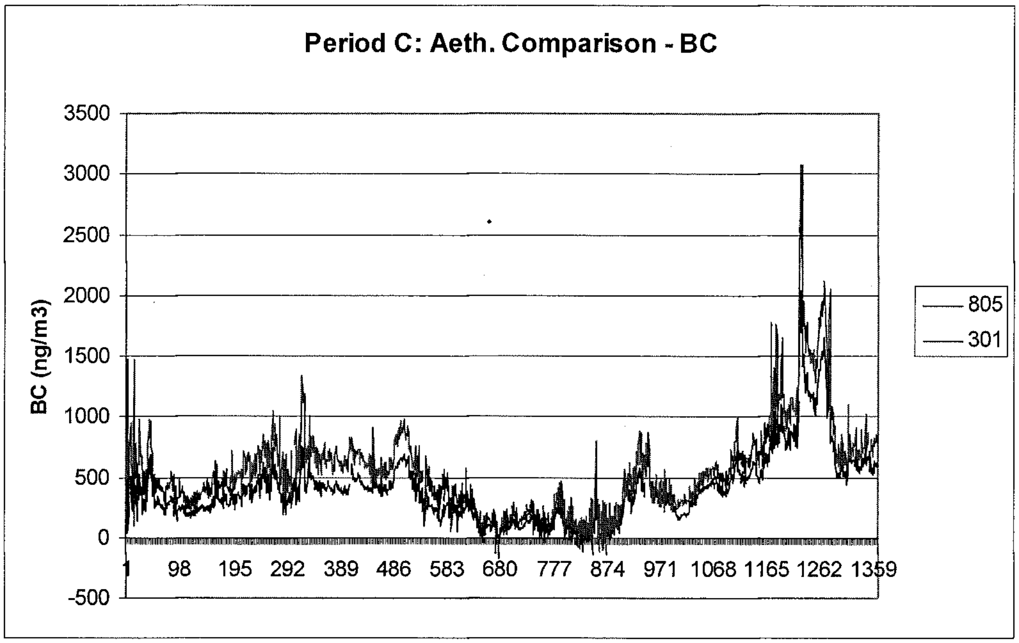


Figure 2c: Time series of analyzer response

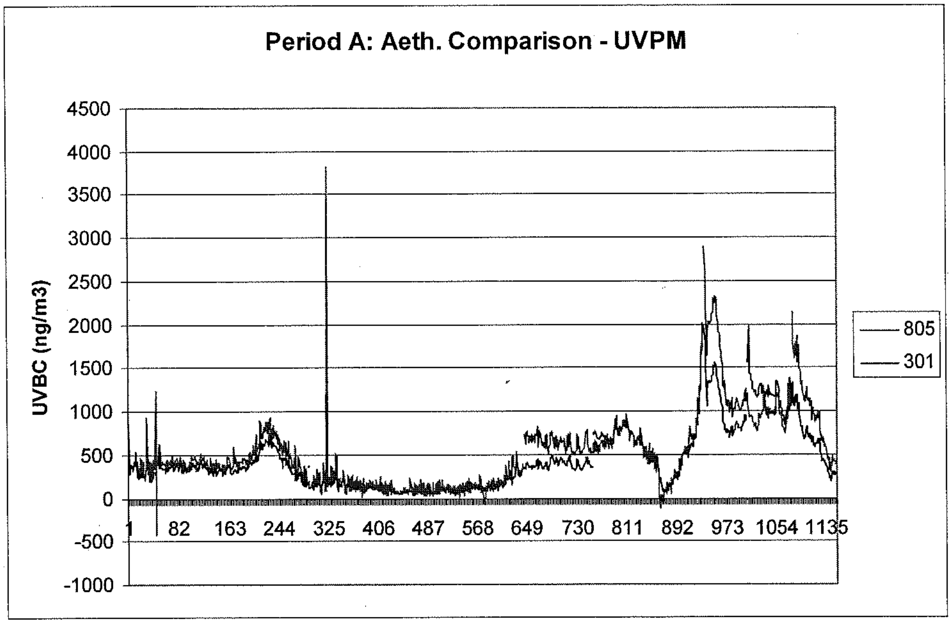


Figure 3a: Time series of analyzer response

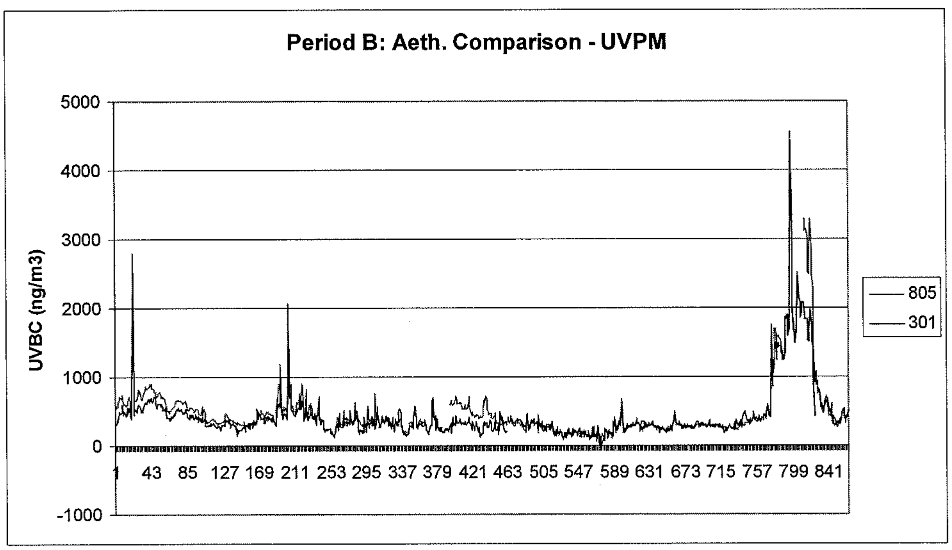


Figure 3b: Time series of analyzer response

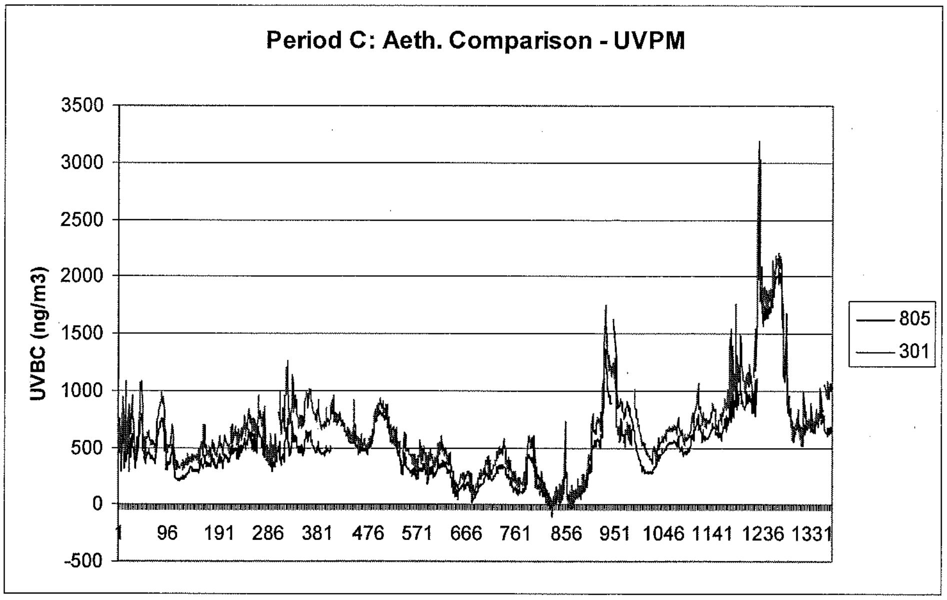


Figure 3c: Time series of analyzer response

Conclusions:
The time series analysis shows that the two Aethalometers track very well on both the black carbon and the UV particulate matter channels. There is more variability or noise seen in analyzer 301 than is seen in analyzer 805. I have spoken to Mr. Gary Bridges at the Magee Company about the variability seen in analyzer 301's response. Gary told me that based on the serial number he believes that analyzer 301 is a Model AE21. The Model AE21 has older electronic and is therefore more susceptible to noise in the response.

Looking at the summary statistic we see that there is a bias between the two analyzers. In period A & C analyzer 805 is significantly lower than analyzer 301 at the 95% confidence limits. Interesting the bias reverses when the sampling lines are reversed and in Period B, analyzer 805 reports higher concentrations. I also note that in Period B the black carbon measurements are not significantly different when evaluated over a 95% confidence interval. The UVPM measurements in Period B are significantly different.

Recommendations:
The results of the January 2011 study support the early comparison study. The time series analyses suggest that the two Aethalometers are making similar measurements of the black carbon and UVPM. The study also supports the conclusion of a bias between the two Aetholmeters. The two analyzers show significant differences that would make it difficult to compare measurements at Cassville with black carbon measurements made in other areas of Wisconsin, with analyzer 805. The reversal of the bias shows the importance of the sampling line and sampling inlet to the measurement process. I am strongly recommending that in any study where multiple Aethalometers are used the following protocol be used. First, that a standard sampling line and inlet configuration be used when operating all analyzers in the study. The analyzers should also be operated in a collocated configuration at some time during the study to establish any bias between the analyzers.

Appendix B: Detailed Project Timeline

Mobile Monitoring Trailer for Air Monitoring Near Roadways EPA Grant: XA-00E46301 Milestones		
Reporting Quarter	Work Description Summary	Project Status
2007 – Q2	April, the Wisconsin DNR submits the proposal "Development and Testing of a Mobile Monitoring Trailer for Improved VOCs and Particulate Carbon Monitoring Near Roadways" The proposal was submitted under the Application Category, "Method Development and Evaluation". The Wisconsin DNR proposes developing a mobile monitoring trailer to house a gas chromatograph and a particulate carbon monitor. When developed the unit will be tested to demonstrate that data quality meet the needs of modelers and risk assessors. The trailer will provide short-term hourly measurements necessary for studying dynamic emissions and atmospheric processes. It will also provide high quality measurements at multiple locations needed to assess the public's risk.	Proposal submitted
2008 – Q1	In February, the Wisconsin DNR is informed the proposal was selected for funding. A date for the start of the funding is not provided.	Proposal selected
2008-Q2	Wisconsin is awarded a Community Assessment Monitoring grant to start on 07/01/2008. The total grant funding is 115,930.00	Proposal Funded
2008-Q3	Wisconsin staff began work on new project funded by an EPA Community Assessment Monitoring (CAM) Grant. Work included developing work guidance documents and equipment purchasing requests. A Magee Aethalometer was purchased for the project.	Project begins
2008-Q4	The project Aethalometer has been temporary placed at Wisconsin Madison East site (55-025-0041) for	Project continuing with purchase and testing of

	initial testing. The Aethalometer has worked as expected and has yielded some interesting results. Measurements between September 14 and December 31, 2008 yield 4261 records, black carbon concentrations averaged 575 ng/m3 and averaged 5.3% of the measured PM2.5. Other project work completed this quarter included issuing purchase orders for the study trailer and for a 10 kW generator to supply power to the trailer.	equipment.
2009-Q1 Mobile Monitoring Trailer for Air Monitoring Near Roadways/ XA-00E46301	Continued testing of the Magee Aethalometer at WI's Madison East site (55-025-0041). Received a 14 ft, dual axial, trailer to be used in the study. The trailer was transferred to a contractor for the installation of a 10 kW generator to supply power to the trailer. Hired the LTE to develop the support system necessary for the analytical instrumentation to be used in the trailer.	Project continuing with receipt of trailer platform and continued testing of equipment. Also hired additional staff for the project. Planning for trailer to be used in the support of the 2009 summer PAMS monitoring.
2009-Q2 Mobile Monitoring Trailer for Air Monitoring Near Roadways/ XA-00E46301	Extensive work was completed to configure a mobile monitoring laboratory in a 14 ft, dual axial, trailer to be used in the study. A contractor completed the installation of a 10 kW generator to supply power to the trailer. The trailer now houses a gas chromatograph, an Aethalometer, and a three dimensional wind speed and direct sensor. The trailer was deployed to Milwaukee where it will service the PAMS site by supplying hourly measurements of VOCs and carbon black. PAMS data will be evaluated to demonstrate the validity of the trailer's measurement system.	Project continuing with completion of trailer laboratory platform and initial testing of equipment in the trailer. Trailer was used in the support of the 2009 summer PAMS monitoring.
2009-Q3	During the second and third quarter	Work continuing,

Mobile Monitoring Trailer for Air Monitoring Near Roadways/ XA-00E46301	the trailer was deployed to Milwaukee where it serviced the PAMS site by supplying hourly measurements of VOC and carbon black. Data from the summertime operation is being reviewed. PAMS data collected with the trailer will be evaluated to demonstrate the validity of the trailer's measurement system. At the completion of the PAMS sampling season the AutoGC analytical system failed. Several attempts were made to restart the system with little success. The trailer and the on board analytical systems will be returned to the Wisconsin DNR shop in Madison. The AutoGC system provides critical VOC information for this project and must be working for the trailer to be deployed for roadway measurements.	but problems with the AutoGC system have set back the project timeline. Monitoring on roadways can not begin until all analytical systems are working as expected. Work will continue to correct the analyzer problems and to return the project to the original timeline.
2009-Q4 Mobile Monitoring Trailer for Air Monitoring Near Roadways/ XA-00E46301	The trailer was returned to the WDNR's Madison Science and Operation Center (SCIOPS) for repairs and continued development. While all analytical systems were not working under optimal conditions, the systems were working well enough for some preliminary testing near roadways. In November and December the trailer was used to sample at several points along Madison south commuter express way ("The Beltline"). The generator worked very well and the analytical systems collected data for over 6 hours on each of three sampling days. Work on the next quarter will focus on correcting several operating problems on board the trailer.	Problems with the AutoGC system continue to initially set back the project timeline. Work will continue to correct the analyzer problems and to return the project to the original timeline.
2010-Q1 Mobile Monitoring Trailer for Air Monitoring Near	Wisconsin DNR's first report on these shakedown tests of the system. The January 2010 report covers monitoring in November and	

Roadways/ XA-00E46301	December. In these studies, the trailer was used to sample at several points along Madison south commuter express way ("The Beltline"). Most additional work in this quarter has been directed at improving the trailer's operational systems to begin monitoring in the next calendar quarter.	
2010-Q2 Mobile Monitoring Trailer for Air Monitoring Near Roadways/ XA-00E46301	In April, the Roadway Mobile Air Monitoring Trailer (RWT) was deployed for air monitoring at two interchanges near Madison. The sites were two large highway interchanges. One interchanges was located near two large truck stops. Monitoring was conducted for a total of two work days at each site. Following the RW monitoring the trailer was returned to the WDNR's Madison operation center to be prepared for deployment in Milwaukee for the Summer PAMS monitoring season. Unfortunately the primary VOC analytical system is no longer functioning well enough for the trailer to be deployed for PAMS monitoring.	Project continues with a second series of spring 2010 roadway monitoring studies. Plans for PAMS monitoring in 2010 are delayed by problems with the AutoGC On June 8, 2010 the Wisconsin DNR requested a no-cost extension of this grant until March 2011. This extension will allow additional time to complete the planned monitoring projects.
2010-Q3 Mobile Monitoring Trailer for Air Monitoring Near Roadways/ XA-00E46301	A second report issued on 8/31/2010, covers the April monitoring when the Roadway Mobile Air Monitoring Trailer (RWT) was deployed for air monitoring at two interchanges near Madison. The sites were two large highway interchanges. One interchanges was located near two large truck stops. Monitoring was conducted for a total of two work days at each site. On 9/3/2010, Mark Allen recommended to Bart Sponseller that work with the AutoGC system be terminated. This recommendation was based on the failure of the unit.	Work continues on the project. After consultation with EPA Region 5 staff a decision is made to add a oxide of nitrogen analyzer to the monitoring trailer. This new analyzer was added to help assess nitrogen dioxide emissions. VOC analysis is dropped.

	Bart accepted that recommendation. No additional VOC monitoring will be done until the analyzer is replaced. On 9/22/2010 the trailer was deployed to the Wisconsin DNR's Cassville site for an Aethalometer comparison to support the LADCO sponsored Biomass Emissions Monitoring Study. In late September the WDNR received a new oxides of nitrogen analyzer and installed this in the roadway trailer. A fall round of testing is planned to look at oxides of nitrogen and black carbon emissions near roadways.	
2010 Q4 Mobile Monitoring Trailer for Air Monitoring Near Roadways/ XA-00E46301	On 11/16/2010 Mark Allen issued the final report on the trailer monitoring at Cassville. This report covers the September trailer deployment to the Wisconsin DNR's Cassville site for an Aethalometer comparison. A fall roadway monitoring study was conducted to investigate particulate carbon and oxides of nitrogen concentrations near roadways in Madison. The study was conducted between 11/2/2010 and 12/08/2010. A total of seven sites were monitored. Sites included a high volume urban roadway, an urban expressway, and interstate highways. The studies include over 48 hours of monitoring.	<u>Project continues with a third field study of air quality near roadways.</u> <u>Project to be completed next quarter.</u>
2011 Q1 Mobile Monitoring Trailer for Air Monitoring Near Roadways/ XA-00E46301	A draft report on the fall 2010 roadway monitoring studies is completed. A Aethalometer study is completed to support the LADCO sponsored Biomass Emission Monitoring study. A draft final report on the monitoring project is completed	

Appendix C: RW Trailer Quality Assurance Project Plan

Quality Assurance Project Plan

For

Operation of the Wisconsin's DNR Roadway Monitoring Trailer to Measure Neighborhood Exposures to Benzene, Particulate and Other Mobile Source VOCs

Table of Contents

PROJECT APPROVAL

1. Project Manager

   ______________________________ ________
   Signature Date

2. Monitoring Quality Assurance Officer

   ______________________________ ________
   Signature Date

3. Monitoring Section Chief

   ______________________________ ________
   Signature Date

4. Environmental Science Section Chief

   ______________________________ ________
   Signature Date

5. Director Bureau of Air Management

   ______________________________ ________
   Signature Date

Acronyms and Abbreviations

AD	Absolute Difference
AQS	Air Quality System
ATMP	Air Toxics Monitoring Program
ATD	Automatic thermal desorption system
AUTOGC	Perkin Elmer Ozone Precursor Analysis System
CFR	Code of Federal Regulations
COC	chain of custody
DAS	data acquisition system
DP1	capillary gas chromatography column coated with 100% dimethylsiloxane
DQA	data quality assessment
DQOs	data quality objectives
FSTL	Field Study Technical Leader
GC	gas chromatography
GIS	geographical information systems
GLP	good laboratory practice
HRGC	high resolution (capillary) gas chromatography
LIMS	Laboratory Information Management System
MPA	monitoring planning area
MQOs	measurement quality objectives
MSA	metropolitan statistical area
NIST	National Institute of Standards and Technology
PAS	Passive adsorbent sampler
PC	personal computer
PCS	Passive canister sampler
PD	percent difference
PLOT	porous layer open tubular chromatography column
PM	Project Manager
QA/QC	quality assurance/quality control
QA	quality assurance
QAO	quality assurance officer
QAPP	quality assurance project plan
QMP	quality management plan
SER	Southeast Region
SOP	standard operating procedure
WDNR	Wisconsin Department of Natural Resources

A. PROJECT MANAGEMENT

This monitoring project will develop and deploy a mobile monitoring station that will provide real-time air quality data near selected roadways and in neighborhoods adjacent to the targeted roadways. The projects' goals are to develop and evaluate the station as a tool for studying air quality for time periods from days to weeks. Analyzers in the mobile station will provide data to evaluate benzene, VOC and particulate concentration gradients near roadways. The project will be conducted by the Environmental Analysis and Outreach of the Bureau of Air Management, Wisconsin DNR. The Air Monitoring Section of the Bureau of Air Management will supply critical support for the study. Elements of the project managements are detailed in this section.

A.1 Roles and Responsibilities

Project Manager – Mark Allen will serve as overall project manager for the project.
Field Study Technical Leader – David Grande will oversee the field studies and sample collection.
Field Operations - Southeast District Field Monitoring Staff will be assigned responsibility for the collection of samples and general project operations. This will include the collection of quality control samples.
Data Validation – Data validation will be the responsibility of Mark Allen and David Grande.
Data analysis – Jeff Myers will take lead responsibility in end-use data analysis. Jeff will evaluate the study data in relation to project goals to support exposure risk assessments.

A.2. Distribution List

A read only electronic copy of this document will be available to all WDNR staff through the department's intranet service. Electronic copies of the document will be specifically provided to the individuals listed below. Hardcopies of the document will be placed in the project handbook. The Project Manager and the Field Study Operations Leader will have copies of the project handbook. Additional copies of the project handbook will be placed at the WDNR-SER's air monitoring laboratory.

<u>Electronic Copies of Quality Assurance Project Plan Distribution List</u>
Motria Caudill – Region 5, USEPA
Bart Sponseller- AM/7
Joanie Burns - AM/7
Jerry Medinger - SER
Mark Allen - AM/7
David Grande - AM/7
Jeff Myers – AM/7
Steve Schuenemann - AM/7

A.3. Problem Definition/Background

<u>A.3.1 Problem Statement and Background</u>
Air pollution in the urban environment has been increasingly indicated as a significant factor affecting the public health. Within urban areas, roadway emissions are thought to be very significant and sometimes the most significant source of air pollution. EPA has reported mobile source emissions may account for 50% or more of the cancer risk in

urban areas (Federal Register, Vol. 71). Currently much of the work to document health risks is epidemiological. Studies have shown increased respiratory health problems associated with traffic related air pollutants. There is a yet unproven hypothesis linking an individuals distance from roadway and asthma. While questions exist about risks in relation to one's proximity to roadways, it has been shown that exposure to mobile source emissions increases health problems including cardiovascular disease, respiratory diseases and cancers. Significant risk drivers from mobile sources include benzene and fine particulate matter. Benzene is a ubiquitous aromatic hydrocarbon that is present in gasoline and is also formed in many combustion processes. Benzene is a known human carcinogen and is considered one of the most significant risk drivers in the urban environment. Roadways are also a major source of fine and ultra fine particulate matter. The fine particulate matter (PMfine) can enter deeply into the lungs and cause tissue damage. Diesel emissions are a major source of PMfine. The 1999 National Air Toxic Assessment (NATA) assigned 100% of the diesel PM from mobile sources. Fine particulate matter can also be linked with VOCs. The heavier, less reactive VOCs grouped as "aromatics" have been associated with the formation of organic carbon (OC) fine particles.

PMfine is currently monitored by filter-based techniques and some limited real-time analytical instruments (TEOMs and Aetholometers). New analytical techniques like the aetholometer will provide data that when combined with the VOC measurements will provide toxicologists and other health professionals the data necessary to assess major risk sources in the urban atmosphere. Another group of pollutants are the oxides of nitrogen. Nitrogen dioxide is a current criteria and a new proposed EPA standard will set the standard for this pollutant at 100ppb for a 1 hour exposure.

Modeling has been and will continue to be the primary tool used to show the dispersion of air pollutants from the roadways. The model concentration data can in turn be used to assess the risk of the public. Modeling efforts like RAIMI combine dispersion modeling with risk assessment to form an important assessment tool that can be used at the state, local and neighborhood levels of analysis. We expect this effort to be especially important for understanding exposure gradients in areas near roadways, which increasingly have been identified in the public health literature as being a potentially variable to consider in epidemiology. The ability to ground truth modeling data becomes very important if that data is to be used by regulators. Currently the ability to check data is limited to a few monitoring stations. The NATTS network compromises only 22 stations nationally. While these NATT sites provide the highest quality data they are very limited in the areas they reach. Assessing the impacts of benzene and other significant volatile pollutants requires the NATTS site data be supplemented with PAMS monitoring data and with local monitoring data. Even with multiple networks taken together the number of monitoring points is smaller than available data for ozone and particulate networks. Another unknown is whether kriging techniques or inverse distance weighting used with regional pollutant data can be effectively be used to interpolate toxic pollutant concentrations.Air monitoring studies focusing on roadways has been limited. Many current monitoring sites were set up to avoid direct impacts from roadways. Additional monitoring studies will be needed if we are to demonstrate the value of modeling and to better understand the causal link between roadway traffic, increased emissions, spatial and temporal exposure gradients and provide and estimate of exposure that can be potentially lined to studies of health effects. In Wisconsin, monitoring studies will be of direct benefit to DNR planning staff and to other state and local health agencies.Efforts to link epidemiological studies, modeling, monitoring, and risk assessment can be used by regulators to determine if emission reductions like those proposed for mobile sources (Federal Register, Vol. 71) can obtain the desired risk reductions.

A.3.2. List of Target Pollutants

The pollutant target list for the study are listed below in Table A1.

TABLE A1: Roadway Studies Target Compounds for Monitoring		
TABLE A1a: Volatile Organic Compounds		
Critical	Priority	Base
BENZENE	N-HEXANE 224-TRIMETHYLPENTANE TOLUENE M/P-XYLENE O-XYLENE 123-TRIMETHYLBENZENE	METHYLCYCLOPENTANE 24-DIMETHYLPENTANE CYCLOHEXANE 2-METHYLHEXANE 23-DIMETHYLPENTANE 3-METHYLHEXANE N-HEPTANE METHYLCYCLOHEXANE 234-TRIMETHYLPENTANE 2-METHYLHEPTANE 3-METHYLHEPTANE N-OCTANE ETHYLBENZENE STYRENE N-NONANE ISOPROPYLBENZENE N-PROPYLBENZENE M-ETHYLTOLUENE P-ETHYLTOLUENE 135-TRIMETHYLBENZENE O-ETHYLTOLUENE 124-TRIMETHYLBENZENE N-DECANE M-DIETHYLBENZENE P-DIETHYLBENZENE UNDECANE DODECANE
A1b: Particulate Matter		
Black carbon	UV Particulate Matter	
A1c: Oxides of Nitrogen		
Nitrogen Dioxide	Nitric Oxide	

Target compounds are organized in to three categories. Critical target compound for this study. Sampling and analysis variables, in the study, should be optimized to provide concentrations of critical compounds with the highest data confidence. Priority target compounds will be important in supporting the measurements and in establishing the sources pollutants. Providing good quality assurance information of these compounds is important. Base compounds are target compounds that will also be measured by the analyses. Providing good quality assurance information on these compounds is desired but not required.

A.3.3 Target Locations for Study

Monitoring will be conducted along a variety of high traffic roadways located in Wisconsin. Monitoring location will be chosen based on several criteria including, access near the roadway, traffic volume on the roadway, past or future modeling of the roadway.

A.4. Project/Task Description

A.4.1 Description of Work to Perform

The Wisconsin DNR will purchase a utility trailer as a platform for the laboratory. A propane powered generator will be installed in the trailer to provide electrical power. The mobile monitoring trailer will house several analytical system including a gas chromatograph, a particulate carbon monitor, and an oxides of nitrogen analyzer. When developed, the mobile laboratory will be tested to demonstrate that data quality meet the needs of modelers and risk assessors. The trailer will provide short-term hourly measurements necessary for studying dynamic emissions and atmospheric processes. It will also provide high quality measurements at multiple locations needed to assess the public's risk.

A.4.2. Project Goals

Goals for the monitoring project will be the following:

a. Purchase and equip a trailer to function as a mobile monitoring platform. The trailer should provide an operational environment for analytical instruments.
b. Install a Perkin Elmer Automated Ozone Precursor Analysis System on board the trailer and develop methods for operating the analyzer on-board the trailer.
c. Install a Magee Aethalometer on board the trailer and develop operating conditions for this analyzer on-board the trailer.
d. Field test the system and assess the utility of the monitoring trailer for various monitoring scenarios.
e. Deploy the Monitoring trailer in field studies and use this information to aid in validation of modeling results and make improvement in risk assessments.

A.4.3. Field Activities

The mobile monitoring laboratory will be towed to selected monitoring location where monitoring studies will be conducted for multiple hours to collect data on pollutants near roadways.

A.5. Project Assessment Techniques
The Project Manager will monitor and assess work on the project. Formal assessments will be made in quarterly reports to the Air Program managers. Quarterly reports will be issued listing the project activity during the previous 90 days. The report will also address any significant findings that will affect activities in the next calendar quarter.

A.6. Schedule of Activities

The project will have four major areas of activities that include

- Purchase a trailer and equipment for fabricating the mobile laboratory.
- Test the laboratory and demonstrate that high quality measurements can be made using the mobile laboratory.
- Use the mobile laboratory as a base for summertime PAMS intensive monitoring
- Use the mobile laboratory for conducting roadway monitoring studies.
-

A.7. Project Records
Important project record will include field notebook, analyzer records, analysis chromatograms and chromatographic reports, project database, quarterly reports, monitoring reports and a final project reports. Records handling is addressed below:

Field sampling notebook will be used by operation staff to record significant information about the project. Information will include operation of the trailer laboratory, changes to the analyzer operation, corrections of problems with the analyzers, and observation made during field studies. The notebook will be keep on board the mobile laboratory trailer.

Analyzer records will be kept electronically on the trailer's computer data system. Analysis chromatograms and chromatographic reports will be maintained electronically on the computer. Data will be in formats compatible with Perkin Elmer's TotalChrom software. The aethalometer data will be captured using the TEKCap software(Tekran) and stored on the computer. The oxides of nitrogen analyzer data will be collected using the APICom software and again stored on the computer. Results data will be transferred from the trailer computer to the project's ACCESS database.

The project database will be in ACCESS format. The database will be located on a DNR network accessible fileservice. Data from the project database can be exported to other software program for additional analysis and review.

Quarterly reports will be prepared using WORD software. Copies of the reports will go to EPA staff and WDNR's Monitoring Section and ES section chiefs. An electronic copy of the reports will be kept on a WDNR DNR network accessible fileservice. A hardcopy of the report will be added to the project files.

Monitoring reports will be issued periodically and will summarize monitoring operation and the data collected in those operations.

The final project reports will be prepared using EXCEL and WORD software. Copies of the reports will go to EPA staff, the WDNR's Quality Assurance Officer, the Monitoring section chief, the ES section chief, all WDNR staff participating in the project. An electronic copy of the final reports will be placed on the WDNR's internet WEB page and will be generally accessible to all interested parties.

A.8. Quality Objectives and Criteria for Measurement Data

A.8.1. Data Quality Objectives
The overall data quality objective is to provide datasets of know quality for use in a accessing pollutant concentrations near roadways. The dataset should also be comparable to current fixed site pollutants monitoring within know limits.

A.8.2. Measurement Quality Objectives
The quality of the dataset will be assessed using standard measurement parameters for completion, accuracy, precision, and compatibility. The parameters will be defined as follows;

Completion – is the percentage of planned samples or minutes that are collected or analyzed and then reported. Completion will be assessed as the number of samples/minutes collected / number of samples/minutes planned * 100%. The standard Wisconsin DNR and EPA goal for completion is 75%. A completion of 75% is considered indicative that the data is representative of the period monitored.

Accuracy – is measured as the deviation of the measured value from a true value. Accuracy is assessed as the percent difference of a measured concentration from a expected (spiked) value. The percent difference is calculated as (measured concentration – expected concentration)/(expected concentration) * 100%.

Precision – is the repeatability of a measurement. Precision will be assessed as the using standard deviation for multiple measurements. The mobile laboratory does not have any collated system to directly assess precision. Where possible the Wisconsin DNR staff will attempt to get collocated data for estimating the measurement precision..

Comparability - is a measure of the bias between this study's data and data collected from established and reported methods. The Wisconsin DNR's air monitoring program will be the reference program for this project. Bias between the programs fixed site analyzers and the analyzers in the mobile laboratory will be assessed visually using a scatter plot and numerical bias will be assessed by the slope and intercept calculated from concentrations of the test and reference method.

A.9. Special Training Requirements/Certification

All personnel who operate DNR air monitoring stations are operators who have undergone an on-the-job training and testing program administered by the Air Monitoring Section. Operation of the mobile monitoring trailer and the analytical systems are considered advanced monitoring techniques. These operation will be conducted by the Air Toxics Chemists experienced in the operation of the equipment.

Special training for this project will include:
- Safe operation of a tow vehicle and a trailer on roadways.
- Safety training for staff working close to roadways.

A.10. Documentation and Records

All hardcopy documentation and hardcopy field records will be stored in the designated project file.

Electronic copies of data and documentation will be stored on a DNR network accessible fileservice. The data will be stored in a subdirectory of the AMPAMS fileservice. Electronic data that does not required immediate access will be compacted (ZIPPED). Compact disk copies will be made of all ZIPPED files. The CDs will be stored in the project file.

B. MEASUREMENT/ DATA ACQUISITION

B11. Sampling Design

<u>B11.1. Scheduled Project Activities, Including Measurement Activities</u>
The project will center on three monitoring activities.

- The first project goal is to purchase equipment and analyzers for the project. Equipment will include a trailer and power generator. Analyzers will include an aethalometer and an oxides of nitrogen analyzer. The AutoGC system and the meteorological sensor will be taken for surplus equipment. The trailer will be configured to a laboratory and all analytical systems will be installed. The goal is to complete this work by spring 2009.

- Beginning in the Summer of 2009 and continuing each summer after, the mobile laboratory will be moved to the parking lot of the Milwaukee Headquarters building of the Wisconsin DNR. During the period from June first to August thirty-first the trailer will serve as Wisconsin's Type two PAMS site. The analyzers on the laboratory will measure hourly measurements of volatile hydrocarbon and particulate matter. The project goal is for the mobile laboratory to provide PAMS monitoring data from June through August each year that the Lake Michigan Regional PAMS program continues..

- The third activity is to conduct roadway monitoring studies between time from January through mid-May and from mid-September through December. Project staff will deploy trailers to various field studies to demonstrate roadway exposure to target pollutants

<u>B.11.2. Rationale for the Design</u>
The AutoGC analytical system is used as the Wisconsin DNR's current methodologies and the methods have been proven in the Photochemical Assessment Monitoring Station (PAMS). Hourly VOC measurements including benzene concentration are collected at the Type 2 PAMS site using a Perkin-Elmer Ozone Precursor analyzer (AutoGC). This unit has been in operation at the Wisconsin site in Wisconsin since 1999. The AutoGC will provide an excellent analytical engine for the assessing exposure near roadway. Moving the AutoGC to a mobile laboratory will allow the Wisconsin DNR to continue PAMS monitoring and to use the AutoGC system for other monitoring projects. The Aethalometer has been used by a number of other agencies for measurements of black carbon from vehicular traffic. Other monitoring parameters collected by the mobile laboratory include three dimensional wind speed and wind direction. The Wisconsin DNR has established operating procedures for these parameters including Standard Operating Procedures (SOPs) and Quality Assurance Project Plans (QAPPs).

The Wisconsin DNR has an established record for carrying out environmental studies similar to that proposed. In 1995 WDNR staff conducted a short intensive study of reformulated gasoline components (Allen, Grande and Foley, 1996). Wisconsin staff also conducted a Benzene near roadway study in Milwaukee (Allen, Grande and Pansch, 2007).

B11.3. Procedure for Locating and Selecting Monitoring Site Selection

All PAMS monitoring will be a continuation of monitoring conducted at the Wisconsin Type 2 PAMS site in Milwaukee. Monitoring will be conducted at the Wisconsin DNR's Milwaukee Headquarter building located at:

2300 N Dr Martin Luther King Jr Dr
Milwaukee WI 53212

The location for the roadway study will selected based a several criteria including the following; safe access for WDNR staff, a high traffic count, pervious RAMI modeling along the roadway, and a nearby population that might be affected by the vehicular traffic.

B.12. Sampling Methods Requirements

All pollutant concentrations will be measure with one of three analyzer mounted in the mobile laboratory.

B.12.a Volatile Organic Compounds (VOCs)

All VOC measurements will be made using a field deployed gas chromatographic system, the Perkin Elmer Automated Ozone Precursor Analysis System (hereafter AutoGC). The AutoGC system provides hourly monitoring of 55 hydrocarbons compounds, many of which originate from mobile sources. The automated gas chromatographic system is complex, comprised of an air sampler, a sample preparation system (Automated Thermal Desorption System), a gas chromatograph with dual FIDs, a data interface, and computer. The components are not easily transportable. Moving the system to alternate locations would require dissembling the system and then reassembling at the new location. To continue to operate the AutoGC system and to extend its operations the Wisconsin DNR will develop a mobile monitoring trailer to house the system. Within the mobile monitoring trailer the assembled AutoGC system can be operationally maintained.

B12.b.Black Carbon

The black carbon measurement is made by optical attenuation. The air sample is drawn into the analyzer and through a spot on a quartz filter tape. Particulate carbon black deposits on the filter. The analyzers light beam is passed through the spot on the filter tape and the quantity of carbon is measured by the decrease in the light energy.

The Magee AE22 dual wavelength analyzer measures at two optical wavelengths. The first measure of black carbon made at an optical absorption of 880 nm. A second measure is made at 370 nm and this is designated as the 'UVPM' concentrations. The UVPM is thought to be a measure indicative of aromatic organic compounds. Examples of aromatic organic carbons include tobacco smoke, PAH mixtures, smoke from wood and other biomass-burning.

Continuous measurements are made of quartz filter as particulate matter loads. When the loading threshold is exceeded the instrument will advance the quartz tape, moving unexposed filter into place, and will then begin loading a new spot on the tape.

B12.c.Nitric Oxide and Nitrogen Dioxide

Nitric oxide reacts with and is oxidized by ozone. This oxidation reaction results in the formation of nitrogen dioxide and the release a light photon in a process called chemiluminesnce. This is a fast reaction and in the presence of an excess of ozone the emitted light is a quantitative measure of the nitrogen oxide present. In the API 200E analyzer the analytical air stream mixes with and reacts with ozone generated within the analyzer. The light produced in the reaction of NO and O3 is measured by a photomultiplier tube.

In a second analytical path nitrogen dioxide is reduced to nitric oxide by passing the air stream through a molybdenum converter at 300 degree C. The reduced nitrogen dioxide and the existing nitric oxide are the measured by the same chemiluminescence's reaction used to measure the nitric oxide. The combined measurement is given the label NOx. The nitrogen dioxide in the air sample is then calculated as the difference between the NOx and the NO measurements.

The microprocessor within the API 200 E analyzer controls and monitors the analyzer's measurements. This includes directing the air through the analytical pathways for NO and for Nox. The microprocessor also controls the sampling flow rate and compensates for atmospheric changes in temperature and pressure. Finally the microprocessor will store calibrations and perform calculations for the measurement of NO, NOx and NO2. The E series analyzers will internally store measurements for download using the iDas software.

B.13. Sample Custody

No actual ambient air samples are retained by the sampling units or by the analyzers used on the RW trailer. The aethalometer does have a sample on a moving tape, but these samples do not provide any qualified back-up sample. No air samples are retained because all measurements are made by continuous monitoring systems. Electronic records of the analytical system responses are made on the RW Trailer's data-logging computer. Internally analog measurements made by the analysis systems are converted into digital signals, converted into concentrations, and then reported as time averaged concentrations. Each system has an assigned data capture program that collects data and transfers data to a text files on the site computer. Data from the computer is downloaded to the project database.

The aethalometer has an electronic data card that provides a data back-up should the computer fail. The API 200E retains data internally until the data is requested by the computer. There is no back-up of VOC data measured by the AutoGC.

B.14. Analytical Methods Requirements

B.14.1. Sampling Line and Inlets

Requirement for the sampling lines

- VOC sampling lines should be chromatographic grade SS.
- Oxides of nitrogen analyzer sampling line should be Teflon or Stainless steel
- The aethalometer requires a size selective cyclone at the sampling inlet. The sampling line should be Freelin Wade 1J-405-01 tubing or equivqlent static dissipative tubing.

All sampling lines will be short (less than 15 feet) and no residency issues are expected.

Both the AutoGC system and the API200E analyzer require external pumps. The Aethalometer has an internal pump.

B.14.3 Analysis Methods

The analysis gas chromatographic system is a commercial Perkin Elmer system capable of automated sample processing, analysis, and data acquisition. The primary components are a sample introduction system, sample conditioning system (for moisture removal), sample concentration system (for sample enrichment), cryofocusing trap (as an option for improving peak shape and resolution), gas chromatograph with FID(s), and a data acquisition and processing system. The system uses two analytical columns to provide separation of hydrocarbons over a C6 to C12 range. The system is computer controlled using Perkin Elmer's TotalChrom software.

The aethalometer measures black carbon by a light attenuation. Particulate matter is deposited on a filter tape. The decrease in light at two selected wavelengths is measured and converted by a know constant to black carbon. The analyzer microprocessor averages the analytical signal over a five minute sampling time and reports the concentration.

The oxides of nitrogen analyzer measures light emissions from the reaction of nitric oxide and ozone. The analyzer measure the air concentration of nitric oxide. The analyzer then passes the air sample through a catalytic converter reducing nitrogen dioxide to nitric oxide, which is then measured as NOx (total oxides of nitrogen). The final calculation of nitrogen dioxide is the subtraction of the original nitric oxide measurement from the NOx measurement. The analyzer make several measurement which are averaged over a 1 minute time period.

B.15. Instrument/Equipment Testing, Inspection, and Maintenance Requirements

All analytical systems will receive regular maintenance as directed in the analyzer SOP or the manufacturer' operation manual. Maintenance other than scheduled, will also be provided as needed.

All analytical system will be inspected before any monitoring project to insure they are operational before moving the trailer.

B.16. Instrument Calibration and Frequency

B.16.1 Instrumentation Requiring Calibration

The gas chromatographic analysis system must be calibrated to correctly identify target compounds and to quantify the concentrations of compounds in the samples. Calibration for identification will use a 55 compounds standard. The standard will be analyzed a minimum of 4 times a day on three days. A Retention Time table will be developed for the data processing program. Unknown compounds will be identified when their retention time falls with a window center on the RT from the RT table. Standard RT windows previously develop by WDNR staff will be used.

Compounds concentrations are proportional to the peak area. A quantitative two component standard will be used for quantification. The gas chromatographic systems flame ionization detector will respond in proportion to the number of carbons in a hydrocarbon compound. The calibration standard contains propane and benzene in a nominal concentration of 10 ppb. The calibration standard for the project in carbon is then propane 30 ppbC (part per billion Carbon) and benzene 60 ppbC. The quantitative standard will be analyzed a minimum of 4 times a day on three days. Peak areas from all runs will be analyzed and a peak response factor will be calculated from the average peak area divided by the concentration in ppbC. Unknown peaks will be quantified by dividing the unknown's peak area by the RF. The analysis system is typically calibrated at the start of the project and at the end of the project. The calibration standard is analyzed on each monitoring excursion of the trailer to verify that calibration has been maintained.

The aethalometer is factory calibrated. NO schedule has been established to check the analyzer calibration.

The API 200E oxide of nitrogen analyzer is calibrated with a known nitric oxide gas standard. The stock gas standard is blended with zero air to create a series of working standard to determine the accuracy of the nitric oxide measurement. The stock gas standard is blended with zero air and mixed with ozone to create nitrogen dioxide. The nitrogen dioxide standard is then analyzed to confirm the efficiency of the analyzer's catalytic converter.

B.16.2. Calibration Standard Materials and Apparatus

Commercially prepared standard gases will be used. The supplier is required to provide a certificate of analysis with the measured gas concentrations and an estimate of the measurement error.

B.17. Inspection/Acceptance for Supplies and Consumables

Consumable supplies include support and gas calibration standards.

- Support gases are used as a carrier for gas chromatography and for the operation of the AutoGC's flame ionization detectors.
- Standard gases are used for calibration and for verifications. Standard gases will be analyzed and compared with older outgoing standards. Based on a calibration using older (and established) standards the new standards should be within expected error of the certified concentration. In addition, analysis standard with be split or exchanged with fixed site operators as an external confirmation of the standards validity.
-

B.18. Data Acquisition Requirements

B.18.1 Acquisition of Measurement Data

Two level of data acquisition will be used on this project.

- The primary level of acquisition is automated data acquisition by the analytical systems. For the AutoGC data system, the original data files (.RAW). will be generated by the system. The GC system will automatically process the data files to identify and quantify the target compounds detected in the samples. Data processing will generate a result file (.RST) and a text report file (.TX1). Copies of the three files will be achieved for a minimum period of 5 years. The aethalometers will create an electronic data file. The API 200E stores data internally and the data is downloaded periodically to the site computer.

- Data is also recorded manually and is generally qualitative in nature. Information includes a description of the site, the weather conditions, and general nature of the roadway traffic.

B.19. Data Management

B.19.1 Background and Overview

Electronic data records will be managed in a project database created using ACCESS software. Within the database will be each analyzer will have its own tables of raw data. Additional tables will be created in the database will support the two main tables. Supporting tables will contain, monitoring location information, definitions for coding used in the main database tables. Pollutant concentration data will be processed to other tables to align sampling duration and frequency.

B19.2 Data Recording

All concentration data will be electronically recorded by the analyzers. Data will be added to the project database.

B19.3 Data Validation

Data will be validated at three levels for the project.

- Level 0 validation of the data focuses on the completeness and accuracy of the database information. Are all required data fields filled. Is the information in the field correct. Do all field samples have match results. Do all results have matching field data.

- Level 1 validations address the quality of the data collected. The primary effort here is to correctly flag the data and add necessary comments. Validation should focus on the identification and quantification of the data.

- Level 2 validation address the quality of the data relative to the project data quality objectives. Validation will focus on accuracy when compared to an outside laboratory, sampling precision, and comparability to established methods.

B.19.4 Data Transformation

The most typically data transformation will be to convert pollutant measurements to common averaging times. Nitrogen oxide is reported in one minute averages, black carbon in 5 minute averages and VOC in one hour averages.

The data will be averaged conventional EPA and Wisconsin DNR rules requiring 75% capture for completeness. A minimum of 4 one minute averages are required for each five minute average and a minimum of nine 5 minute averages are required for each hourly average. All averages will be arithmetic.

B.19.5. Data Summary and Characterization

Data will typically be summarized and statistically characterized using EXCEL spread sheet software. Spreadsheet software will provide basic summary information including data counts, data averages, date ranges (including minimums and maximums) and data variability (as standard deviations). Spread sheet software also allows basic data plotting to visually inspect the data.

B.19.6. Data Storage and Retrieval
Data will be stored on the DNR's internal network at a central located file that can be accessed by all project staff. Upon completion of the project the database, and all electronic files related to the project will be achieved to compact disks. A hardcopy of the final report and all project data will be keep in the monitoring sections files for a minimum of five years.

C. ASSESSMENT/OVERSIGHT

C.20. Assessments and Response Actions

Assessment of the field sampling project and the sample analysis will be made by staff directly assigned to these tasks. Any problems and corrective action will be relayed to the Project Manager or the FSTL. E-mail messages will be the preferred method to alert the project manger of problems.

The project manager will check on progress each week.

C.21. Reports to Management

Quarterly reports on the project will be made to the designated EPA staff, the WDNR Monitoring Section Chief, the WDNR Environmental Sciences Section Chief, the SER Monitoring Supervisor, and project staff.

A final report will also be made to EPA staff, the WDNR Monitoring Section , the WDNR Environmental Sciences Section Chief, WDNR Environmental Sciences Section Chief the SER Monitoring Supervisor, and project staff..

C.22. Data Review

Data will be periodically reviewed and validated. If data review indicates a problem corrective action will be taken to insure data validity.

Upon completion of the field studies and the complete analysis of all collected samples the project database will undergo a final review. The data base will provide a measure of each target compound for each sample collected. As part of the final review each data record will be given a final data flag to indicate the quality of the data against the goals set in this QAPP.

Data will be summarized and that summary will include the completeness of the field studies, the results for quality control tests and the comparability of study methods to established methods.

The final data base will be forwarded to data end users for their evaluation and use in charactering roadway benzene concentrations.

D. VALIDATION AND USABILITY

D.23. Validation, Verification and Analysis Methods

The overall goal is to create a complete set of monitoring data of know data quality for the end data users. To accomplish this the project staff will collect field samples, analyze those samples, and report the analysis data. The data end users will examine and evaluate the near roadway benzene concentration gradients using the data supplied by the study.

D.24. Reconciliation with Data Quality Objectives

The DQO for this project is to create a complete dataset of know quality for use in evaluating roadway emission and validating risk assessment modeling for roadways. After the data set is assembled it can be evaluated against the goals in the DQO. This evaluation will focus on meeting several criteria including the following:

- Have the analytical methods successfully provided data to create a complete data set for roadway monitoring studies?
- Is the data in the data of good quality when evaluated for accuracy and precision as defined in this QAPP?
- Is the dataset comparable to data collected at the fixed monitoring site? If a bias is shown between fixed site and RW trailer methods, can that bias be reliably quantified?
- Can the dataset show the expected concentration gradients and atmospheric dynamics at the target roadways.

Roadway Trailer Final Report

Appendix D: SOPs for Project

Wisconsin Department of Natural Resources
Air Monitoring

Standard Operations Procedures

Magee Aethalometer
AE22
SOP 8.8

By the signatures below, the Wisconsin Department of Natural Resources/Air Monitoring certifies that the information contained in this document is complete and accurate at the time of submittal to EPA Region 5

***Name:*__________________________*Signature*__________________*Date*____**

Air Monitoring QA Co-Ordinator

***Name:*___________________________*Signature*__________________*Date*____**

Air Monitoring Section Chief

***Name:*____________________________*Signature*__________________*Date*___**

Air Management Bureau Director

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8.8.1 General Information

8.8.1.1 Introduction

Black carbon is an air pollutant produced from the combustion of carbon based fuels. Both elemental and black carbon are components of fine particulate matter (PMfine) that can enter deeply into the lungs and cause tissue damage. Black carbon differs from elemental carbon in the method of analysis. Black carbon is measured with the Aethalometer using an optical attenuation method. In contrast, elemental carbon is measured using thermal/chemical analyses. Some research (Hitzenberger, et.al.) have suggested that black carbon and elemental carbon analyses are in agreement when viewed within the variability of the different analysis methods.

There are a number of sources of black carbon, but roadways in particular are significant because they are a major source of fine and ultra fine particulates. Measured black carbon is considered a surrogate for elemental carbon and can therefore be an indicator of traffic activity. The diesel component of roadway emission is assumed to be a major source of PMfine. This assumption was used in the 1999 National Air Toxic Assessment (NATA) where one hundred percent of the diesel PM was assigned as coming from mobile sources. PMfine in total is currently monitored by filter-based techniques (FRMs) and some limited real-time analytical instruments (TEOMs and BAMs). The Aethalometer offers a reliable real-time technique designed to estimate the black carbon fraction of the PMfine.

The Aethalometer is one of several techniques that provide data to ground truth modeling data. Modeling data importance is indicated by its extensive use by planner and regulators.

8.8.1.2 Principle of Operation

The black carbon measurement is made by optical attenuation. The air sample is drawn into the analyzer and through a spot on a quartz filter tape. Particulate carbon black deposits on the filter. The analyzers light beam is passed through the spot on the filter tape and the quantity of carbon is measured by the decrease in the light energy.

The Magee AE22 dual wavelength analyzer measures at two optical wavelengths. The first measure of black carbon made at an optical absorption of 880 nm. A second measure is made at 370 nm and this is designated as the 'UVPM' concentrations. The UVPM is thought to be a measure indicative of aromatic organic compounds. Examples of aromatic organic carbons include tobacco smoke, PAH mixtures, smoke from wood and other biomass-burning.

Continuous measurements are made of quartz filter as particulate matter loads. When the loading threshold is exceeded the instrument will advance the quartz tape, moving unexposed filter into place, and will then begin loading a new spot on the tape.

8.8.1.3 Safety Precautions

The operator must follow all standard precautions used when working at a Wisconsin DNR air monitoring site.

- The Aethalometer uses standard electrical power and the operator should when ever possible disconnect the power before working inside the analyzer.
- The Aethalometer inlet is typically at an elevated position. If the operator needs to work on the inlet they should insure that all appropriate fall protections are in place.
- The Aethalometer does not require the use of any compressed support or standard gases.
- The Aethalometer does not use any liquids or any dangerous light sources that would require special eye protection. Operators are advised to use standard eye protection for equipment work.

8.8.2 Installation Procedure

8.8.2.1 List of Tools/Supplies

The AE22 Aethalometer is a self contained analyzer. The unit is typically installed in an electrical rack. The unit is secured by means of rack screws on front panel. The rear of the analyzer contains several connection points. These connection points include the power cable, the data cable and the sampling line inlet. There is also a port for an auxiliary pump. The Wisconsin DNR operation procedures typically rely on the analyzer's internal pump. No auxiliary external pump is used.

The sampling line is a 3/8 inch plastic line secured to the rear of the analyzer with a plastic screw connection. The sampling line should be no more than 30 feet in length. The exterior end of the sampling line should be equipped with a particle selection device, typically a 2.5 micron cyclone. The Wisconsin DNR uses a BGI SCC 1.829 cyclone. The SCC 1.829 is designed for photometer applications and provides a PM2.5 cut at 5 LPM sampling rate.

8.8.2.2 Instrument Set-up

The front panel of the analyzer is hinged to allow the operator to open the front of the analyzer to expose the sampling tape and optical bench. Opening the front also allows access to the flash memory data card located in the lower left hand part of the analyzer. The analyzer's on/off switch is located inside the analyzer.

When turned on the analyzer will perform a number of initial instrument tests. The analyzer will then go to a stand-by mode. Actual sampling will begin when clock is at the start of a five-minute sampling period. The five minute sampling periods are the hour plus n * 5 minutes, where n equal 1,2,3…11.

8.8.2.3 Siting

Siting criteria follows basic rules for all air monitoring. The sampling inlet should be place in a location that is unobstructed, or at least minimally obstructed.

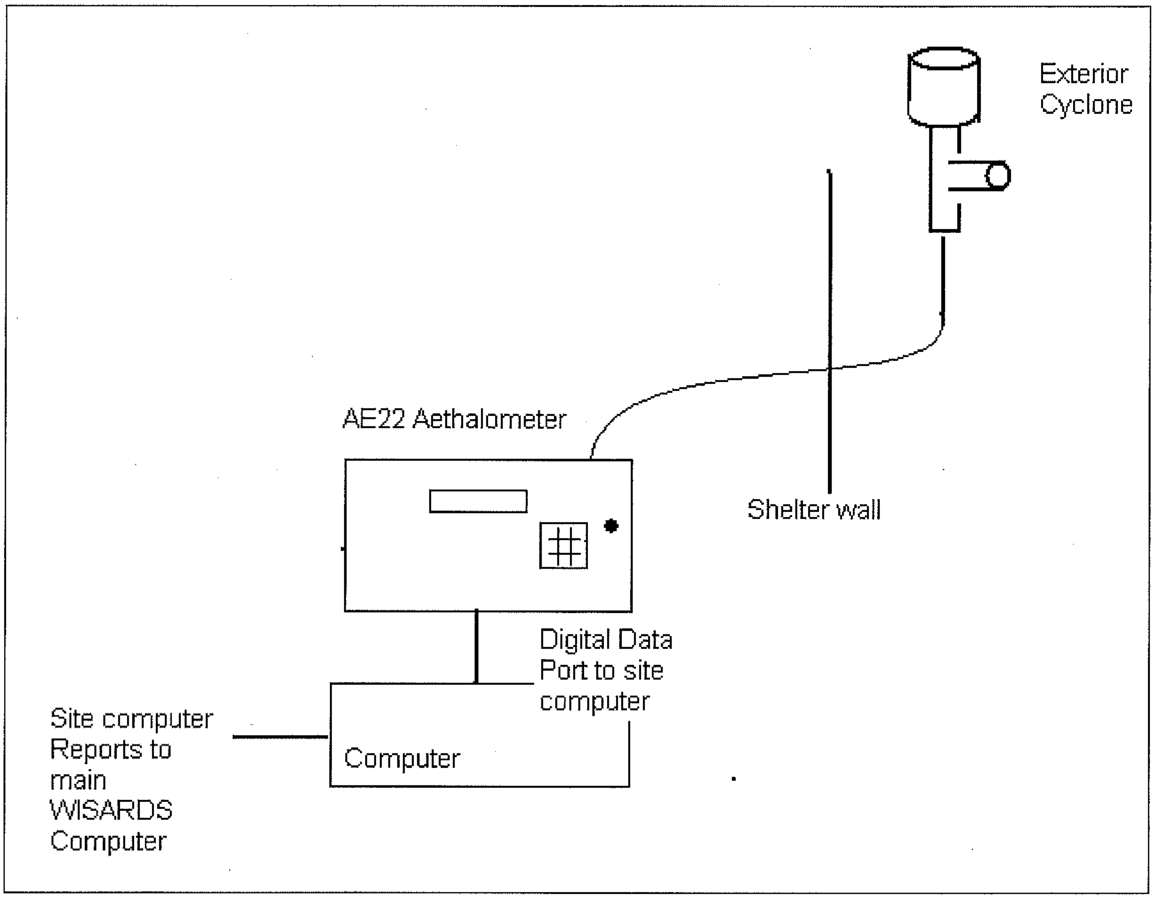
8.8.2.4 Data Logger Connection

At the rear of the analyzer is a nine pin D style connector providing a standard serial COM port output for digital data reporting. This port will connect with a standard null data cable to a serial port in the computer. At the analyzer's data port only pins 2,3 and the 7 ground pin are used.

The receiving computer uses commercially available communication software (TekCap). The AE22 Aethalometer outputs data once per time base period, at the end of the period. The data, transmitted as a data line, is written as a line at the end of the sampling period. No buffer or backup is available. The capture program must be operating at the time the data is written or the data string is lost.

A back-up of measurement data is made to a PC flash memory card drive inside the analyzer.

8.8.3 Configuration



8.8.4 Calibration Overview

The AE22 Aethalometer measures black carbon as a function of the rate of change of the optical attenuation on the quartz filter. The rate of change is converted to a black carbon concentration using a specific attenuation constant assigned for the analyzer. No direct calibration of the analyzer's optical measurement system is necessary or possible.

The analyzer's operation relies on three parameters. The first is the change in measured optical attenuation. The second is the specific attenuation constant assigned for the analyzer. This constant can not be changed by the operator. The third and final parameter is the sampling flow rate. The sampling flow rate is assigned by the operator. Once assigned the flow rate is monitored and maintained by the analyzer. The analyzer uses a mass flow meter that in turn controls the speed of the air sampling pump. The mass flow meter can be recalibrated if the sampling flow rate changes significantly.

8.8.5 Verification Procedures

The AE22 Aethalometer has two verification procedures that should be done periodically to check important measurement parameters.

The first verification is conducted using an optical test strip supplied with the analyzer. This test is an automated procedure that is programmed into the analyzer. Follow direction for the test in section 14.5.8 Optical Test Procedure of the manual. The procedure is copied as an appended to this SOP.

The second verification is a check of the sample flow meter response. This is accomplished by comparing displayed air sampling rate with a measure of air sampling rate with an external primary of transfer standard. The flow measurement device is connected to the port of the rear of the analyzer. The percent difference between the measured and the displayed flow rate is calculated using the equation below:

% Difference = (indicated-measured)/measured.

Analyzer flow rate is typically report in terms of Standard Liters Per Minute, defined as 70°F (20°C) temperature, and 1013 mob pressure.

If the flowmeter display differs from the actual measured flow by more that 10% a flowmeter calibration should be conducted using the procedure in Section 14.5.6 Calibrate Flowmeter of the Magee Manual.

8.8.6 Routine Service Checks

8.8.6.1 General Information

The AE22 Aethalometer operates as a turnkey system. The analyzer does not require any external support or calibration gases. The operator's main responsibilities is to monitor the operating parameter to insure that operation goals are met. Service checks are primarily associated with checking site data and operating parameters.

8.8.6.2 Daily Checks

The daily check can be done remotely by examining the analyzer data file retrieved by the daily analyzer polling. Check the daily data files for any indication that the analyzer may be experiencing problems requiring operator attention. Data checks should include a check for completeness and a reality check of the data. Excessive negative values, high outliers, and high data variation should be investigated.

8.8.6.3 Weekly

The weekly check is performed on site. Check the system date and time on the Aethalometer display and on the external data logger. Make sure both times are within 5 minutes of the site time. Site time on the Wisconsin data loggers is checked daily during the polling operation. In addition to the display screen the analyzer has a series of indicator lights. The control panel has five lights of different colors to indicate operational status:

GREEN = normal operation, gathering valid data.
FLASHING GREEN = OK, re-initialization after tape advance.
YELLOW = Needs attention, but instrument still running, data still OK.

RED = Problem, instrument stopped.

Check the analyzer time against the site computer and correct the Aethalometer time if necessary. The Aethalometer must be stopped to change the time. Check the displayed sample flow rate on the Aethalometer and record in the analyzer logbook. Note if the flow rate is changed significantly. Check the filter tape supply. Re-tension the tape roll if needed. Make sure the spots have clean uniform borders. Document all weekly checks in the dedicated Aethalometer logbook.

8.8.6.4 Monthly Checks
While the Aethalometer is in normal run mode, perform an external flow check.

With the Aethalometer measurements paused, change the Aethalometer data card. While stopped also make a check of the analyzer lamp voltage. Document the monthly checks in the dedicated Aethalometer logbook.

8.8.6.5 Annual Checks
Perform an optical strip check according to the procedure in the manual. Change the Quartz Tape once a year, or as needed. See section 12.1 of the Magee Scientific Aethalometer Manual. These directions must be followed exactly. Disassemble and clean the optical cylinder inside of the instrument once a year (at the same time the tape is changed). See section 19.1 of the Magee Scientific Aethalometer Manual. Inspect and clean the sampling head cyclone.

8.8.6.6 Audits
No Audits are done at this time for the Aethalometer.

8.8.7 Data Retrieval

8.8.7.1General Information

The Magee Aethalometer has two routes for reporting black carbon data. The primary method used by the Wisconsin DNR is to capture the digital data report. Data is also collected on a flash memory data card and this will serve as a back-up data source. Instrument data is electronically captured as a digital stream at the monitoring site by the monitoring computer. The data capture software is the same as used for capture mercury data. The software will write a daily data file to the site computer's hard drive. Data files can be removed from the on-board computer using standard data transfer devices. Data files can be routinely retrieved by linking the site's computer to a remote computer and then downloading the data.

The AE22's data files are text based, space delimited files containing approximately one day's data. The file contains one record for each analysis made by the AE22 analyzer. Each record has 13 fields (see Table 1(a)). The analyzer's data is added to a project's ACCESS database. Additional fields are typically added to create a complete working database. Additional fields typically add information on the site location and flag the data quality.

The report time for the AE22 five minute average is the start time for the period. This conforms to the Wisconsin DNR's data rule that the concentration is report as the time the sampling period begins.

Table 1: AE22 Aethalometer Data Tables	
1(a). Site Text File Structure	
Field	Field Name
Field1	Date
Field2	Starting Time
Field3	BC concentration in ng/m3
Field4	UVPM concentration in ng/m3
Field5	Sample flow rate in LPM
Field6	BC Sensing Beam Zero
Field7	BC Sensing Beam measurement
Field8	BC Reference Beam zero
Field9	BC Reference Beam measurement
Field10	BC Sampling period time fraction
Field11	BC Optical Attenuation (absorbance)
Field12	UV Sensing Beam Zero
Field13	UV Sensing Beam measurement
Field14	UV Reference Beam zero

8.8.7.2Apparatus

The digital data port at the rear of the AE22 chassis is connected to the site computer through a serial RS232 connection. Both the AE22 and the computer connect with a standard nine pins "D" connection.

Data is direct connected on the computer with a standard PC flash memory card. The card must be routinely removed, downloaded as a back-up and then replaced. Operation will be interrupted if the flash memory is completely filled.

8.8.8 Data Submittal

8.8.8.1 General Information -Data Reduction

All Aethalometer data is provided as 5 minute measurements from the AE22 analyzer. The analyzer writes the digital data string at the completion of the 5 minute sampling period. The time stamp for the data line is the start of the five minute sampling period. This convention is consistent with the WDNR data standard and no adjustment is required.

The Aethalometer data can be averaged to provide alternate longer sampling periods including 1 hour and 24 hour periods. Averaging the data will remove some short term details but will make the data consistent with other air measurements.

8.8.8.2 Sample Chain of Custody

No actual ambient air samples are retained by the sampling unit or by the analyzer. The analyzer does have a sample on a moving tape, but these samples do not provide any qualified back-up sample. The samples are not retained because all measurements are made by a continuous monitoring system. An electronic record of the monitor response is made on the site data-logging computer. Internally all analog measurements are converted into digital signals, converted into concentrations, and then reported as 5-minute average concentrations. The data capture program collects the data and transfers the data to a text file on the site computer. The WISARDS polling routine or another remote computer can in turn connect to the site computer to retrieve the data file.

A electronic data card in the analyzer serves as a data back-up should the site computer fail.

8.8.9 Maintenance and Procedures

8.8.9.1 General Information

The AE22 Aethalometer operates as a turnkey system. The system is controlled through power switches. The main switch is at the back of the analyzer. A switch behind the hinged front panel is typically used to start and stop the analyzer. When in operation the unit can be paused by pressing the ESC key twice. The analyzer will prompt the user for the security code. The default code of 111 is used by the WDNR. Note the unit's keyboard is slow. Be sure the security code is registering on the front panel before pushing the enter button.

The front keypad is used to navigate the operations of the analyzer. The analyzer must be in a standby mode to use the key pad. Operational functions are accessed by toggling the up and down arrows. Use the ENTER key to access a function and the ESC key to exit the function.

8.8.9.2 Maintenance Schedule

Period	Maintenance Procedure
Daily	Review data files for any problems.
Weekly	Check operating parameters, time clock.
Monthly	Flow verification, replace data card.
Semi annually	Optical card check
Annually	Clean optical cylinder Change quartz tape

8.8.10 Training

All personnel who operate the AE22 Aethalometer must receive training in the basic operation of that equipment. Training will typically be conducted on a one to one basis with designated staff. Staff designated as trainers will have both knowledge in the theory and operation of the Aethalometer analyzer and a record of experience operating the analyzer.

Advanced monitoring techniques will be conducted by the Air Toxics Chemists experienced in the instrument/analyzer operations.

8.8.11 Trouble Shooting

When addressing analyzer problems, the operator should first seek to locate and if possible isolate the particular system that is failing. Communication problems, for example, may originate in one of several points in the data processing operation. Some points are within the analyzer and some are external to the analyzer.

Common problems with the analyzer may be corrected by restarting the analyzer, cleaning the cyclone, and replacing the data card.

For more complex or persistent problems, the operator should consult the Magee manual. A partial list of analyzer error codes is provided below.

Error Message	Explanation
Error code 5	- Usually indicates a problem with the drive.
Error code 6	- Usually an error in the program code or in older units when using CF cards above 32MB. The older analyzers can not handle free space large than around 30 MB. To correct you fill up 128MB cards until free space is down to 31 MB. - Another cause for this error is the presence of a bad disk on chip.
Error Code 14	- Indicates a problem writing data to the disk. Check to insure the data card is not full. Try another fresh disk/card. When using a flashcard make sure the card is formatted with the FAT option.
Error Code 55	- Usually a problem with the floppy disk or flashcard drive. Make sure the card is not full. Try another fresh disk. If using a flashcard make sure its formatted with the FAT option
Error Code 250	-This usually means that the computer board is not receiving info from the electronics board located underneath the

	computer board.
Error Message "Instrument being controlled by.... via com2" .	Indicates the front display is not receiving communications from the main computer board. This message is a built in message in the display board itself.

APPENDIX A: References

Hitzenberger, R. , Petzold , A. Bauer , H. , Ctyroky, P., Pouresmaeil, P . , Laskus, L . , and Puxbaum, H. "Intercomparison of Thermal and Optical Measurement Methods for Elemental Carbon and Black Carbon at an Urban Location", Environ. Sci. Technol. 2006, 40, 6377-6383

C. Lioussea, H. Cachiera and S.G. Jenningsb (1993) Optical and thermal measurements of black carbon aerosol content in different environments: variation of the specific attenuation crosssection, sigma (ó) Atmospheric Environment. Part A. General Topics Volume 17, 8, June 1993, p 1203-1211

APPENDIX B: Forms

There are no forms for the Aethalometer. Analyzer information is recorded in a dedicated instrument log book.

APPENDIX C: MAGEE TEST procedures

From MAGEE 2005.07

Optical Test Procedure

Note that this procedure is a 'protected' function and requires the Security Code as a password.

This procedure performs a routine QC/QA check on the correct operation of the photo detectors, whose signals are the fundamental basis of the measurement. It uses the *Optical Test Strip* provided with the instrument. **Do Not Lose This Strip! Keep the Test Strip Clean, Flat and Smooth !** Contact Magee Scientific if a replacement is required, but be informed that the test is only relevant when repeatedly performed with the same *Test Strip*.

The *Optical Test Strip* consists of laminated material whose optical density at one end is greater than that at the other. The test procedure automatically determines the optical densities measured by the photo detectors, and writes the results to disk as a human-readable ASCII text file. The significance of the test is to be sure that the readings remain constant over time, i.e. from one test to the next. The actual numerical values of the calculated parameters are intrinsically meaningless: it is their constancy when measuring the same *test strip* that assures consistent performance of the instrument. The Optical Test Procedure guides the user through the various actions that are necessary, with prompts on the display screen.

The Optical Test Strip has a serial number printed at one end that should match the serial number of the instrument. Enter this number when prompted. Check that there is a floppy disk in the disk drive.

Open the door, and remove the two thumb screws that secure the rectangular metal cover over the sampling chamber in the center of the instrument. This provides access to the area where the filter tape passes through the analysis system.

Cut the filter tape on the left side of the chamber with scissors. Press ENTER when prompted. The remaining tape will be pulled out onto the right-hand spool.

When prompted, insert the test strip from the left-hand side. Its printed serial number should be facing upwards on the right-hand side. Push it in from the left until the tip of the arrow printed on it is just visible in alignment with the edge of the base block. Press ENTER when ready.

The first phase of the test will proceed automatically: the lamp will turn ON and OFF to determine the optical transmission signals for the 'front' portion of the test strip. At the end of the first set of measurements, the transmission values will be displayed. It is not necessary to write them down, as they are saved to disk. Press ENTER to proceed. The mechanism will go through three tape-advance cycles in order to pull the test strip forward, taking approximately 5 minutes. Please be patient.

The second phase of the test will cycle the lamps again and measure the optical transmission signals for the 'rear' portion of the test strip. The program will then calculate the quantities 'S

Density', 'R Density', and 'Balance'. The signals, results and other information will be written to a file on the disk under file name 'OTxxxxxx.TXT' where 'OT' represents Optical Test, and 'xxxxxx' is the date coded in either 'US' or 'EURO' format, i.e. MMDDYY or DDMMYY. This text file provides the definitive report on the optical transmission signals and the balance between the Sensing and Reference signals. This text file should be printed out and saved in the laboratory records book.

The display screen will then prompt the user to re-insert the filter tape from the left-hand side. After pulling it through, re-attach it to the tape on the right-hand take-up spool. Replace the rectangular metal cover with its two thumb screws.

LAMP Check

A lamp check can be made when the instrument is restarted and in the 60 second countdown or when the analyzer is paused from operations.

Use the down arrow button to scroll throu the analyzers functions util the screen displays 'Signals & Flow'

Hit Enter twice. You should get this screen:

```
SenV= 0.0204V Lamp=0
RefV= 0.0197V   Filter
FlowV= 2.30V= 3.99 LPM
 Press ESC to Exit
```

2) Push the #1 on your keypad to access the lamp voltages for the first lamp. See display below. Record the SenV and RefV numbers that come up.

```
SenV= 3.4335V Lamp=1
RefV= 2.0515V   Filter
FlowV= 2.30V= 3.99 LPM
 Press ESC to Exit
```

3) Now push the #2 on your keypad to access the lamp voltages for the second lamp. Record the SenV and RefV numbers that come up.

```
SenV= 1.634V  Lamp=2
RefV= 0.855V   Filter
FlowV= 2.30V= 3.99 LPM
 Press ESC to Exit
```

Low values for the lamps may indicate the optic need cleaning or that the they may indicate a problem with the Optical board itself.

When completed press the ESC button to return to the function menu. Using the arrows toggle to the “Operate” function and enter to restart the analyzer measurement operations.

Wisconsin Department of Natural Resources/Air Monitoring

Standard Operations Procedures

Advanced Pollution Instrutments
200 E
Oxides of Nitrogen Analyzer

(This draft not yet completed)

RW TRAILER STANDARD OPERATING PROCEDURES

SYSTEM : Operation of the Roadway (RW) Trailer Generator

The RW trailer is equipped with a Kohler 10MW generator configured to run on propane gas. The generator should supply sufficient power to operate the on-board analytical equipment as well as the supporting environmental systems. Most of the time the trailer will be supplied by a line power through a large power cord. This line power is termed "Shore power" throughout the rest of the document.

Shore power is provided by a 240 V, 50 amp circuit that can be wire into a 4 prong power receptacle or directly into a power cord. The trailer end of the power cord is equipped with a IP67 receptacle and electrical plug that will connect to the trailer.

The trailer is equipped with a transfer switch designed to automatically transfer trailer systems to generator power when the shore power is removed. This should be done carefully to avoid damaging the analytical equipment.

Shore to Generator Power Transferr

The procedure for use in transferring the trailer from shore power to the on-board generator, is as follows.

1. The analytical systems appear to tolerate the power transition from shoreline to generator power and it is not necessary to turn off any instrument power. The current UPS unit is unreliable under generator power and the computer and PE Nelson interface should be plugged directly into trailer power.

2. Open the supply gas values. Start the generator from outside the trailer.

3. Move to the inside and check all critical system for any disturbances. If all instruments are operating well and the generator is running as expected remove shore power. This is best accomplished by first quickly unplugging the four prong wall plug. Then remove the connection to the trailer.

4. Again check all instruments to insure that they are operating as expected. Make any adjustments necessary.

Operating the generator.

The generator has typically used about 1.9 kg of propane per hour of operation. The propane tanks will typically ice during operation and this may stop flow enough to cause generator failure. To prevent this regularly do manual transfers from one tank to the other. This will prevent one tank from being in operation for extend time periods and limit the amount of icing.

Generator to Shorepower Transfer

This is the procedure to use in transferring from on-board generator back to the shore power.

1. Most analytical systems appear to tolerate the power transition from generator to shoreline power. One instrument that has shown not to tolerate the transition is the PE ATD and it should be in standby and turned off before transitioning to shore power.
2. Attached the shoreline power cord first to the trailer. Then plug into the wall outlet in one smooth motion.
3. Check the inside instrumentation to insure that all instrument are operating as expected.
4. Turn the generator off from outside the trailer. Close the supply gas values.
5. Again check all instruments and restart instruments not currently operating. Transfer power for the computer and the PE nelson back to the UPS unit

RW TRAILER STANDARD OPERATING PROCEDURES

SYSTEM: Operation of the RW Trailer's GPS Antenna

The RW Trailer has been equipped with a Garmin GPS 18 Antenna. The unit is a fully compatible NMEA GPS antenas that connects to a PC. The unit is a small puck style antenna, at 61mm in diameter and it is *Wide Area Augmentation System* (WAAS) enabled.

WAAS is basically, a system of satellites and ground stations that provide GPS signal corrections, giving the user an even better position accuracy. The manufacturer has estimated that the GPS provides an average of up to five times better accuracy. A typical WAAS-capable receiver can give you a position accuracy of better than three meters 95 percent of the time. The RW trailer mounted GPS antenna is equipped serial DB9 connector to attach to the RW trailer's data computer. The unit is powered by a 12 volt DC transformer. The antenna unit is made to work with most NMEA 0183 GPS software, but in the RW trailer application position data will be directly accessed.

The operator may use the GPS 18 antenna in two basic modes. The first mode is to establish the RW trailer position when the trailer is stationary. In this case, the trailer is parked a location for monitoring and the operator uses the GPS 18 to establish the position for later interpretation of the data. In the second mode a GPS log is created to establish the position of the RW trailer as the trailer is moving. This mode is used when collecting data "on the fly". One or more of the RW trailer's analyzers are operating as the trailer is in motion. The GPS log can then be used by the operator when reviewing the analyzer's data to establish the RW trailer's location when critical measurements were made.

The operation of the Garmin GPS 18 antenna includes three parts, with the analysis of the data being addressed in the second part of this OP. The three steps for operation are to power the antenna, to access the antenna data, and then to capture the antenna data.

1. Power

The antenna is normally left in an OFF state by disconnection the electrical power. The operator connects the power from the transformer to the antenna and the antenna will begin to acquire satellite signals.

2. Access the signal.

The computer can access the antenna signal using the HyperTerminal communication program that is a standard accessory on all Wisconsin DNR computers. The "Connect Using" box should be set to the computer's communication port into which the antenna is plugged. The configuration should be 4800,8,N,1.

In the HyperTerminal Window the operator will see the antenna data stream past formatted as a series of NMEA sentences.

3. Capturing signal.

The antenna signal can be captured for analysis using the HyperTerminal transfer routine. This operation requests the program to capture the text and assign a filename the user has selected for the text. Once started the HyperTerminal software will collect data until directed to stop. The operator may collect data for several minutes when establishing a fixed position for the RW trailer. Alternatively, the operator may allow the HyperTerminal program to collect data for a longer time to establish a position log as the trailer is in motion.

Analyzing the Data

Collecting Data

The Garmin GPS 18 antenna outputs a string of NMEA (National Marine Electronics Association) sentences that can be logged using the computer HyperTerminal program. A sample of the text output is show below. The set of lines or records shown in the example covers the antenna's output for approximately four seconds.

```
SAMPLE GPS Output
$GPRMC,132309,A,4327.2681,N,08837.4720,W,025.1,359.3,050310,002.6,W*7F
$GPGGA,132309,4327.2681,N,08837.4720,W,2,10,0.9,270.1,M,-33.8,M,,*7A
$GPGSA,A,3,02,04,05,10,12,13,17,23,29,30,,,1.6,0.9,1.3*32
$GPGSV,3,1,10,02,78,316,50,04,45,061,50,05,39,189,49,10,56,165,50*76
$GPGSV,3,2,10,12,54,258,51,13,14,067,46,17,16,116,43,23,08,040,45*78
$GPGSV,3,3,10,29,11,301,47,30,36,299,50*73
$GPRMC,132310,A,4327.2753,N,08837.4722,W,025.2,359.1,050310,002.6,W*7A
$GPGGA,132310,4327.2753,N,08837.4722,W,2,10,0.9,269.6,M,-33.8,M,,*71
$GPGSA,A,3,02,04,05,10,12,13,17,23,29,30,,,1.6,0.9,1.3*32
$GPGSV,3,1,10,02,78,316,50,04,45,061,50,05,39,189,49,10,56,165,50*76
$GPGSV,3,2,10,12,54,258,51,13,14,067,46,17,16,116,43,23,08,040,46*7B
$GPGSV,3,3,10,29,11,301,46,30,36,299,50*72
$GPRMC,132311,A,4327.2824,N,08837.4723,W,025.6,358.9,050310,002.6,W*78
$GPGGA,132311,4327.2824,N,08837.4723,W,2,10,0.9,268.6,M,-33.8,M,,*7F
$GPGSA,A,3,02,04,05,10,12,13,17,23,29,30,,,1.6,0.9,1.3*32
$GPGSV,3,1,10,02,78,316,50,04,45,061,50,05,39,189,49,10,56,165,50*76
$GPGSV,3,2,10,12,54,258,51,13,14,067,46,17,16,116,43,23,08,040,46*7B
$GPGSV,3,3,10,29,11,301,46,30,36,299,50*72
$GPRMC,132312,A,4327.2897,N,08837.4722,W,026.0,358.9,050310,002.6,W*77
$GPGGA,132312,4327.2897,N,08837.4722,W,2,10,0.9,268.0,M,-33.8,M,,*73
```

For most typical monitoring operations the most significant lines in the above paragraph are the GPGGA lines with the position data. As single sample line is show below along with a description of the data contained in the line.

$GPGGA,132309,4327.2681,N,08837.4720,W,2,10,0.9,270.1,M,-33.8,M,,*7A

Where: $GPGGA is the GPS data type
- 132309 is the time in UTC (subtract 6 hours for CST)
- 4327.2681,N, is latitude
- 08837.4720,W is longitude
- 2 is data quality (0 is invalid) typically
- 10 is number of satellites
- 0.9 is the Horizontal dilution of position
- 270.1,M is altitude and units
- -33.8,M, is the height of geoids (mean sea level) above WGS84 ellipsoid
- *7A is checksum

Processing data

The data lines are typically inputted to a spreadsheet program like EXCEL. During, or after the import the data is parsed using commas to mark and delineate the fields. The next step is to conduct a sort procedure on the lines of data keying the GPS data type. Once this is done the users can select the position data for additional use.

The time can be parsed as character 1&2 as hour, 3&4 as minute, and 6&7 as the seconds. The hour should as be mathematically adjusted for the local time zone. For Central Standard Time the users subtract 6 hours.

RW TRAILER STANDARD OPERATING PROCEDURES

SYSTEM: Meteorological Sensors

Background: The meteorological sensor system provides critical auxiliary information for monitoring studies. The system provide in formation on wind direct and speed during monitoring operations. Data is provided in ten second increments which can then be averaged to longer periods to match the pollutant monitoring data.

Overview of system:

The Campbell CSAT3 is a three-dimensional sonic anemometer. It measures wind speed and the speed of sound along three orthogonal axes. From the measurements the system computes the orthogonal wind direct, wind speed and sonic temperature. The CSAT3 is used to measure average horizontal wind speed and direction. In addition the CSAT can be used in eddy covariance and other study applications to measure the turbulent fluctuations of horizontal and vertical wind. End data users can then calculate the turbulent wind fluctuations, momentum flux and friction velocity.

Campbell Scientific's CSAT3 3-D Sonic Anemometer has a 10 cm vertical measurement path, operates in a pulsed acoustic mode, and is designed to withstand exposure to harsh weather conditions. Three orthogonal wind components (u_x, u_y, u_z) and the speed of sound (c) are measured and output at a maximum rate of 60 Hz. While Analog output is available, the RW trailer typically uses one of two types of digital outputs.

OceanServer manufacturers a solid state, Three - Axis Attitude Sensors, hereafter the electronic compass, used on the RW Trailer to position the anemometer. The electronic compass is directly connected to the RW Trailer's computer data system and can be accessed with the OceanServer software.

Deploying the system

The meteorological measurement system is deployed using the following series of steps.

1. Link met sensor and electronic compass
2. Deploy the sensor array on tower
3. Align the sensor array
4. Power the system
5. Download met data

A detailed description of each step follows:

Linking Met Sensor and Electronic compass: The electronic compass provides the RW trailer operator with a tool to align the sensor. The electronic compass is enclosed in a gray box mounted on a precision machined rod. A designation of north is inscribed on the compass enclosure. At deployment the sonic anemometer sensor is attached to the opposite end of the rod using a 3/8" SS screw. Align the sensor so the anemometer arms point north relative to the compass housing. Next make an alignment check of compass and the anemometer. This alignment links the two systems. Place a circular level on the compass housing and level the housing to the horizontal plane. Examine the circular level mounted on the anemometer and verify that it is also level relative to the horizontal plan. The sensor array is now ready for deployment.

Deploy the sensor array on the mast: The first step in this procedure is to determine north. This is down by compass or by map. Using the perpendicular tube mounts attach the sensor array to the mast and position the anemometer to point nominally north when the mast is position upright. Lift the mast into position and attached the two braces. Next attach the electronic compass lead to the junction box near the RW trailer door. Attached the compass power and open the OceanServe software. Open the compass port, activing the program. The program will now show the position of the compass relative to three positional axes of rotations.

The compass is the designator for the met array, three dimensional body can be rotated about three orthogonal axes. Borrowing aviation terminology, these rotations will be referred to as yaw, pitch, and roll. The yaw rotation for our purpose is used to set the sensor azimuth and will hereafter be refer to as azimuth. The pitch rotation is about the y axis and roll rotation is about the x-axis.

Align the sensor array: The sonic anemometer must be aligned in three dimensions. The sensor must point north, and the sensor must be horizontally level. To do this the operator first aligns the azimuth North. If the electronic compass does not read within 4 degrees of north (356 to 4 degrees), adjust the sensor array by lower the mast and repositioning the sensor. When the azimuth is correct pointing north, adjust the pitch and roll. Pitch and roll are adjusted by loosing the coupling on the mast diagonal brace and sliding the vertical mast forward or backward. The goal is to have the pitch and roll with +/-2 degrees of zero (-2 to 2). The operator should be able to align the sensor with a couple of adjustments.

The OceanServer program will allow the operator to log the sensor position during the study. If it is necessary to get a wind speed and wind direct accuracy greater than the benchmarks list about, the data user is advised to take the log data and correct the wind speed and direct using the array position data. That is to correct the data for the compass positional data.

Power the met sensor: Once aligned the met sensor should be powered and connected to the data logger. The connection sequence is to first connect the sensor cable to the translator box. When this step is completed the cable from the translator box to the RW trailer connection box is completed. Inside the trailer the data logger is connected to its power pack. The met sensor is now collecting data.

Download the data: The operator should now open the Campbell CR10X1 software on the RW trailer computer. Press the connect button and connect to the data logger. After powering up the logger and connecting to the logger the operator needs to first syncronize the logger clock to the RW trailer computer. This should be done immediately or the measurements will is incorrectly time stamped.

Next collect data. Press the collect button to download data to a file on the computer. The COLLECT ALL button will download all the data in the logger. The COLLECT button will download only that data collected since the last download. In general, the COLLECT feature is better. The COLLECT ALL feature downloads an excess amount of data.

The met data can be examined graphically or numerically. The general rules for the numeric data are listed below. Use these rules to do a quick check of the data. The numeric data should agree with a visual survey of the wind, typically by observing a flag.

Ux >0 when wind come from the north and <0 when winds come from the south

Uy >0 when wind come from the west and <0 when winds come from the east

Uz >0 when wind come from above and <0 when winds come from below

Processing the Data:

Meteorological measurements were made using a Campbell CSAT sonic anemometer and are logged digitally on a Campbell data logger. Three dimensional wind measurements made using the CSAT are collected as three orthogonal vectors Ux, Uy, and Uz. Where Ux is the north south axis of the horizontal wind, Uy is the east west axis, and Uz is the axis transectioning the horizontal plane. The data record from the logger contains 10 fields that are described in Table 1.

Table 1: Data Record Fields from logger			
Field	**Field Name**	**Description**	**Example**
1	Logger ID	Data logger identification	210
2	Year	Year	2010
3	Julian Day	Date in Julian format (day of year)	321
4	Time	Time in hour & minutes	628
5	seconds	Seconds	0
6	Ux	Wind vector along the x-axis	0.90725
7	Uy	Wind vector along the y-axis	2.4752
8	Uz	Wind vector along the z-axis	-0.2915
9	Ts	temperature in degrees C	5.498
10	diag	diagonal of data	18

Vector data is converted to spherical coordinates of *Rho* (speed), *Theta* (azimuth), and *Chi* (elevation). A diagram of the spherical coordinates is shown in Figure 1. When averaging data for longer time periods (5 minute, 1 hour, 24-hour), the vector data is first averaged for the time periods. Then the average of the vector data is converted into the spherical coordinates. Conventions for the three vectors are given in Table 2.

Table 2: Conventions for Orthogonal Wind Vectors

Ux >0 when wind originates from the north and <0 when wind originates from the south.
Uy >0 when wind originates from the west and <0 when wind originates from the east.
Uz>0 when wind originates from the above and <0 when wind originates from the below

Wind is conventionally measured as speed and direction. Wind direction is defined by a compass circle placed on a horizontal plane. Winds measured in three directions are reported as speed and two spherically define coordinates. The speed is designated as *Rho*, and is reported in meters/second. The azimuth or *Theta* angle is the conventional planar circle. The elevation or *Chi* is the angle of the wind from the horizontal plane. Conventions for naming wind use the direction of travel. Thus a two dimensional wind of 45 degree is designated a "northeast wind". The *Theta* angle for the wind is treated similarly. The *Chi* angle also is name by the direction of travel. A *Chi* of >90 degrees is said to be a downward wind and a wind of <90 degrees is said to be an upward wind.

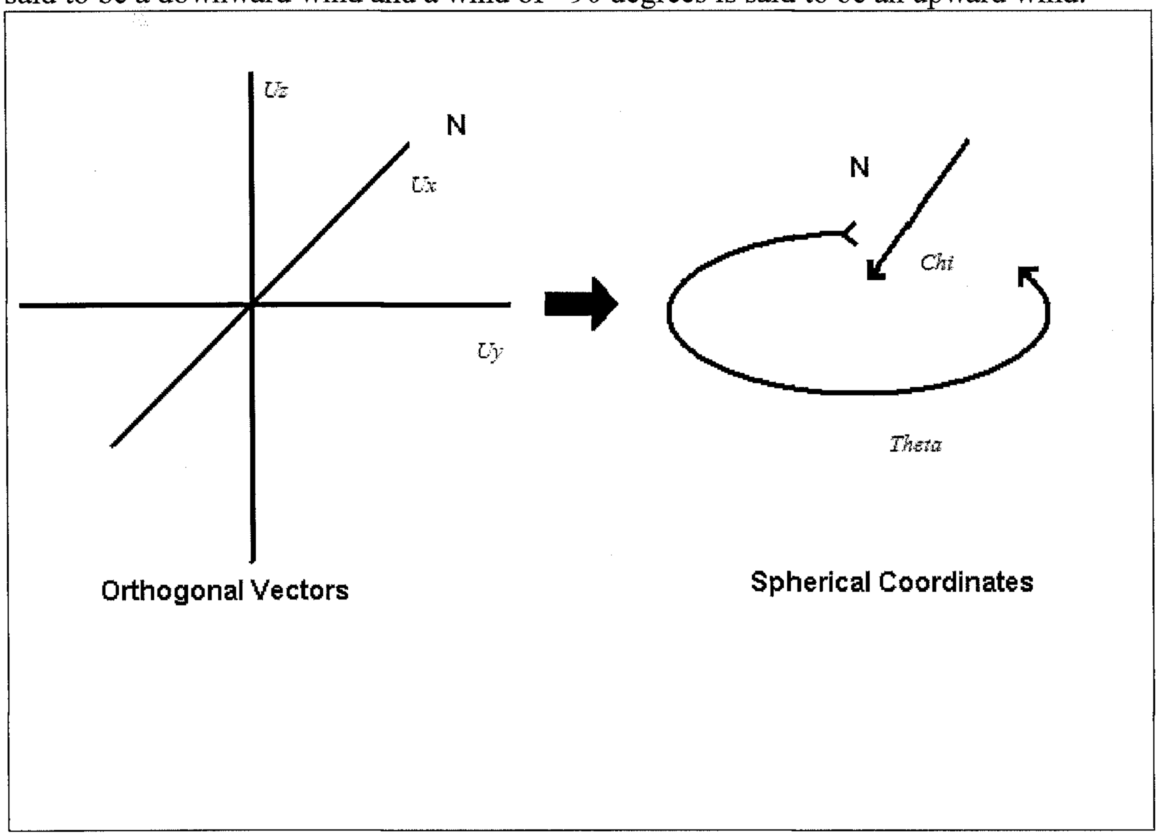


Figure B1. The transformation of orthogonal coordinates to spherical coordinates.