Biomass Fuel Usage at Wisconsin Power Plants

Final Report
August 2012

PREPARED BY:

MICHAEL KOERBER¹;
DR. DONNA KENSKI¹;
BILL ADAMSKI¹;
JOE HOCH²;
BART SPONSELLER³;
¹LAKE MICHIGAN AIR DIRECTORS CONSORTIUM,
³WISCONSIN DEPARTMENT OF NATURAL RESOURCES

This report was funded through the Environmental and Economic Research and Development Program of Wisconsin’s Focus on Energy.
Acknowledgements

We would like to acknowledge the measurement personnel involved in this project for their dedication and efforts in collecting the ambient and emissions data:

**Ambient Measurements**

Ashland, WI Site:  
Dr. Sharon Anthony, Northland College
Sean McIlrath, Northland College
Alex Bruns, Northland College

Cassville, WI Site:  
Jason Treutel
Gary Olson
Mark Allen, Wisconsin DNR

General Support:  
Bruce Rodger, Wisconsin DNR
Clyde Sweet, Illinois State Water Survey

**Emissions Measurements:**  
MACTEC Consulting and Engineering (Mike Maret, James Schoenberger, Kathryn Morrison), Southern Air Solutions (Stanley Arnold, Geoffrey Schoenberger), Enthalpy Analytical, Inc., and SGS Minerals Services, Inc.

University of Wisconsin, State Lab of Hygiene (Dr. James Schauer, Jeffrey DeMinter, and Martin Shafer)

We would also like to thank Xcel Energy and Alliant Energy for their help and assistance in providing access at their facilities for the emissions measurements.

Thanks also to the following people for their work in analyzing the ambient and emissions data, and producing the wonderful graphics for this report:

- Dr. Donna Kenski, LADCO
- Abby Jaye, LADCO
- William Adamski, Wisconsin DNR
- Jason Treutel, Wisconsin DNR
- Mike Majewski, Wisconsin DNR
- Joseph Hoch, Wisconsin DNR
- Dr. Charles Stanier, University of Iowa
- Charles Hester, AMEC
### Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>BenMap</td>
<td>Environmental Benefits Mapping and Analysis Program</td>
</tr>
<tr>
<td>BNSF</td>
<td>Burlington Northern and Santa Fe (Railroad)</td>
</tr>
<tr>
<td>BC</td>
<td>Black carbon</td>
</tr>
<tr>
<td>CAMx</td>
<td>Comprehensive Air Quality Model with Extensions</td>
</tr>
<tr>
<td>DC</td>
<td>Delta C</td>
</tr>
<tr>
<td>EC</td>
<td>Elemental carbon</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>HNO₃</td>
<td>Nitric acid</td>
</tr>
<tr>
<td>ICR</td>
<td>Information Collection Request</td>
</tr>
<tr>
<td>ISWS</td>
<td>Illinois State Water Survey</td>
</tr>
<tr>
<td>LADCO</td>
<td>Lake Michigan Air Directors Consortium</td>
</tr>
<tr>
<td>MMBtu</td>
<td>Million British Thermal Units</td>
</tr>
<tr>
<td>NESHAP</td>
<td>National Emission Standards for Hazardous Pollutants</td>
</tr>
<tr>
<td>NH₃</td>
<td>Ammonia</td>
</tr>
<tr>
<td>NH₄</td>
<td>Ammonium</td>
</tr>
<tr>
<td>NO</td>
<td>Nitrogen oxide</td>
</tr>
<tr>
<td>NO₂</td>
<td>Nitrogen dioxide</td>
</tr>
<tr>
<td>NOₓ</td>
<td>Nitrogen oxides</td>
</tr>
<tr>
<td>NO₃</td>
<td>Nitrate</td>
</tr>
<tr>
<td>N₂O</td>
<td>Nitrous oxide</td>
</tr>
<tr>
<td>OC</td>
<td>Organic carbon</td>
</tr>
<tr>
<td>OM</td>
<td>Organic matter</td>
</tr>
<tr>
<td>P</td>
<td>Pressure</td>
</tr>
<tr>
<td>PM</td>
<td>Particulate matter</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>Particulate matter with size of 2.5 micrometers or less</td>
</tr>
<tr>
<td>PSAT</td>
<td>Particulate Source Apportionment</td>
</tr>
<tr>
<td>SO₂</td>
<td>Sulfur dioxide</td>
</tr>
<tr>
<td>SO₄</td>
<td>Sulfate</td>
</tr>
<tr>
<td>T</td>
<td>Temperature</td>
</tr>
<tr>
<td>WD</td>
<td>Wind direction</td>
</tr>
<tr>
<td>WDNR</td>
<td>Wisconsin Department of Natural Resources</td>
</tr>
<tr>
<td>WRF</td>
<td>Weather Research and Forecasting</td>
</tr>
<tr>
<td>WS</td>
<td>Wind speed</td>
</tr>
</tbody>
</table>
## Table of Contents

<table>
<thead>
<tr>
<th>Section-Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Executive Summary</strong></td>
<td>iv</td>
</tr>
<tr>
<td><strong>1.0 Introduction</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>2.0 Emissions Measurements</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>3.0 Ambient Air Quality Measurements</strong></td>
<td>10</td>
</tr>
<tr>
<td><strong>4.0 Ambient Air Quality Data Analyses</strong></td>
<td>14</td>
</tr>
<tr>
<td>4.1 Overview of data analyses</td>
<td>14</td>
</tr>
<tr>
<td>4.2 What are the air quality levels in Cassville and Ashland, and how do these levels compare with other nearby sites?</td>
<td>14</td>
</tr>
<tr>
<td>4.3 What meteorological conditions and source regions are associated with high and low concentrations in Cassville and Ashland?</td>
<td>31</td>
</tr>
<tr>
<td>4.4 How sensitive are PM$_{2.5}$ concentrations in Cassville and Ashland to changes in precursor concentrations?</td>
<td>38</td>
</tr>
<tr>
<td><strong>5.0 Air Quality Modeling</strong></td>
<td>40</td>
</tr>
<tr>
<td>5.1 Overview of modeling analysis</td>
<td>40</td>
</tr>
<tr>
<td>5.2 What is the contribution of the two power plants to air quality in Cassville and Ashland?</td>
<td>45</td>
</tr>
<tr>
<td>5.3 What is the air quality benefit of using biomass fuels at power plants in Wisconsin?</td>
<td>50</td>
</tr>
<tr>
<td><strong>6.0 Summary</strong></td>
<td>52</td>
</tr>
<tr>
<td><strong>7.0 References</strong></td>
<td>54</td>
</tr>
</tbody>
</table>

**Appendix 1** Quality Assurance Notes  
**Appendix 2** Review of Aethalometer Data  
**Appendix 3** Daily PM$_{2.5}$, SO$_4$, and NO$_3$ Measurements  
**Appendix 4** Cassville Train Impact Analysis  
**Appendix 5** Wood Smoke Analysis  
**Appendix 6** Letter from Xcel Energy
EXECUTIVE SUMMARY

The Lake Michigan Air Directors Consortium (LADCO), in conjunction with the Wisconsin Department of Natural Resources (WDNR) and the University of Wisconsin-Madison, worked together to characterize the emissions, air quality impacts, and public health benefits of burning biomass fuels at power plants in Wisconsin. Interest in biomass fuels has increased in recent years due to economic, environmental, and national security reasons. In the Midwestern U.S., in particular, there has been a significant increase in the number of new/modified source permit applications involving biomass fuel usage.

The study focused on two power plants currently using biomass fuels: Alliant Energy’s Nelson Dewey Plant in Cassville, WI; and Xcel Energy’s Bay Front Plant in Ashland, WI – see figure to right. Three tasks were performed: stack testing, ambient monitoring, and data analyses (including air quality modeling).

Stack Testing: In September 2010, emission measurements were made at both facilities using EPA-approved methods. During testing, the boiler at Bay Front burned mostly wood waste with small amounts of tire-derived fuels, and the boiler at Nelson Dewey burned about 64% bituminous coal, 16% petroleum coke, and 20% corn fiber pellets.

Ambient Monitoring: WDNR established special purpose monitoring sites in Cassville and Ashland – see figure below. These sites operated from July 2010 to June 2011. Measurements at each site focused on PM<sub>2.5</sub> mass and chemical species, various gaseous pollutants, and meteorology.

Data Analysis: Data from the special purpose monitoring sites, and other sites in Wisconsin and neighboring states, were reviewed to provide information on air quality in the upper Midwest, and to help assess the effect of using biomass fuels. Data analyses included simple graphics to describe/display the measurement data; back trajectories and pollution roses to identify
contributing sources; examination of PM$_{2.5}$-mass and precursor relationships to identify critical chemical species on high concentration days; and air quality modeling to assess the effect of expanded use of biomass fuels in the State.

Three major lessons were learned from this study

- **Characterization of air quality in the two Wisconsin communities**
  - Measurements for several criteria pollutants (PM$_{2.5}$, NO$_2$, SO$_2$), while not intended to be used for compliance purposes, indicate relatively “clean” air quality in these communities relative to federal air quality standards.
  - Ambient concentrations for all measured pollutants are generally lower in Ashland compared to Cassville.
  - Higher concentrations for PM$_{2.5}$ and NO$_x$ occurred during the colder months (November – March) and appear to be due to a combination of seasonal emissions activities and meteorology (i.e., lower nighttime mixing heights during the winter).

- **Source attribution in the two Wisconsin communities**
  - The impact of the two power plants is evident for certain pollutants, e.g., pollution roses indicate that these sources are the dominant contributors to local SO$_2$ concentrations.
  - In Cassville, passing trains on the adjacent BNSF railroad tracks have a major impact on certain combustion-related pollutants – e.g., NO/NO$_2$/NO$_x$ and BC.
  - PM$_{2.5}$ concentrations appear to be mostly regional in nature, with only modest impacts from local sources (e.g., residential wood burning activities contribute to PM$_{2.5}$ and BC concentrations during the winter months). Modeling shows that emissions from sources in Wisconsin and neighboring states are the largest contributors to PM$_{2.5}$ concentrations, with Wisconsin power plants having a relatively small impact.
  - High wintertime PM$_{2.5}$ concentrations are slightly more sensitive to reductions in ammonia concentrations than reductions in nitrate concentrations.

- **Effect of biomass burning in the two Wisconsin communities (and statewide)**
  - Use of biomass fuels at the power plants in these communities serves to decrease emissions for certain air pollutants; in particular, for SO$_2$. The results of the stack tests at Nelson Dewey and Bay Front are generally consistent with a number of stack tests at industrial facilities burning biomass fuels (mostly, wood-based fuels). However, a number of technical issues were identified with the Nelson Dewey and Bay Front stack tests, which creates some uncertainty in the reported values.
  - Assuming the use of biomass fuels at power plants across the State results in lower SO$_2$ emissions and, consequently, lower PM$_{2.5}$ concentrations. The associated public health benefits were found to be greatest in higher population Midwest urban areas.
Section 1.0 Introduction

In FY2010, the U.S. Environmental Protection Agency (EPA) provided funding ($195,000) to the Lake Michigan Air Directors Consortium (LADCO) to “support state and local work for effective and early collaboration on energy projects to ensure the seamless integration of federal NEPA and state requirements and to reduce state/federal regulatory redundancy. This includes building expertise to effectively collaborate and negotiate in the early and later stages of energy development, conduct needed monitoring and modeling to assess impacts and develop guidance, policy and regulatory implementation as related to energy development." The LADCO States decided to use the energy funds on a project to characterize the emissions, air quality impacts, and public health benefits of burning biomass fuels at power plants in Wisconsin. Additional funding was provided from the Wisconsin Focus on Energy ($243,351) for the full project¹. Other participants in the study include the Wisconsin Department of Natural Resources (WDNR), the University of Wisconsin-Madison, and two Wisconsin power companies.

1.1 Project Overview
The main objectives of this project are to characterize the emissions, air quality impacts, and public health benefits of burning biomass fuels, instead of fossil fuels, at power plants in Wisconsin. Currently, Wisconsin power plants emit pollutants which adversely affect air quality in the state and which can contribute to climate change. Use of biomass fuels reduce emissions of these pollutants and, thereby, improve air quality and provide public health benefits, but there is little quantitative information on these effects.

Several power plants in Wisconsin are currently using, or planning to use, biomass fuels, including Alliant Energy’s Nelson Dewey Plant in Cassville, WI, and Xcel Energy’s Bay Front Plant in Ashland, WI. During periods of biomass fuel usage in September 2010, emissions were measured using EPA-approved methods.

To understand air quality levels in Cassville and Ashland, WDNR operated special purpose monitoring sites in each community from July 1, 2010 to June 30, 2011. Analyses of the monitoring data, including the application of mathematical computer models, were conducted to assess the impact of biomass fuel usage at these two power plants. Additional sensitivity modeling was performed to assess the impact of using biomass fuels at power plants throughout the State.

1.2 Statement of Work
The Wisconsin biomass fuels project consists of three main tasks:

(1) Emission Measurements: A contractor and the University of Wisconsin-Madison conducted emission measurements for gaseous and PM$_{2.5}$ species at two power plants in Wisconsin burning biomass fuels: Alliant Energy’s Nelson Dewey Plant in Cassville, WI, and Xcel Energy’s Bay Front Plant in Ashland, WI. Measurements were collected in September 2010 using EPA-approved methodologies for the following pollutants: PM, SO$_2$, NOx, and total hydrocarbons. The samples were subsequently analyzed by the University of Wisconsin to produce more detailed emissions profiles for the carbonaceous component of the PM$_{2.5}$ emissions.

¹ On December 8, 2009, the Wisconsin Focus on Energy approved the additional funding for this project.
The contractor provided an electronic data set of emission measurements for the two power plants, along with a technical report summarizing the emission measurement program. The contractor also submitted the data to EPA via the Electronic Reporting Tool (ERT).

(2) Air Quality Measurements: WDNR operated air quality instruments to collect ambient measurements in Cassville, WI and Ashland, WI. Continuous measurements for PM$_{2.5}$-mass, PM$_{2.5}$-black carbon, SO$_2$, NO$_x$, and meteorology (wind speed, wind direction, and temperature), 1-in-3 day filter-based measurements for PM$_{2.5}$-species, and 1-in-3 day denuder-based measurements for ammonia (NH$_3$) and nitric acid (HNO$_3$) were collected for a period of 12 months in each location to support air quality analyses and to inform Wisconsin citizens about local air quality. The air quality instruments were operated in conformance with WDNR's standard operating procedures, which were approved by EPA.

WDNR validated the data and prepared a comprehensive database with hourly and daily average measurements for all air quality and meteorological parameters.

(3) Air Quality Analyses: LADCO and WDNR conducted air quality analyses to quantify the impact of burning biomass fuels at power plants in Wisconsin. The analyses consisted of several methods to characterize the spatial pattern, temporal profile, and chemical composition of the air quality measurements, and included the use of a regional photochemical model (CAMx). In addition, WDNR applied EPA’s Environmental Benefits Mapping and Analysis Program (BenMAP) to estimate the health impacts associated with changes in ambient air pollution due to using biomass fuels.

This report is organized in the following sections. This section provides an overview of the Wisconsin biomass fuels project. Section 2 reviews the emission measurements and Section 3 reviews the ambient air quality measurements. Section 4 summarizes the air quality data analyses and Section 5 summarizes the air quality modeling. Key study findings are discussed in Section 6.
Section 2.0 Emission Measurements

LADCO retained MACTEC Engineering and Consulting, Inc. of Research Triangle Park, North Carolina to conduct emissions testing at the Bay Front Station and the Nelson Dewey Generating Station. (Note, although testing was also planned for another facility – i.e., the DTE Energy Stoneman Generating Station - this facility was under an extended outage and was not online in time for the test program.)

Prior to the stack testing, a Quality Assurance Project Plan was prepared and submitted to EPA for review and approval (MACTEC, 2010). The plan was approved by EPA, Region 5 on August 25, 2010.

The Xcel Energy Bay Front Power Plant is located at 122 N. 14th Avenue West, in Ashland, Ashland County, WI. Construction of Boiler B20 commenced in 1953; the unit startup was in 1954. Construction of Boiler B21 commenced in 1951; unit startup was in 1952. The boilers and the associated air pollution control devices for each boiler are essentially identical: Babcock and Wilcox spreader stoker boilers with a rated output capacity of 250,000 lbs. steam per hour, or 275 MM Btu/hr. Boiler B20 vents out stack S10 and Boiler B21 vents out stack S11. In addition, there is a third unit at Bay Front (Boiler 24), which vents out stack S13. Boiler 24 burns mostly sub-bituminous coal, and a small amount of natural gas.

Testing on Boiler B21 at the Bay Front Generating Station was conducted during the period of September 14-16, 2010. Boiler B21 (and Boiler B20) currently burn varying combinations of wood, railroad ties, coal, natural gas, and tire derived fuels. The fuel fired during the testing was mostly wood waste with small amounts of tire-derived fuel (Appendix 6).

Figure 2.1 Bay Front Station, with B21 (S11) on left
The Alliant Energy Nelson Dewey Generating Station is located at 11999 County Road VV, Cassville, Grant County, WI. Boilers B21 and B22 are Babcock and Wilcox cyclone furnaces with rated heat inputs of 1,260 MM Btu/hr for coal or No. 2 fuel oil. Both boilers were installed in 1959. Both boilers vent out the same stack (S11). Testing of the boiler was scheduled to occur during a planned maintenance outage for Boiler B22. Therefore, only emissions from Boiler B21 were present in the common stack.

Testing on Boiler B21 at the Nelson Dewey Generating Station was conducted during the period of September 20-22, 2010. The fuel fired during the testing consisted of approximately 64% bituminous coal, 16% petroleum coke, and 20% corn fiber pellets.

Measurements of the target pollutants and stack gas parameters were made using EPA Test Methods, as found in Title 40 Part 60, Appendix A of the Code of Federal Regulations (40 CFR 60, Appendix A) and methods designated by EPA as “Other Test Methods” or OTMs. LADCO requested that MACTEC conduct measurements for nitrous oxide (N2O). EPA has not promulgated a method specifically for the measurement of N2O in stack gases. MACTEC used a Gas Filter Correlation/Infra-Red (GFC/IR) analyzer to quantify N2O. The analyzer was operated using the basic procedures outlined in EPA Method 7E. Table 2.1 summarizes the methods that were used. Samples of the as-fired fuels were collected by personnel at each plant and transferred to MACTEC.
Table 2.1 Sampling Methods for Bay Front and Nelson Dewey Stack Testing

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Parameter</th>
<th>Measurement Principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA Method 1</td>
<td>Sample Point Location</td>
<td>Linear Measurement</td>
</tr>
<tr>
<td>EPA Method 2</td>
<td>Velocity &amp; Flow</td>
<td>Gas Differential Pressure, Thermocouple</td>
</tr>
<tr>
<td>EPA Method 3A</td>
<td>Oxygen, Carbon Dioxide</td>
<td>Paramagnetic Analyzer, NDIR Analyzer</td>
</tr>
<tr>
<td>EPA Method 4</td>
<td>Moisture Content</td>
<td>Gravimetric</td>
</tr>
<tr>
<td>EPA Method 5/26A</td>
<td>Filterable Particulate Matter</td>
<td>Gravimetric</td>
</tr>
<tr>
<td></td>
<td>Hydrogen Chloride</td>
<td>Ion Chromatography</td>
</tr>
<tr>
<td>EPA Method 6C</td>
<td>Sulfur Dioxide</td>
<td>Ultra-violet</td>
</tr>
<tr>
<td>EPA Method 7E</td>
<td>Nitrogen Oxides (NO2)</td>
<td>Chemiluminescence</td>
</tr>
<tr>
<td>EPA Method 7E (modified)</td>
<td>Nitrous Oxide (N2O)</td>
<td>NDIR/GFC</td>
</tr>
<tr>
<td>EPA Method 10</td>
<td>Carbon Monoxide</td>
<td>NDIR/GFC</td>
</tr>
<tr>
<td>EPA OTM 27/28</td>
<td>Fine Particulate Matter (PM2.5)/CPM</td>
<td>Inertial Separation/Dry Impingement</td>
</tr>
</tbody>
</table>

The fuel samples were analyzed by SGS for the parameters shown in Table 2.2.

Table 2.2 Analysis Methods for Bay Front and Nelson Dewey Fuel Sampling

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Analytical Method</th>
<th>Measurement Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass Fuel (Bay Front)</td>
<td>ASTM D 3176</td>
<td>Ultimate Analysis</td>
</tr>
<tr>
<td></td>
<td>ASTM D 5685</td>
<td>Gross Calorific Value</td>
</tr>
<tr>
<td></td>
<td>ASTM D 3173</td>
<td>Moisture</td>
</tr>
<tr>
<td>Combined Fuel - bituminous coal, petroleum code, and biomass fuel (Nelson Dewey)</td>
<td>ASTM D 3172</td>
<td>Proximate Analysis</td>
</tr>
<tr>
<td></td>
<td>ASTM D 3176</td>
<td>Ultimate Analysis</td>
</tr>
<tr>
<td></td>
<td>ASTM D 5685</td>
<td>Gross Calorific Value</td>
</tr>
<tr>
<td></td>
<td>ASTM D 4208</td>
<td>Chlorine</td>
</tr>
</tbody>
</table>
Table 2.3 summarizes the measured concentrations and mass emissions rates from the stack tests. Further information, including a review of process operating conditions, sampling methods, quality assurance/quality control procedures, and results, is provided in MACTEC, 2011. It should be noted that there is some uncertainty associated with the reported values, in light of limitations addressed in the final report and several concerns raised in a December 16, 2011, letter from Xcel Energy (Appendix 6).

Table 2.3 Summary of Stack Test Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bay Front Station (Average)</th>
<th>Nelson Dewey Station (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stack Gas Volumetric Flow, dscfm</td>
<td>69,657</td>
<td>280,452</td>
</tr>
<tr>
<td>Average Stack Temperature, °F</td>
<td>353</td>
<td>284</td>
</tr>
<tr>
<td>Carbon Dioxide Content, % by dry volume, d.b.</td>
<td>11.9</td>
<td>13.5</td>
</tr>
<tr>
<td>Oxygen Content, % by volume, d.b.</td>
<td>8.8</td>
<td>5.7</td>
</tr>
<tr>
<td>Moisture, % by volume</td>
<td>18.2</td>
<td>10.9</td>
</tr>
<tr>
<td>Carbon Monoxide Emission Rate, lb/hr</td>
<td>34.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Carbon Monoxide Emission Rate, lb/MMBTU</td>
<td>0.15</td>
<td>0.005</td>
</tr>
<tr>
<td>Nitrogen Oxides (as NO2) Emission Rate, lb/hr</td>
<td>42.4</td>
<td>467.4</td>
</tr>
<tr>
<td>Nitrogen Oxides (as NO2) Emission Rate, lb/MMBTU</td>
<td>0.179</td>
<td>0.37</td>
</tr>
<tr>
<td>Nitrous Oxides (N2O) Emission Rate, lb/hr</td>
<td>2.51</td>
<td>8.7</td>
</tr>
<tr>
<td>Nitrous Oxides (N2O) Emission Rate, lb/MMBTU</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Sulfur Dioxide Emission Rate, lb/hr</td>
<td>8.9a</td>
<td>1,868</td>
</tr>
<tr>
<td>Sulfur Dioxide Emission Rate, lb/MMBYU</td>
<td>0.04a</td>
<td>1.48</td>
</tr>
<tr>
<td>PM Emission Rate, lb/hr</td>
<td>5.07</td>
<td>64</td>
</tr>
<tr>
<td>PM Emission Rate, lb/MMBTU</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>PM2.5 Emission Rate, lb/hr</td>
<td>3.1</td>
<td>28.1</td>
</tr>
<tr>
<td>PM2.5 Emission Rate, lb/MMBTU</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>CPM2.5 Emission Rate, lb/hr</td>
<td>6.6</td>
<td>34.6</td>
</tr>
<tr>
<td>CPM2.5 Emission Rate, lb/MMBTU</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Total PM2.5 Emission Rate, lb/hr</td>
<td>9.7</td>
<td>62.7</td>
</tr>
<tr>
<td>Total PM2.5 Emission Rate, lb/MMBTU</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>HCl Emission Rate, lb/hr</td>
<td>&lt;0.0238</td>
<td>41.5</td>
</tr>
<tr>
<td>HCl Emission Rate, lb/MMBTU</td>
<td>&lt;0.0001</td>
<td>0.03</td>
</tr>
</tbody>
</table>

*a Based on average of two valid runs (Runs 1 and 2)*
Additional analysis of the PM filters were performed by the Wisconsin State Lab of Hygiene to identify chemical speciation. The filters and analyses are summarized in Table 2.4. The analysis results in Table 2.5 show higher OC and EC concentrations associated with biomass (wood) fuel at Bay Front, compared to the use of mostly coal at Nelson Dewey. Total PM$_{2.5}$ emissions at Bay Front, however, are lower than at Nelson Dewey – see Table 2.3.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Description</th>
<th>Mass (mg)</th>
<th>Calculated Emissions Rate (H/MMBTU)</th>
<th>ECOC</th>
<th>GCMS</th>
<th>IC</th>
<th>ICPMS</th>
<th>WSOC</th>
<th>ROS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay Front Run 1 Method 5/26A Filt</td>
<td>Biomass; PM Quartz Filter</td>
<td>14.1</td>
<td>0.0191</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Bay Front Run 2 Method 5/26A Filt</td>
<td>Biomass; PM Quartz Filter</td>
<td>14.4</td>
<td>0.0197</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Bay Front Run 3 Method 5/26A Filt</td>
<td>Biomass; PM Quartz Filter</td>
<td>18.7</td>
<td>0.0261</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Bay Front Run 4 Method 5/26A Filt</td>
<td>Biomass; PM Quartz Filter</td>
<td>15.4</td>
<td>0.0189</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Nelson Dewey Run 1 Method 5/26A Filt</td>
<td>Coal; PM Quartz Filter</td>
<td>29.4</td>
<td>0.0350</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Nelson Dewey Run 2 Method 5/26A Filt</td>
<td>Coal; PM Quartz Filter</td>
<td>40.7</td>
<td>0.0489</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Nelson Dewey Run 3 Method 5/26A Filt</td>
<td>Coal; PM Quartz Filter</td>
<td>53.1</td>
<td>0.0682</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Method 5/26A Blank</td>
<td>Quartz  ND</td>
<td>ND</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Bay Front Run 1 OTM 27/28 Filt</td>
<td>Biomass; PM Quartz Filter</td>
<td>6.6</td>
<td>0.0090</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bay Front Run 2 OTM 27/28 Filt</td>
<td>Biomass; PM Quartz Filter</td>
<td>9.6</td>
<td>0.0122</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bay Front Run 3 OTM 27/28 Filt</td>
<td>INVALID Negative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nelson Dewey Run 1 OTM 27/28 Filt</td>
<td>INVALID Negative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nelson Dewey Run 2 OTM 27/28 Filt</td>
<td>Coal; PM Quartz Filter</td>
<td>19.5</td>
<td>0.0247</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nelson Dewey Run 3 OTM 27/28 Filt</td>
<td>Coal ; PM Quartz Filter</td>
<td>12.2</td>
<td>0.0162</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OTM 27/28 Front Blank</td>
<td>Quartz  ND</td>
<td>ND</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bay Front Run 1 OTM 27/28 CPM Filt</td>
<td>Biomass; SVOC Teflon GFF</td>
<td>ND</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bay Front Run 2 OTM 27/28 CPM Filt</td>
<td>Biomass; SVOC Teflon GFF</td>
<td>ND</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bay Front Run 3 OTM 27/28 CPM Filt</td>
<td>Biomass; SVOC Teflon GFF</td>
<td>ND</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nelson Dewey Run 1 OTM 27/28 CPM Filt</td>
<td>Coal; SVOC Teflon GFF</td>
<td>ND</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nelson Dewey Run 2 OTM 27/28 CPM Filt</td>
<td>Coal; SVOC Teflon GFF</td>
<td>ND</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nelson Dewey Run 3 OTM 27/28 CPM Filt</td>
<td>Coal; SVOC Teflon GFF</td>
<td>ND</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OTM 27/28 CPM Blank</td>
<td>Teflon GFF  ND</td>
<td>ND</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2.5 Chemical Analysis Results

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>OC(µg/sample)</th>
<th>OC unc</th>
<th>EC(µg/sample)</th>
<th>EC unc</th>
<th>TC(µg/sample)</th>
<th>TC unc</th>
</tr>
</thead>
<tbody>
<tr>
<td>METHOD BLANK 5/26A FB</td>
<td>115.04</td>
<td>15.06</td>
<td>0.00</td>
<td>9.31</td>
<td>115.04</td>
<td>19.71</td>
</tr>
<tr>
<td>METHOD BLANK 5/26A FB(2)</td>
<td>136.20</td>
<td>16.12</td>
<td>0.00</td>
<td>9.31</td>
<td>136.20</td>
<td>20.77</td>
</tr>
<tr>
<td>METHOD BLANK 5/26A FB(3)</td>
<td>141.84</td>
<td>16.40</td>
<td>0.00</td>
<td>9.31</td>
<td>141.84</td>
<td>21.05</td>
</tr>
<tr>
<td>METHOD BLANK 5/26A FB(4)</td>
<td>158.04</td>
<td>17.21</td>
<td>0.00</td>
<td>9.31</td>
<td>158.04</td>
<td>21.86</td>
</tr>
<tr>
<td><strong>average</strong></td>
<td><strong>137.78</strong></td>
<td><strong>16.20</strong></td>
<td><strong>0.00</strong></td>
<td><strong>9.31</strong></td>
<td><strong>137.78</strong></td>
<td><strong>20.85</strong></td>
</tr>
<tr>
<td>NELSON DEWEY 5/26A-RUN1</td>
<td>164.34</td>
<td>17.52</td>
<td>0.00</td>
<td>9.31</td>
<td>164.34</td>
<td>22.18</td>
</tr>
<tr>
<td>NELSON DEWEY 5/26A-RUN1(2)</td>
<td>127.67</td>
<td>15.69</td>
<td>0.00</td>
<td>9.31</td>
<td>127.67</td>
<td>20.35</td>
</tr>
<tr>
<td>NELSON DEWEY 27/28 RUN1</td>
<td>116.15</td>
<td>15.12</td>
<td>0.00</td>
<td>9.31</td>
<td>116.15</td>
<td>19.77</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>130.93</strong></td>
<td><strong>15.85</strong></td>
<td><strong>0.00</strong></td>
<td><strong>9.31</strong></td>
<td><strong>130.93</strong></td>
<td><strong>20.51</strong></td>
</tr>
<tr>
<td>NELSON DEWEY 5/26A-RUN2</td>
<td>288.08</td>
<td>23.71</td>
<td>0.00</td>
<td>9.31</td>
<td>288.08</td>
<td>28.37</td>
</tr>
<tr>
<td>NELSON DEWEY 5/26A-RUN2(2)</td>
<td>186.07</td>
<td>18.61</td>
<td>0.00</td>
<td>9.31</td>
<td>186.07</td>
<td>23.27</td>
</tr>
<tr>
<td>NELSON DEWEY 27/28 RUN2</td>
<td>184.38</td>
<td>18.53</td>
<td>0.00</td>
<td>9.31</td>
<td>184.38</td>
<td>23.18</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>205.07</strong></td>
<td><strong>19.56</strong></td>
<td><strong>0.00</strong></td>
<td><strong>9.31</strong></td>
<td><strong>205.07</strong></td>
<td><strong>24.22</strong></td>
</tr>
<tr>
<td>NELSON DEWEY 5/26A-RUN3</td>
<td>182.21</td>
<td>18.42</td>
<td>0.00</td>
<td>9.31</td>
<td>182.21</td>
<td>23.07</td>
</tr>
<tr>
<td>NELSON DEWEY 5/26A-RUN3(2)</td>
<td>168.09</td>
<td>17.71</td>
<td>0.00</td>
<td>9.31</td>
<td>168.09</td>
<td>22.37</td>
</tr>
<tr>
<td>NELSON DEWEY 27/28 RUN3</td>
<td>188.62</td>
<td>18.74</td>
<td>0.00</td>
<td>9.31</td>
<td>188.62</td>
<td>23.39</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>173.00</strong></td>
<td><strong>17.96</strong></td>
<td><strong>0.00</strong></td>
<td><strong>9.31</strong></td>
<td><strong>173.00</strong></td>
<td><strong>22.61</strong></td>
</tr>
<tr>
<td>BAY FRONT 5/26A-RUN1</td>
<td>785.90</td>
<td>48.60</td>
<td>214.36</td>
<td>20.03</td>
<td>1000.26</td>
<td>63.98</td>
</tr>
<tr>
<td>BAY FRONT 5/26A-RUN1(2)</td>
<td>735.25</td>
<td>46.07</td>
<td>237.72</td>
<td>21.19</td>
<td>972.97</td>
<td>62.61</td>
</tr>
<tr>
<td><strong>average</strong></td>
<td><strong>760.57</strong></td>
<td><strong>47.34</strong></td>
<td><strong>226.04</strong></td>
<td><strong>20.61</strong></td>
<td><strong>986.62</strong></td>
<td><strong>63.29</strong></td>
</tr>
<tr>
<td>BAY FRONT 5/26A-RUN2</td>
<td>1030.86</td>
<td>60.85</td>
<td>273.94</td>
<td>23.00</td>
<td>1304.80</td>
<td>79.20</td>
</tr>
<tr>
<td>BAY FRONT 5/26A-RUN2(2)</td>
<td>1064.31</td>
<td>62.52</td>
<td>335.55</td>
<td>26.09</td>
<td>1399.86</td>
<td>83.96</td>
</tr>
<tr>
<td><strong>average</strong></td>
<td><strong>1047.59</strong></td>
<td><strong>63.56</strong></td>
<td><strong>304.74</strong></td>
<td><strong>24.98</strong></td>
<td><strong>1352.33</strong></td>
<td><strong>81.58</strong></td>
</tr>
<tr>
<td>BAY FRONT 5/26A-RUN3</td>
<td>1107.14</td>
<td>64.67</td>
<td>126.31</td>
<td>15.62</td>
<td>1233.45</td>
<td>75.63</td>
</tr>
<tr>
<td>BAY FRONT 5/26A-RUN3(2)</td>
<td>1062.76</td>
<td>62.45</td>
<td>100.74</td>
<td>14.35</td>
<td>1163.50</td>
<td>72.14</td>
</tr>
<tr>
<td><strong>average</strong></td>
<td><strong>1084.95</strong></td>
<td><strong>65.06</strong></td>
<td><strong>113.52</strong></td>
<td><strong>14.98</strong></td>
<td><strong>1198.47</strong></td>
<td><strong>75.35</strong></td>
</tr>
<tr>
<td>BAY FRONT 5/26A-RUN4</td>
<td>1094.44</td>
<td>64.03</td>
<td>258.34</td>
<td>22.22</td>
<td>1352.78</td>
<td>81.60</td>
</tr>
<tr>
<td>BAY FRONT 5/26A-RUN4(2)</td>
<td>1084.43</td>
<td>63.53</td>
<td>247.88</td>
<td>21.70</td>
<td>1332.30</td>
<td>80.58</td>
</tr>
<tr>
<td><strong>average</strong></td>
<td><strong>1089.43</strong></td>
<td><strong>63.78</strong></td>
<td><strong>253.11</strong></td>
<td><strong>22.06</strong></td>
<td><strong>1342.54</strong></td>
<td><strong>82.08</strong></td>
</tr>
</tbody>
</table>

Notes: Reported 8/29/11 by jeff.deminter@slh.wisc.edu
Results have not been blank subtracted
Results reported as µg/sample
0.00 indicates a non-detect
NA indicates the result is not available

Lab Notes: Sample size: ~90mm Quartz
Approximate exposed sample area: 46.54cm²
Area used for ECOC analysis: 1.0cm²
To provide context for the Wisconsin stack test results, a contractor obtained a copy of the emissions test data that was submitted to EPA in response to their Information Collection Request (ICR) that was used to support the development of the industrial/commercial boilers NESHAP (AMEC, 2011). The ICR database includes data from hundreds of boilers burning a variety of fuels and controlled by a wide range of control devices. The data were first sorted by fuel type to produce a dataset that included only those combustion units that burned biomass as the primary fuel or, in most cases, the only fuel being burned during the testing. For the primary pollutants of interest, two graphics were created: a scatter plot and a bar-whisker plot. For PM, CO, SOX, and NOX, the tested emission levels from the Bay Front and Nelson Dewey units were included on the whisker plots.

Figure 2.3 summarizes the results of hundreds of emissions tests conducted on a range of industrial/commercial boilers burning various types of biomass. Most of the boilers were burning either wet or dry wood in the form of bark, chips, sawdust, and hogged scrap. The results show that the Nelson Dewey and Bay Front test results are generally consistent with a large number of other biomass test data. (Note, the higher NOX and SOX values for Nelson Dewey reflect the use of 80% coal and only 20% biomass during the stack test.)

Figure 2.3  Summary of ICR database by pollutant, plus Nelson Dewey (orange square) and Bay Front (blue triangle) test results
Section 3.0 Ambient Air Quality Measurements

To provide information on air quality in Cassville and Ashland, WDNR established and operated two special purpose monitoring sites in these communities from July 2010 to June 2011 (see Figures 3.1 and 3.2). The Cassville site was located next to the Burlington Northern Santa Fe (BNSF) railroad tracks (near Front St and Wisconsin St) about 1.35 km southeast of the Nelson Dewey plant, and about 1.2 km northwest of the Stoneman plant. The Ashland site was located at 11th Ave W (near 4th St W) about 0.7 km southeast of the Bay Front plant.

Figure 3.1 Cassville Air Monitoring Site

Figure 3.2 Ashland Air Monitoring Site

Measurements at each site focused on PM$_{2.5}$ mass and chemical species, various gaseous pollutants, and meteorology. Table 3.1 shows the instrumentation deployed at each site.
Table 3.1 Special Purpose Monitoring Equipment

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Pollutants</th>
<th>Sampling Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magee Scientific Aethalometer Model AE21</td>
<td>BC</td>
<td>continuous (1-hr ave)</td>
</tr>
<tr>
<td>Super SASS Sequential Sampler, 8-channel</td>
<td>PM2.5-mass, SO4, NO3, NH4, EC, OC</td>
<td>24-hour, 1-in-3 day schedule</td>
</tr>
<tr>
<td>ISWS Denuder Sampler</td>
<td>NH3, HNO3, SO2</td>
<td>24-hour, 1-in-3 day schedule</td>
</tr>
<tr>
<td>Met One BAMS-1020</td>
<td>PM2.5-mass</td>
<td>continuous (1-hr ave)</td>
</tr>
<tr>
<td>Teledyne API SO2 Analyzer, Model 100E</td>
<td>SO2</td>
<td>continuous (1-hr ave)</td>
</tr>
<tr>
<td>Teledyne API NO/NO2/NOx Analyzer, Model 200E</td>
<td>NO, NO2, NOx</td>
<td>continuous (1-hr ave)</td>
</tr>
<tr>
<td>Met One Meteorological System</td>
<td>WS, WD, T, P, relative humidity</td>
<td>continuous (1-hr ave)</td>
</tr>
</tbody>
</table>

The air quality instruments were operated in conformance with WDNR’s standard operating procedures, which were approved by EPA:

PM$_{2.5}$
- OP.7.3 Standard Operation Procedure for the Particulate Matter (PM$_{2.5}$) Met One SASS Sampler
- Met-One Instruments Beta Attenuation Mass Monitor Standard Operation Procedures, Minnesota Pollution Control Agency (MPCA). The WDNR recently started testing this type of monitor and is currently following MPCA’s SOP.

Black Carbon [BC]
- Standard Operating Procedures for the Magee Scientific Dual Channel Aethalometer, Michigan Department of Environmental Quality (MDEQ). The WDNR has been following MDEQ’s SOP. This SOP will be used as a template for a future WDNR SOP.

Meteorology
- QA.9.0.10 Meteorological Parameter Quality Assurance Plan. This document outlines a series of criteria to be used in assessing the validity of meteorological monitoring data recorded by WDNR.

Sulfur Dioxide [SO$_2$]
- QA.2.0 Sulfur Dioxide Quality Assurance Plan. This document includes WDNR procedures for assessing and reporting the precision and accuracy of the recorded data as required by 40 CFR 58, Appendix A.

Oxides of Nitrogen [NO$_x$]
- QA.5.0 Oxides of Nitrogen Quality Assurance Plan. WDNR’s NOx QA plan has been developed in accordance with EPA’s Quality Assurance Handbook for Air Pollution Measurement Systems.

Ammonia [NH$_3$]
- WDNR does not have an SOP for NH3, but the Illinois State Water Survey has developed an SOP for their pumped denuder system (ISWS, 2010). A Quality Assurance Project Plan for this sampling (ISWS, 2003) was approved by U.S. EPA on December 16, 2003.
Several comments on the ambient air quality measurements should be noted:

- WDNR conducted a thorough review of the continuous data from the Cassville and Ashland sites. Notes of all changes and periods of questionable data are provided in Appendix 1. The data files were edited accordingly (i.e., removed data that was invalidated and highlighted/commented the periods that were flagged as questionable).

- WDNR also conducted a thorough review of the PM$_{2.5}$ speciation data from the Cassville and Ashland sites. Notes of all changes and periods of questionable data are provided in Appendix 1. The data files were edited accordingly (e.g., rows were added for missed 1:3 sample dates). Flags were applied to data that did not meet all criteria and invalid flags were applied to samples that violate major criteria or had no result available. The majority of the flagged data may still be considered usable with caution.

- A 1-day intercomparison study at Cassville between the LADCO aethalometer (Model AE21) and a WDNR-owned aethalometer (Model AE22) was performed on September 22, 2010 (WDNR, 2010). The results of the study suggest differences in the response of the two aethalometers. The LADCO aethalometer had a greater standard deviation, indicating a greater measurement variation.

  A follow-up study was performed at the WDNR shop in Madison, WI from January 6 to January 18, 2011 (WDNR, 2011). Overall, the two aethalometers tracked very well on both the black carbon and the UV particulate matter channels. There was more variability or noise with the LADCO aethalometer compared to the WDNR aethalometer. According to the instrument manufacturer, Model AE21 has older electronics and is, therefore, more susceptible to noise in the response. The study also showed that there is a bias between the two analyzers – i.e., the WDNR aethalometer readings are significantly lower than those from the LADCO aethalometer.

  Further detail on the two intercomparison studies is provided in Appendix 2.

- The Cassville site is located adjacent to the BNSF railroad tracks. The passing trains (about 30-40 per day) had a major impact on the measured concentrations for NO/NO$_2$/NO$_x$ and BC. For example, the 12-month pollution rose for NO$_x$ (see also Section 4.2) is presented in Figure 3.3 with a Google Earth image. The highest concentrations (represented by the light blue and dark green colors) are clearly coming from the direction of the railroad tracks.

The LADCO aethalometer collected data at Cassville from July 2010 to January 2001, and was then moved to Ashland where it collected data from late January to June 2011.
A detailed analysis was conducted of train passes (estimated based on the train schedule) and 1-minute concentration data at Cassville for the month of October 2010. An example plot is provided in Figure 3.4 for two days (October 8 and 20, 2010). Most of the high 1-minute concentrations occur at the estimated time of train passes, further demonstrating the impact of the trains on short-term concentration data at this site.
Section 4.0 Ambient Air Quality Data Analyses

Analyses of the data were conducted to produce a conceptual model, which is a qualitative summary of the physical, chemical, and meteorological processes that control the formation and distribution of pollutants in a given region. This section reviews the relevant data analyses and describes our understanding of air quality in Cassville and Ashland, with respect to current conditions, data variability (spatial, temporal, and chemical), influence of meteorology (including transport patterns), precursor sensitivity, and source culpability.

4.1 Overview of data analyses
To describe and understand air quality in southwestern and northern Wisconsin, and assess the impact of the two power plants, several key questions need to be addressed.

- What are the air quality levels in Cassville and Ashland, and how do these levels compare with other nearby sites in Wisconsin/Minnesota/Iowa?
- What meteorological conditions and source regions are associated with high and low concentrations in Cassville and Ashland?
- How sensitive are PM$_{2.5}$ concentrations in Cassville and Ashland to changes in precursor concentrations?
- What is the contribution of the two power plants to air quality in Cassville and Ashland?
- What is the net air quality benefit of using biomass fuels at power plants in Wisconsin

The first three questions are addressed below, along with various data analyses. The other two questions are addressed in the following section.

4.2 What are the air quality levels in Cassville and Ashland, and how do these levels compare with other nearby sites?

Tabular summaries of the measured air quality and meteorological parameters for the two special purpose monitoring sites are provided in Tables 4.1 and 4.2. Further discussion is provided below for the PM$_{2.5}$-mass and speciation measurements, gas measurements (SO$_2$, NO/NO$_2$/NO$_x$, NH$_3$, and HNO$_3$), and BC measurements.

PM$_{2.5}$ Measurements
PM$_{2.5}$ mass concentrations were measured using two methods: BAMS, which provides continuous (1-hour) data, and SASS, which provides 24-hour values. A scatterplot of daily BAMS v. SASS PM$_{2.5}$ mass concentrations at the two sites is provided in Figure 4.1. There is generally good agreement between the two sets of 24-hour average values.
Table 4.1. Summary of Special Purpose Monitoring – Cassville, WI (Jul 1, 2010 – Jun 30, 2011)
Table 4.2. Summary of Special Purpose Monitoring – Ashland, WI (Jul 1, 2010 – Jun 30, 2011)
Figure 4.1  BAMS v. SASS Daily PM$_{2.5}$ Concentrations at Cassville (top) and Ashland (bottom)

Scatterplot: Ave 24 Hr PM$_{2.5}$ Concentrations
Continuous 24-Hr (BAM) Aves vs Integrated Daily Filter (SASS) Measurements
Ashland (WI) Biomass Monitoring Site
113 Sampling Days during July 2010 - June 2011

Regression line equation:
y = 0.81x + 2.45
y = BAM 24-hr PM2.5
x = SASS 24 hr PM2.5
Sq of corr. coeff. ($r^2$) = 0.554
During the 12-month study period, most of the high PM$_{2.5}$ concentrations (> 25 ug/m$^3$) occurred in the winter (December – March) as seen in Figure 4.2. This figure, as well as the scatterplot in Figure 4.3, also shows that PM$_{2.5}$ values at Cassville were generally greater than those at Ashland - i.e., 11.6 ug/m$^3$ (Cassville average) v. 7.0 ug/m$^3$ (Ashland average).

**Figure 4.2** Daily PM$_{2.5}$ Concentrations at Cassville and Ashland (ug/m$^3$) – BAMS data

**Figure 4.3** Ashland v. Cassville Daily PM$_{2.5}$ Concentrations (SASS data)

<table>
<thead>
<tr>
<th></th>
<th>Cassville</th>
<th>Ashland</th>
</tr>
</thead>
<tbody>
<tr>
<td># PM2.5 obs:</td>
<td>104</td>
<td>104</td>
</tr>
<tr>
<td>Ave(ug/m$^3$):</td>
<td>11.6</td>
<td>7.0</td>
</tr>
<tr>
<td>Median(ug/m$^3$):</td>
<td>10.5</td>
<td>5.8</td>
</tr>
<tr>
<td>Max(ug/m$^3$):</td>
<td>28.1</td>
<td>19.7</td>
</tr>
</tbody>
</table>
Figure 4.4 shows the PM$_{2.5}$ 12-month (annual) average and 98$^{\text{th}}$-percentile daily average values for the study period (July 2010 - June 2011) for the upper Midwest.\(^2\) There is an obvious north-south gradient, with generally lower values to the north and higher values to the south. Annual and daily PM$_{2.5}$ values in northern Wisconsin (including the Ashland area) are fairly low (compared to the air quality standards), whereas PM$_{2.5}$ values across parts of southern Wisconsin, eastern Iowa, northern Illinois, and Indiana approach the level of the standards.

![Figure 4.4 Spatial map of PM$_{2.5}$ annual average (left) and daily average values (right)](image)

Figure 4.4 also shows that the annual and daily PM$_{2.5}$ values at the two special study sites are similar to values at other nearby sites. Figure 4.5 compares PM$_{2.5}$ data from Cassville and the nearby Potosi monitor, which is located 22 km away (upper plot), and PM$_{2.5}$ data from Ashland and the nearby Bad River monitor, which is located 16 km away (lower plot). The Cassville-Potosi values are similar and well correlated ($r^2=0.9$), whereas the Ashland-Bad River values are quite different and poorly correlated ($r^2=0.6$) due to siting differences (i.e., Bad River monitor is in a more remote setting.)

A more rigorous spatial analysis was conducted by LADCO as part of its recent 5-year regional network assessment (LADCO, 2010). The results for Wisconsin (which used Potosi and Bad River data) indicate that the Potosi (Cassville) and Bad River (Ashland) monitors are representative of a fairly broad area in these parts of the state - see Figure 4.6.

---

\(^2\) The concentration values in the figure represent data for a 1-year period and should not be used to assess compliance with the NAAQS. Attainment/nonattainment is based on data for a 3-year period.
Figure 4.5 Daily PM$_{2.5}$ Concentrations: Potosi v. Cassville (top) and Bad River v. Ashland (bottom)
In the Midwest, PM$_{2.5}$ is comprised of mostly ammonium sulfate, ammonium nitrate, and organic carbon in approximately equal proportions on an annual average basis. Figure 4.7 provides a spatial map of the 12-month average PM$_{2.5}$ species concentrations for the upper Midwest. Nitrate is more important at northern sites and sulfate is more important at southern sites. Organic carbon is significant at almost all sites in the region.

Figure 4.7 Spatial map of average species contribution to PM$_{2.5}$ mass (July 2010 – June 2011)

Figure 4.8 shows the average monthly PM$_{2.5}$ species concentrations for the special study sites. At both sites, nitrate and sulfate concentrations are higher during the winter months, with higher concentrations at Cassville. Significant levels of organic carbon are measured at both sites throughout much of the year.

Figure 4.9 shows the average PM$_{2.5}$ species concentrations for high and low PM$_{2.5}$ concentrations days at the special study sites. High PM$_{2.5}$ concentrations are comprised of increased organic carbon, nitrate, and sulfate concentrations. (Note, the sum of the reported species may not equal the measured PM$_{2.5}$ mass because data are not available for all species, such as ammonium and crustal/soil, and the organic matter concentration was estimated by multiplying the organic carbon concentration by a factor of 2.)
Figure 4.8 Monthly average PM$_{2.5}$ species concentrations at Cassville (top) and Ashland (bottom)

**Cassville (550435500) Biomass Site**
- 117 Sampling Days During July 2010 - June 2011

**Ashland (550035500) Biomass Site**
- 115 Sampling Days During July 2010 - June 2011

Average Monthly 24 Hr-Ave'd Speciated PM$_{2.5}$ Concentrations
Nitrate (NO$_3$), Sulfate (SO$_4$), Organic Matter (OM) & Elemental Carbon (EC)

Ave. Mon. 24 Hr EC (ug/m$^3$)
Ave. Mon. 24-Hr OM (ug/m$^3$)
Ave. Mon. 24 Hr SO$_4$ (ug/m$^3$)
Ave. Mon. 24 Hr NO$_3$ (ug/m$^3$)
Gas Measurements

Figure 4.10 shows the 1-hour SO₂ (99th-percentile) and NO₂ (98th-percentile) concentrations for the study period (July 2010- June 2011) for the upper Midwest. Higher SO₂ concentrations (see orange and red dots) are measured at several locations throughout the region, presumably in the vicinity of large SO₂ sources. Higher NO₂ concentrations are measured only in the Chicago urban area.

---

The concentration values in the figure represent data for a 1-year period and should not be used to assess compliance with the NAAQS. Attainment/nonattainment is based on data for a 3-year period.
Time series plots of the NOx, NO, and NO2 daily peak 1-hour concentrations at Ashland and Cassville are provided in Figure 4.11. This figure, as well as Figure 4.12, shows that NOx/NO/NO2 values are generally higher at Cassville than Ashland. The Ashland time series shows several periods of very high concentrations (> 40 ppb) during the Nov-Jan period, whereas the Cassville time series shows many such high periods throughout the year. The high concentrations at Ashland may be due to meteorology (see Figure 4.32 and related discussion) and at Cassville is likely due to impacts from passing trains (see Figures 3.3 and 3.4, and related discussion).

Figure 4.11 Time series of NOx, NO, and NO2 daily peak 1-hour concentrations at Ashland (top) and Cassville (bottom)
Figure 4.12 Time series of daily peak 1-hour NO$_2$ concentrations

A time series plot of daily peak 1-hour SO$_2$ concentrations at Cassville and Ashland is provided in Figure 4.13. More frequent high SO$_2$ concentrations (>20 ppb) were measured at Cassville than at Ashland.

Figure 4.13 Time series of daily peak 1-hour SO$_2$ concentrations
A denuder-based sampler was provided by the Illinois State Water Survey (ISWS) to collect precursor gas concentrations: ammonia (NH₃), nitric acid (HNO₃), and SO₂. The 12-month average concentrations for these three gases, along with blank levels, are shown in Figure 4.14. Precursor gas concentrations are higher at Cassville than Ashland. Also, it should be noted that NH₃ blanks are significant, which suggests that it may be appropriate to blank-correct these data when looking at seasonal or annual averages.

![Figure 4.14 12-month average HNO₃, NH₃, and SO₂ concentrations at Cassville and Ashland](image)

A time series of the daily (1-in-3 day) NH₃ and HNO₃ concentrations from Cassville and Ashland is presented in Figure 4.15. NH₃ is higher at Cassville than Ashland, but there are similar seasonal patterns at both sites (e.g., higher values in summer, lower values in winter). Several high NH₃ concentrations occurred at Cassville in spring, due, possibly, to more agricultural activity nearby. HNO₃ is low at both sites, with little seasonal variation. (Note, the period January - March with zero concentrations at both sites is suspicious and will be reviewed by the ISWS.)

![Figure 4.15 Time series of daily NH₃ (left) and HNO₃ (right) values for Cassville and Ashland](image)

A plot showing seasonal average NH₃ concentrations for Cassville, Ashland, and several other locations with passive NH₃ samplers (Horicon, WI, Bondville, IL, and Fernberg, MN) is provided in Figure 4.16. At all of these Midwest sites, there is a distinct seasonal pattern with low concentrations in the winter (Jan-Mar). NH₃ levels at Fernberg, MN (Boundary Waters Canoe Area) are low year-round.
Figure 4.16 Seasonal average NH$_3$ concentrations for Ashland, Cassville, and several passive sampler locations

Scatterplots of NH$_3$, HNO$_3$, and SO$_2$ data from Cassville and Ashland show no significant correlations, except perhaps a very slight correlation between NH$_3$ and HNO$_3$ – see Figure 4.17.

Figure 4.17 Scatterplot of NH$_3$, HNO$_3$, and SO$_2$ concentrations at Ashland and Cassville
Black Carbon Measurements

Black carbon (BC) is measured by the aethalometer, and elemental carbon (EC) is measured by the SASS sampler. Although different measurements, both are used as chemical markers for mobile sources (e.g., diesel vehicles) and biomass burning. Figure 4.18 compares the daily average BC and EC data at Cassville. The correlation is rather poor ($r^2 = 0.3$), which may be due in part to uncertainty with the aethalometer data (see discussion in Section 3).

The aethalometer measures light absorption at two wavelengths: 880 nm (referred to as black carbon) and 370 nm (referred to as ultraviolet-absorbing carbon [UVC or UVPM]). The difference in these two measurements (delta C or DC) has been used as indicator of biomass burning (e.g., wood smoke) – see Sandradewi, et al, 2008.

Figure 4.19 shows that DC values increase with decreasing temperature, especially temperatures below 30°F, which suggests that colder weather activity (e.g., residential wood burning) may be an important source of emissions.
Interestingly, there is little day-of-week variation in the DC values (see Figure 4.20), which suggests that the temporal pattern in certain recreational activities during colder weather (i.e., weekend fireplace usage) is not a major factor.

Figure 4.20 DC values for colder hours by day of week

Figure 4.21 shows scatterplots of BC and DC v. wind direction, and Figure 4.22 shows the BC and DC pollution roses at Cassville. Higher BC concentrations are associated with winds from the NW thru SE, indicating the impact of the passing trains. The DC plot shows high values primarily associated with winds from the N-NE, due, perhaps, to wood smoke being trapped and channeled through Furnace Branch Creek- see discussion in Section 4.3. There appears to be little impact on BC levels from the use of biomass fuels at the two nearby power plants or wood burning activities (e.g., use of wood stoves and fireplaces) in the small community of Cassville (population 1,000). The scatterplot shows no sharp peaks, as would be present from a nearby point source, and no elevated values from the direction of the community (i.e., from the SE).
Figure 4.22 DC (lower left) and BC (upper right) pollution roses at Cassville (Oct–Jan)

Figure 4.23 shows scatterplots of BC and DC v. wind direction at Ashland. High BC and DC values are associated with winds from the SE sector (90 – 180°), despite infrequent winds in that direction. This could indicate the impact of wood burning activities across the somewhat larger community of Ashland (population 8,700). There appears to be little impact on BC levels from the use of biomass fuels at the nearby power plant.

Figure 4.23 Scatterplot of BC and DC v. wind direction at Ashland
4.3 What meteorological conditions and source regions are associated with high and low concentrations in Cassville and Ashland?

The role of meteorology in affecting air quality concentrations can be complex. Wind speed and wind direction govern the movement of air masses, temperature and humidity affect atmospheric chemistry, and temperature can play a role in the emissions of some precursor species. Two analyses were performed to provide information on the meteorological conditions (and source regions) associated with high and low concentrations in Cassville and Ashland: wind and pollution roses, and back trajectories.

Wind and Pollution Roses

Wind and pollution roses were prepared using data from the two special study sites to show how concentration levels vary as a function of wind direction. The Ashland roses (Figure 4.24) reflect the strong SW and NE wind flow patterns, with higher pollutant concentrations (i.e., the light blue, dark green, and dark blue colors in the figure) associated with winds from the SW. Although less frequent, winds from the NW (i.e., the direction of the Bay Front plant) are associated with higher SO$_2$ concentrations.

The Cassville roses (Figure 4.25) reflect the channeling of the Mississippi River valley (clear NW and SE wind flow patterns), along with winds from the NE (apparently reflecting a secondary channeling effect from the Furnace Branch Creek — see Figure 4.26).
Figure 4.25 Wind and pollution roses for Cassville (July 2010-June 2011)

Figure 4.26 Terrain map around Cassville, WI
Given the strong influence of the wind roses, it may be difficult to ascertain the directions associated with the higher pollutant concentrations. To make it easier to see these important (high pollution) directions, scatterplots were prepared showing pollutant concentration v. wind direction. The scatterplot for SO$_2$ is provided in Figure 4.27. For both sites, the SO$_2$ signal is clear: highest concentrations occur at 300 deg for Ashland, and about 310 deg for Cassville. These directions point towards the major nearby SO$_2$ sources (i.e., Bay Front power plant in Ashland, and Nelson Dewey power plant in Cassville) – see Figure 4.28 and 4.29.

Figure 4.27 Scatterplot of SO$_2$ v. wind direction for Ashland (left) and Cassville (right)

Figure 4.28 Map showing SO$_2$ pollution rose and nearby power plant in Ashland
The scatterplot for NO$_x$ is provided in Figure 4.30. The NO$_x$ signal at Cassville shows higher concentrations coming from the NW thru SE. As discussed previously, this suggests that the passing trains have a major impact on the NO/NO$_2$/NO$_x$ measured at this site. At Ashland, high concentrations seem to come from every direction. To understand this better, Ashland NO$_x$ concentrations were examined as a function of day of week and hour of day.

Figure 4.31 shows higher concentrations in the October-March period, but lower concentrations on weekends compared to weekdays. This pattern suggests that something other than wintertime weekend recreational activities (e.g., snowmobiles on the nearby Tri-County Corridor Trail) is responsible for the higher concentrations.
Figure 4.31 Average weekday and weekend NOx concentrations at Ashland

Figure 4.32 shows much higher concentrations in the morning and evening during the late fall through early spring period. This pattern suggests that meteorology (i.e., low mixing heights) during these times of the year may be more responsible for the higher concentrations.

Figure 4.32 Average NOx concentrations by hour of day at Ashland
The PM$_{2.5}$ signal is less clear with higher concentrations coming from every direction (see Figure 4.33), suggesting the large regional signature for this pollutant.

Figure 4.33 Scatterplot of PM$_{2.5}$ v. wind direction for Ashland (left) and Cassville (right)

Back Trajectories
Back trajectories were generated using the HYSPLIT model with winds based on NOAA’s modeled EDAS data. The data were generated on a 40-km grid basis, so they do not reflect local terrain or smaller scale conditions. Trajectories were also generated at a height of 500 m, emphasizing regional (over local) contributions. In the case of Cassville, where the local terrain is complex (river bluffs, plus channeling of the wind through the river valley), the on-site meteorological data are a more accurate depiction of relevant wind patterns for determining local sources. The trajectory analysis is better suited for determining mid- to long-range transport.

Contoured trajectory plots are presented in Figure 4.34 for BC, NO$_x$, SO$_2$, and PM$_{2.5}$. Areas shaded red represent areas most likely to be upwind on higher concentration days and areas shaded blue represent areas most likely to be upwind on lower concentration days (with darker shading representing higher frequency).

The BC and NO$_x$ trajectory plots show a relatively small area of dark red surrounding the two special study sites, indicating the impact of local sources.

The SO$_2$ trajectory plot shows a strong source to the NW of the Cassville monitoring site (i.e., the Nelson Dewey power plant), which is consistent with the SO$_2$ pollution rose. No such pattern shows up in Ashland, given the weaker source signal and lower SO$_2$ concentrations at Ashland.

The PM$_{2.5}$ trajectory plot shows the regional nature of this pollutant (i.e., impacts from many different directions), with a tendency for higher concentrations to be associated with transport from the south and lower concentrations with transport from the north. This is generally consistent with a Classification and Regression Tree (CART) analysis conducted by LADCO, which showed high PM$_{2.5}$ is most strongly associated with extended periods of slow wind speeds (stagnant air masses) as well as southerly wind directions; warm temperatures in the summer and temperatures around freezing in the winter; and temperatures and pressures that are increasing from previous days (LADCO, 2011).
Figure 4.34. Contoured trajectory plots for BC (upper left), NO$_x$ (upper right), SO$_2$ (lower left), and PM$_{2.5}$ (lower right)
4.4 How sensitive are PM$_{2.5}$ concentrations in Cassville and Ashland to changes in precursor concentrations?

The sensitivity of PM$_{2.5}$ concentrations to changes in precursor concentrations can be assessed using indicator ratios, such as the gas ratio (Ansari and Pandis, 1998). The gas ratio is calculated using the following formula:

\[
\text{Gas Ratio (GR)} = \frac{\text{total ammonia} - 2 \times \text{total sulfate}}{\text{total nitrate}}
\]

GR values less than 1 represent ammonia sensitive conditions and GR values greater than 1 represent nitrate sensitive conditions. Figure 4.35 shows the GR values for Ashland and Cassville. The values approach 1 during the winter months, indicating more ammonia sensitive conditions during this time of the year. The remainder of the year is characterized by nitrate sensitive conditions.

![Figure 4.35 Gas ratio values for Ashland and Cassville for the 12-month study period](image)

Figure 4.35 Gas ratio values for Ashland and Cassville for the 12-month study period

Figure 4.36 shows how the GR values vary both as function of season and PM$_{2.5}$ mass concentration. The highest PM$_{2.5}$ concentrations generally occur in late fall and winter, and reflect low GR values (1 or less).

![Figure 4.36 Gas ratio as function of PM$_{2.5}$ mass concentrations. The plot on the left reflects data from Ashland for each season, and the plot on the right reflects data from Ashland and Cassville for winter (Jan-Mar).](image)

Figure 4.36 Gas ratio as function of PM$_{2.5}$ mass concentrations. The plot on the left reflects data from Ashland for each season, and the plot on the right reflects data from Ashland and Cassville for winter (Jan-Mar).
A thermodynamic equilibrium model (ISORROPIA) was also applied to provide information on the effect of changes in precursor concentrations on PM$_{2.5}$ concentrations in Cassville and Ashland. Figure 4.37 shows PM$_{2.5}$ concentrations as a function of ammonia and nitrate concentrations. Reductions in nitrate (i.e., movement to the left of baseline value [represented by the red star]), as well as reductions in ammonia (i.e., movement downward), result in lower PM$_{2.5}$ concentrations. The figure indicates slightly greater sensitivity to nitrate reductions at Cassville, and slightly greater sensitivity to ammonia reductions at Ashland.

**Figure 4.37 Predicted PM$_{2.5}$ mass concentrations at Cassville (left) and Ashland (right) as a function of ammonia (y-axis) and nitrate (x-axis) for high PM$_{2.5}$ days (> 15 ug/m$^3$)**

This analysis shows differences in the response to changes in precursor concentrations by location and season. PM$_{2.5}$ concentrations at Cassville appear to be slightly more sensitive to nitrate reductions at Cassville, and slightly more sensitive to ammonia reductions at Ashland. PM$_{2.5}$ concentrations in winter are more sensitive to ammonia reductions, and in summer are more sensitive to sulfate reductions. The winter results are consistent with the findings of LADCO’s Winter Nitrate Study (Baek, et al, 2010).
Section 5.0 Air Quality Modeling

Air quality models are relied on by federal and state regulatory agencies to support planning efforts. Used properly, models can assist policy makers in deciding which control programs are most effective in improving air quality, and meeting specific goals and objectives. For example, models can be used to conduct “what if” analyses, which provide information for policy makers on the effectiveness of candidate control programs.

The modeling analyses for this study were conducted in accordance with EPA’s modeling guidelines (EPA, 2007a). This section reviews the development, evaluation, and application of the modeling system for this study.

5.1 Overview of Modeling Analysis

The air quality analyses were conducted with the CAMx model, with emissions and meteorology generated using Emissions Modeling System and the Weather Research and Forecasting (WRF) model, respectively. The LADCO States have relied on CAMx as the primary regional modeling tool for several years for the following reasons: performance, operator considerations (e.g., ease of application and resource requirements), technical support and documentation, model extensions (e.g., 2-way nested grids, process analysis, source apportionment, and plume-in-grid), and model science. CAMx model set-up for this study is summarized below:

- **Version:** CAMx v5.2
- **Chemistry:** CB05 gas phase chemistry, SOA chemistry updates, ISORROPIA inorganic chemistry, SOAP organic chemistry, RADM aqueous phase chemistry
- **Deposition:** AERMOD dry deposition
- **Other:** PPM horizontal transport

The modeling domain consisted of the National RPO grid at 36 km and an inner Midwest grid at 12 km – see Figure 5.1. The vertical resolution in the air quality model consists of 16 layers extending up to 15 km, with higher resolution in the boundary layer.

![Figure 5.1 CAMx Modeling Domain](image)
For the modeling presented in this report, the existing regional emissions inventory and meteorology developed by LADCO for a 2007 base year were used (Base Cv7). Although this time period does not coincide to that of the special purpose monitoring, it does represent the most recent year for which the necessary model inputs are available and should give a good representation of air quality impacts. Further modeling may be conducted at a later date, if emissions and meteorological data are developed for the time period of the special purpose monitoring (i.e., 2010-2011).

Meteorological inputs were derived using the WRF model. A map showing the WRF modeling domain and grid resolution is provided in Figure 5.2.

![Figure 5.2 WRF Modeling Domain](image)

The 2007 WRF meteorological modeling was conducted by the State of Iowa. The model set up and configuration for the model run is described in AER, 2011. Key findings of the 2007 WRF evaluation were:

- Meteorological fields agree with our conceptual understanding of the physical processes of the atmosphere, and, as such, are representative of the observed weather conditions.

- The WRF model adequately captures the diurnal cycle of temperature, moisture, and wind. During periods when the surface flow is forced more strongly by synoptic weather systems, such as during the winter, forecast errors for the wind speeds are minimized. During spring and summer when strong insolation increases the depth of the mixed layer, the model tends to underpredict surface wind speeds during the afternoon. Conversely, the model maintains mixing that is too strong during the overnight hours.
Surface wind fields are well represented in the model. Domain-wide wind speed forecasts averaged over full days and for longer timer periods did not exhibit a prolonged or substantial speed bias. Wind direction forecasts did not exhibit substantial biases, however, mean absolute errors were at or slightly above the critical threshold of 30°.

Temperature and moisture fields generally match the observations. Mean biases in temperature were typically within the critical threshold of 0.5°C. Mean absolute error values during the wintertime were approximately 2°C, and during the summertime values were somewhat lower than that.

Both mean bias and mean absolute errors for specific humidity were well within acceptable thresholds, even during the summer when levels of moisture in the atmosphere are significantly higher than in the cold winter months.

Emission inventories were prepared for a 2007 base year using 2007 data for EGU point, nonroad, on-road, and biogenics, and 2008 data for the other sectors (non-EGU point and area). For on-road, off-road, ammonia, and biogenic sources, emissions were estimated using emission models. Three other off-road categories are not accounted for by the NONROAD emissions model: commercial marine, aircraft, and rail. Marine emissions were based on LADCO’s Base M (2005) inventory, aircraft emissions for 2008 were provided by the States, and rail emissions were based on a new 2008 inventory prepared by ERTAC. For point and area sources, emissions were prepared using data supplied by the LADCO States. For the rest of the modeling domain, Base M (2005) inventories will be used until more recent inventories are available from other regional organizations.

A summary of annual emissions by pollutant and source sector is provided in Figure 5.3.

Basecase modeling was performed to evaluate CAMx model performance (i.e., assess the model's ability to reproduce the observed concentrations). Model performance was assessed by comparing modeled and monitored concentrations. Graphical (e.g., side-by-side spatial plots, time series plots, and scatter plots) and statistical analyses were conducted to assess the reasonableness of the model results.
Figure 5.4 shows the monthly average bias for PM$_{2.5}$ by chemical species for monitoring sites in the 12 km domain. For most species, model bias is generally small (i.e., within 1 ug/m$^3$). Exceptions include organic carbon (which is generally low for most months), and sulfate and nitrate (which are overestimated for a few months).

![Figure 5.4. PM$_{2.5}$ monthly average bias (2007)](image)

Time series plots for nitrate, sulfate, and organic carbon for an urban site (Milwaukee) and a rural site (Seney National Wildlife Refuge) are provided in Figure 5.5.

![Figure 5.5. Modeled v. measured sulfate, nitrate, and organic carbon concentrations at Milwaukee (top) and Seney NWR (bottom)](image)
These results indicate that the modeled concentrations are generally consistent with monitoring data. Overall, the model is able to simulate the magnitude, spatial pattern, and temporal profile of measured PM$_{2.5}$ mass and species concentrations. The one apparent limitation of the model is its underestimation of organic carbon concentrations, especially during the summer, which has been found in prior regional modeling applications (USEPA, 2011).
5.2 What is the contribution of the two power plants to air quality in Cassville and Ashland?

Several model runs were conducted to determine the impact of Wisconsin power plants on air quality in the State. A brief description of these runs, along with graphical presentations of the model results, is provided below.

Biomass Run 1: Emissions for Bay Front and Nelson Dewey were adjusted from the 2007 base year values to reflect the biomass fuel usage during the September 2010 stack tests (i.e., Bay Front at 100% biomass firing, and Nelson Dewey at 20% biomass co-firing):

Bay Front
B20/S10 - reduce SO₂ by 50%
B21/S11 - reduce SO₂ by 80%
B24/S13 – no change (assume no biomass fuel use)

Nelson Dewey
B21/B22 (S11) – reduce SO₂ by 20%

Biomass Runs 2a and 2b: Emissions for all other power plants in the State were adjusted to reflect a low (10%) and a high (25%) co-firing rate for biomass fuels. (Emissions for Bay Front and Nelson Dewey were kept at the Run 1 levels.) SO₂ emissions were reduced by 10% for the low rate scenario (Run 2a) and by 25% for the high rate scenario (Run 2b).

Figure 5.6 shows the difference in quarterly average PM$_{2.5}$ concentrations between those predicted between the basecase (LADCO’s 2007 base year inventory) and Biomass Runs 1, 2a, and 2b. For Run 1, most of the air quality improvement occurs in the vicinity of the Nelson Dewey, which is consistent with the greater emissions change represented by this scenario (i.e., SO₂ emissions differences are about 3,000 tons per year at Nelson Dewey and about 230 tons per year at Bay Front). The biggest change in PM$_{2.5}$ concentrations occurs during Quarter 3 (summer). For Runs 2a and 2b, the air quality improvement is enhanced due to the additional SO₂ emission reductions at other power plants in the State.
Figure 5.6 Quarterly difference plots for PM$_{2.5}$ – biomass emissions sensitivity runs

Biomass Run 1 (effect of biomass fuels at Bay Front and Nelson Dewey – 100% at Bay Front and 20% at Nelson Dewey)

Biomass Run 2a (effect of biomass fuels at WI EGUs – 100% at Bay Front, 20% at Nelson Dewey, and 10% at other facilities)

Biomass Run 2b (effect of biomass fuels at WI EGUs – 100% at Bay Front, 20% at Nelson Dewey, and 25% at other facilities)
PSAT Run: Emissions from each source sector (EGU, non-EGU, area, on-road, and nonroad sources) were tracked for states in the Midwest for the base run with the particulate source apportionment tool (PSAT) in CAMx. The purpose of this run was to estimate the contribution of these sources to PM$_{2.5}$ concentrations.

Figures 5.7 and 5.8 (on the next two pages) provide results for annual and daily average PM$_{2.5}$ concentrations at Cassville and Ashland. States closest to the special purpose monitors had the largest impact (i.e., Wisconsin, Iowa, and Minnesota at Cassville, and Wisconsin and Minnesota at Ashland). Important contributing sources included EGU and non-EGU point sources. Wisconsin EGUs, however, were found to have a relatively small impact on PM$_{2.5}$ concentrations at the two monitoring sites.

Zero-out Run: To provide an alternative assessment of the contributions from Wisconsin power plants, the base case was rerun by zeroing-out SO$_2$ emissions from power plants in the State.

Figure 5.9 compares the results for PM$_{2.5}$-sulfate for the zero-out run and the PSAT run. The magnitude and spatial pattern of the source impacts are similar; thus, verifying the PSAT source contributions.

**WI EGU’s PSAT and Zero-out: PSO4 (ug/m$^3$)**

![Figure 5.9 Quarterly average sulfate impact from Wisconsin power plants based on PSAT modeling (top) and zero-out modeling (bottom)]](image-url)

47
Figure 5.7 Annual and daily PM$_{2.5}$ source apportionment at Cassville
Figure 5.8 Annual and daily PM$_{2.5}$ source apportionment at Ashland
5.3 What is the air quality benefit of using biomass fuels at power plants in Wisconsin?

The human health benefit of using biomass fuels was estimated using the CAMx air quality model outputs and EPA’s BenMap model (Environmental Benefits Mapping and Analysis Program). BenMAP uses the CAMx modeled change in air quality (in this case, PM\(_{2.5}\)), determines the relationship between PM\(_{2.5}\) and certain health effects, and applies that relationship to the exposed population. For this application of BenMAP, the change in air quality was the difference between the 2007 base year emissions (baseCv7) and Biomass Run 2b (25% SO\(_2\) reduction).

Figure 5.10 shows the BenMAP-derived difference between the base and biomass run. The maximum 24-hour average PM\(_{2.5}\) reduction was 0.2 ug/m\(^3\).

![Figure 5.10 Change in daily PM\(_{2.5}\) concentration: Biomass Run 2b v. base](image)

Some of the health effects in BenMAP associated with PM\(_{2.5}\) include acute bronchitis, acute myocardial infarction, acute respiratory symptoms, and mortality. BenMAP calculates a value for each health benefit at every grid cell, which can then be plotted on the modeling domain. Figure 5.11 shows the impact of the PM\(_{2.5}\) reduction on mortality and acute respiratory events over the modeling domain. The largest benefits occur in the higher populated urban areas, with the maximum benefit in the Chicago area. The location of maximum benefits does not coincide with the location of maximum PM\(_{2.5}\) reduction. This is because part of the health effects calculation involves the multiplication of the air quality change and exposed population. The maximum PM\(_{2.5}\) reduction occurs in a relatively sparsely populated region; therefore, a smaller number of deaths and a smaller number of acute respiratory events were calculated.
In BenMAP, the health effect incidence results are calculated for each grid cell. They can be aggregated up to state level. Table 5.1 lists the Midwest state-level number of incidences avoided for several health effects for the biomass run.

**Table 5.1 Aggregated State-Level BenMAP Health Effects for Biomass Run**

<table>
<thead>
<tr>
<th>Health Effect</th>
<th>MN</th>
<th>IA</th>
<th>IL</th>
<th>IN</th>
<th>MI</th>
<th>WI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Resp.</td>
<td>7,438</td>
<td>4,490</td>
<td>22,996</td>
<td>6,622</td>
<td>10,619</td>
<td>15,096</td>
</tr>
<tr>
<td>Asthma</td>
<td>130</td>
<td>79</td>
<td>414</td>
<td>130</td>
<td>190</td>
<td>255</td>
</tr>
<tr>
<td>Chronic Bronchitis</td>
<td>7</td>
<td>4</td>
<td>20</td>
<td>6</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Acute Bronchitis</td>
<td>15</td>
<td>9</td>
<td>46</td>
<td>14</td>
<td>21</td>
<td>28</td>
</tr>
<tr>
<td>Mortality</td>
<td>1</td>
<td>2</td>
<td>33</td>
<td>11</td>
<td>9</td>
<td>7</td>
</tr>
</tbody>
</table>

BenMAP is also able to estimate the cost savings of health benefits associated with control strategy programs. The dollar amounts associated with each health effect are part of the EPA Standard Valuation Functions included in the model. Estimates of the value (dollar amounts) of the avoided health problems for the Midwest states are listed in Table 5.2.

**Table 5.2 Cost Savings of BenMAP Health Effects for Biomass Run**

<table>
<thead>
<tr>
<th>Health Effect</th>
<th>MN</th>
<th>IA</th>
<th>IL</th>
<th>IN</th>
<th>MI</th>
<th>WI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Resp.</td>
<td>$400,790</td>
<td>$241,949</td>
<td>$1,239,092</td>
<td>$356,818</td>
<td>$572,236</td>
<td>$813,436</td>
</tr>
<tr>
<td>Asthma</td>
<td>$21,074</td>
<td>$12,799</td>
<td>$66,906</td>
<td>$20,992</td>
<td>$30,767</td>
<td>$41,227</td>
</tr>
<tr>
<td>Chronic Bronchitis</td>
<td>$2,826,937</td>
<td>$1,768,249</td>
<td>$8,470,396</td>
<td>$2,444,874</td>
<td>$4,004,712</td>
<td>$5,859,833</td>
</tr>
<tr>
<td>Acute Bronchitis</td>
<td>$931</td>
<td>$554</td>
<td>$2,925</td>
<td>$916</td>
<td>$1,339</td>
<td>$1,797</td>
</tr>
<tr>
<td>Mortality</td>
<td>$193,729,760</td>
<td>$145,962,144</td>
<td>$649,518,400</td>
<td>$207,296,736</td>
<td>$335,222,304</td>
<td>$464,931,584</td>
</tr>
</tbody>
</table>
Section 6. Summary

LADCO, in conjunction with the WDNR and the University of Wisconsin-Madison, worked together to characterize the emissions, air quality impacts, and public health benefits of burning biomass fuels at power plants in Wisconsin. Three major lessons were learned from this study.

- Characterization of air quality in the two Wisconsin communities
  - Measurements for several criteria pollutants (PM$_{2.5}$, NO$_2$, SO$_2$), while not intended to be used for compliance purposes, indicate relatively “clean” air quality in these communities relative to federal air quality standards.
    - Daily average PM$_{2.5}$ concentrations (based on BAMS data) never exceeded the NAAQS of 35 ug/m$^3$ NAAQS (i.e., peak daily values = 28.0 ug/m$^3$ at Ashland and 35.0 ug/m$^3$ at Cassville).
    - Hourly average NO$_2$ concentrations at both sites never exceeded the NAAQS of 100 ppb (i.e., peak daily 1-hour values = 39.9 ppb at Ashland and 39.8 ppb at Cassville).
    - Hourly average SO$_2$ concentrations never exceeded the NAAQS of 75 ppb at Ashland (i.e., peak daily 1-hour value = 35 ppb), and rarely exceeded 75 ppb at Cassville (i.e., 4$^{th}$ highest (99%) peak daily 1-hour value = 68 ppb).
  - Ambient concentrations for all measured pollutants, including precursor levels, are generally lower in Ashland compared to Cassville.
  - Higher concentrations for PM$_{2.5}$ and NO$_x$ occurred during the colder months (November – March) and appear to be due to a combination of seasonal emissions activities and meteorology (i.e., lower nighttime mixing heights during the winter).
  - PM$_{2.5}$ chemical composition is comprised of mostly sulfate, nitrate, and organic carbon. Nitrate and sulfate concentrations are significant during the winter months, with higher concentrations at Cassville. High levels of organic carbon are measured at both sites throughout much of the year. High PM$_{2.5}$ concentrations are comprised of increased organic carbon, nitrate, and sulfate concentrations.

- Source attribution in the two Wisconsin communities
  - The impact of the two power plants is evident for certain pollutants, e.g., pollution roses indicate that these sources are the dominant contributors to local SO$_2$ concentrations.
  - In Cassville, passing trains on the adjacent BNSF railroad tracks have a major impact on certain combustion-related pollutants – e.g., NO/NO$_2$/NO$_x$ and BC.
  - PM$_{2.5}$ concentrations appear to be mostly regional in nature, with only modest impacts from local sources (e.g., residential wood burning activities contribute to PM$_{2.5}$ and BC concentrations during the winter months). At the two special purpose monitoring sites, modeling shows that emissions from sources in Wisconsin and
neighboring states are the largest contributors to PM$_{2.5}$ concentrations, with Wisconsin power plants having a relatively small impact (e.g., Nelson Dewey had a small impact at Cassville, while Bay Front had very little impact at Ashland).

- High wintertime PM$_{2.5}$ concentrations are slightly more sensitive to reductions in ammonia concentrations than reductions in nitrate concentrations.

- Effect of biomass burning in the two Wisconsin communities (and statewide)

  - Use of biomass fuels at the power plants in these communities serves to decrease emissions for certain air pollutants; in particular, for SO$_2$. The results of the stack tests at Nelson Dewey and Bay Front are generally consistent with a number of stack tests at industrial facilities burning biomass fuels (mostly, wood-based fuels). However, a number of technical issues were identified with the Nelson Dewey and Bay Front stack tests, which creates some uncertainty in the reported values.

  - Assuming the use of biomass fuels at power plants across the State results in lower SO$_2$ emissions and, consequently, lower PM$_{2.5}$ concentrations. The associated public health benefits were found to be greatest in higher population Midwest urban areas.
Section 7. References


LADCO, 2011, “Updated PM$_{2.5}$ and Ozone CART Analysis, 1999 – 2010, September 6, 2011 PowerPoint presentation to LADCO Project Team.


Appendix 1  Quality Assurance Notes

Appendix 2  Review of Aethalometer Data

Appendix 3  Daily PM$_{2.5}$, SO$_4$, and NO$_3$ Measurements: Comparisons of Cassville and Ashland Site with Nearby PM$_{2.5}$ Sites

Appendix 4  Cassville Train Impact Analysis

Appendix 5  Wood Smoke Analysis
### APPENDIX 1
Quality Assurance Notes

**Biomass 2010-2011 Missing/Invalid/Flagged Continuous Data**  
(non-calibration periods of missing/invalid/flagged data six hours or greater)

<table>
<thead>
<tr>
<th>Airs #</th>
<th>Site Name</th>
<th>Para</th>
<th>Start Date</th>
<th>Start Hour</th>
<th>End Date</th>
<th>End Hour</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>PM2.5</td>
<td>7/1/10</td>
<td>00:00</td>
<td>7/3/10</td>
<td>15:00</td>
<td>Sampler still doing zero background check (IN-027)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>Met, PM2.5</td>
<td>7/23/10</td>
<td>17:00</td>
<td>7/27/10</td>
<td>05:00</td>
<td>AC not working in trailer, temps &gt; 86 degrees (Flagged 303)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>NO/NO2/NOx</td>
<td>7/22/10</td>
<td>07:00</td>
<td>07/27/10</td>
<td>14:00</td>
<td>Biweekly Calibration, AC not working in trailer, temps &gt; 86 degrees, Calibration Check (IN-008, F-303, IN-027)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>SO2</td>
<td>7/22/10</td>
<td>07:00</td>
<td>07/27/10</td>
<td>19:00</td>
<td>Biweekly Calibration, AC not working in trailer, temps &gt; 86 degrees, Calibration Check (IN-008, F-303, IN-027)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>SO2</td>
<td>10/6/10</td>
<td>04:00</td>
<td>10/13/10</td>
<td>10:00</td>
<td>PMT board needed to be replaced after a lamp peaking procedure (IN-008)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>NO/NO2/NOx</td>
<td>12/15/10</td>
<td>05:00</td>
<td>12/24/10</td>
<td>13:00</td>
<td>Period between two biweekly checks is suspect high, believed to be a system leak (IN-008, F-317, IN-008)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>WS</td>
<td>12/31/10</td>
<td>06:00</td>
<td>1/4/11</td>
<td>10:00</td>
<td>Wind speed sensor frozen (IN-011)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>All</td>
<td>1/20/11</td>
<td>01:00</td>
<td>1/23/11</td>
<td>19:00</td>
<td>Logger failure (IN-200)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>SO2</td>
<td>2/16/11</td>
<td>13:00</td>
<td>2/17/11</td>
<td>07:00</td>
<td>OTN check, recalibration (IN-027)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>All</td>
<td>3/15/11</td>
<td>00:00</td>
<td>3/15/11</td>
<td>06:00</td>
<td>Power outage (IN-010)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>WS</td>
<td>3/12/11</td>
<td>14:00</td>
<td>3/13/11</td>
<td>11:00</td>
<td>Wind speed sensor frozen (IN-011)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>WS</td>
<td>3/14/11</td>
<td>00:00</td>
<td>3/14/11</td>
<td>08:00</td>
<td>Wind speed sensor frozen (IN-011)</td>
</tr>
<tr>
<td>55-003-5500</td>
<td>Ashland</td>
<td>WS</td>
<td>3/15/11</td>
<td>00:00</td>
<td>3/15/11</td>
<td>06:00</td>
<td>Wind speed sensor frozen (IN-011)</td>
</tr>
<tr>
<td>55-043-5500</td>
<td>Cassville</td>
<td>WS</td>
<td>12/20/10</td>
<td>20:00</td>
<td>12/21/11</td>
<td>12:00</td>
<td>Wind speed sensor frozen (IN-011)</td>
</tr>
<tr>
<td>55-043-5500</td>
<td>Cassville</td>
<td>SO2</td>
<td>2/1/11</td>
<td>17:00</td>
<td>2/3/11</td>
<td>14:00</td>
<td>Internal pump seized, replaced with external pump (IN-014, IN-023, IN-008)</td>
</tr>
<tr>
<td>55-043-5500</td>
<td>Cassville</td>
<td>WS</td>
<td>2/21/11</td>
<td>09:00</td>
<td>2/21/11</td>
<td>10:00</td>
<td>Wind speed sensor frozen (IN-011)</td>
</tr>
<tr>
<td>55-043-5500</td>
<td>Cassville</td>
<td>SO2</td>
<td>3/26/11</td>
<td>00:00</td>
<td>3/26/11</td>
<td>12:00</td>
<td>Internal pump seized, replaced with external pump (IN-014, IN-008)</td>
</tr>
<tr>
<td>55-043-5500</td>
<td>Cassville</td>
<td>WS</td>
<td>3/23/11</td>
<td>16:00</td>
<td>3/24/11</td>
<td>09:00</td>
<td>Wind speed sensor frozen (IN-011)</td>
</tr>
<tr>
<td>55-043-5500</td>
<td>Cassville</td>
<td>PM2.5</td>
<td>4/19/11</td>
<td>03:00</td>
<td>4/19/11</td>
<td>08:00</td>
<td>Building fire upwind of site (EX-156)</td>
</tr>
</tbody>
</table>
Biomass 2010-2011 PM$_{2.5}$ Speciation Data

Ashland
No sample COC sheet, need info to calculate result - Invalid
7/22/10

Sample Date Incorrect due to makeup or error - note
3/19/11 – ran 3/20/11 4/09/11 – ran 4/10/11
4/30/11 – ran 5/1/11 6/29/11 – ran 6/30/11

Sample time not within 1 hr of midnight - invalid
1/3/11 5/3/11

Sample time not within 1 hr of 24 hr sample – invalid
5/3/11

Run Time Flag - Flag
10/20/10 – Channel 1 – T filter 3/16/10 – Channel 1 – T filter
3/25/11 – Channel 5 – T filter 4/30/11 (ran 5/1/11) – Channel 5 – T filter

Temp Flag - Flag
12/16/11 – Channel 5 – T filter 3/1/11 – Channel 1 – T filter

High CV - Flag
9/8/10 – Channel 1 – T filter – 5.8 10/20/10 – Channel 1 – T filter – 9.9
1/2/10 – Channel 5 – T filter – 5.4 12/10/10 – Channel 5 – T filter – 8.7
12/16/10 – Channel 5 – T filter – 12.3 12/25/10 – Channel 1 – T filter – 6.0
1/12/11 – Channel 1 – T filter – 8.9 2/8/11 – Channel 5 – T filter – 5.6
3/1/11 – Channel 1 – T filter – 10.4 3/16/11 – Channel 1 – T filter – 6.6
3/25/11 – Channel 5 – T filter – 6.3 4/3/11 – Channel 1 – T filter – 6.1
4/12/11 – Channel 5 – T filter – 6.8 4/30/11 (ran 5/1/11) – Channel 5 – T filter – 10.4

Max Delta Temp > 5 - Flag
5/3/11 – Channel 2 – Q filter 5/3/11 – Channel 3 – N Filter

Temp Received at lab > 5 C – Flag
7/10/10 – 10.0 7/10/10 – 10.0
7/13/10 – 9.5 7/16/10 – 9.5
7/19/10 – 18.9 7/25/10 – 18.9
7/28/10 – 14.9 7/31/10 – 14.9
8/3/10 – 4.7 8/6/10 – 4.7
8/18/10-FB – 7.6 8/18/10 – 7.6
8/21/10 – 7.6 8/24/10 – 15.5
8/27/10 – 15.5 9/5/10 – 15.3
9/8/10 – 15.3 4/9/10 – no entry
4/12/10 – no entry 4/15/10 – no entry
4/18/10 – 5.4 4/21/10 – 5.4
4/24/10 – 5.1 4/27/11 – 5.1
4/30/11 – 5.1 5/30/11 – 7.1
6/2/11 – 7.1

Other
12/31/10 – no sample collected - Invalid
Cassville
Several load and retrieval times were estimated using the surrounding samples. No significant impact on the data.

Sample Date Incorrect due to makeup or error - note
7/31/10 ran – 8/1/10 10/17/10 ran – 10/22/10
10/20/10 ran – 10/26/10 11/11/10 ran – 11/14/10
4/27/11 ran – 4/29/11

Sample failed Volume, Flow and CV - Invalid
10/11/10 – pump seized
10/14/10 – sample missed due to pump failure
10/29/10 – sample was an attempted makeup sample ran back to back
11/10/10 – sample was an attempted makeup sample ran back to back channel 5 & 6, channel 7 was okay.
04/30/11 – sample was an attempted makeup sample ran back to back channel 1 & 2, channel 3 was okay.

Incorrect filed entry 8/21/10 for Max/Min BP – Avg BP was fine – No significant impact on the data - Flag
No Max Delta temp provided by sampler – No significant impact on the data - Flag
9/8/10 – Channel 1 – T filter only 9/17/10 – Channel 1 – T filter only
9/23/10 – channel 6 – Q filter only

Temp Received at lab - Flag
7/7/10 – 5.8 7/10/10 – 5.8
7/13/10 – 22.4 7/16/10 – 22.4
7/19/10 – 18.3 7/22-10 – 18.3
8/18/10 – 4.3 8/21/10 – 4.3
9/20/10 – 5.1 9/23/10 – 5.1
10/05/10 – 4.4 10/8/10 – 4.4
10/11/10 – 4.4 5/24/11 – 5.0
5/27/11 – 5.0 5/30/11 – 5.0
6/11/11 – 10.0

Other
2/2/11 – Teflon filter module had some snow enter through the top, may have damaged the sample. - Invalid
4/12/11 – Nylon sample broken from definer ring, brittle and torn – Invalid
4/18/11 – Fire on main street of Cassville on 4/19/11. Samples may have been passively exposed. - Flag
4/21/11 – Fire on main street of Cassville on 4/19/11. Samples may have been passively exposed. - Flag
APPENDIX 2
Review of Aethalometer Data

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 Headquarters 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.
Table 1: Location and Time Data for the Cassville Site Tests.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Start Time (CST)</th>
<th>End Time (CST)</th>
<th>Elevation (m)</th>
<th>Lat</th>
<th>Long</th>
</tr>
</thead>
<tbody>
<tr>
<td>09/22/2010</td>
<td>Permanent site located along a frontage access road on the west edge of the city and very near the Mississippi.</td>
<td>NA</td>
<td>NA</td>
<td>200</td>
<td>42.716 N</td>
<td>90.995 W</td>
</tr>
<tr>
<td>9/22/2010</td>
<td>The mobile laboratory was parked along the same frontage road to the south of the monitoring site.</td>
<td>07:30</td>
<td>15:00</td>
<td>194</td>
<td>42.937 N</td>
<td>90.597 W</td>
</tr>
</tbody>
</table>

**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>
<thead>
<tr>
<th>TABLE 2: Summary Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Start Time</strong></td>
</tr>
<tr>
<td><strong>End Time</strong></td>
</tr>
<tr>
<td><strong>First Test</strong></td>
</tr>
<tr>
<td><strong>Second Test</strong></td>
</tr>
<tr>
<td><strong>BC (ng/M3)</strong></td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>SD</td>
</tr>
<tr>
<td>Ave.Abs Dif</td>
</tr>
<tr>
<td>Ave.Perc Dif</td>
</tr>
<tr>
<td>Study Abs Dif</td>
</tr>
<tr>
<td>Study Per Dif</td>
</tr>
<tr>
<td><strong>UVPM (ng/M3)</strong></td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>SD</td>
</tr>
<tr>
<td>Abs Dif</td>
</tr>
<tr>
<td>Perc Dif</td>
</tr>
<tr>
<td>Study Abs Dif</td>
</tr>
<tr>
<td>Study Per Dif</td>
</tr>
</tbody>
</table>

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.
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 $U_x$, $U_y$, and $U_z$. Where $U_x$ is the north south axis of the horizontal wind, $U_y$ is the east west axis, and $U_z$ is the axis transectioning the horizontal plane.

Vector data is converted to spherical coordinates of $R$ho (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>
<thead>
<tr>
<th>Table 3: Conventions for Orthogonal Wind Vectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_x &gt;0$ when wind originates from the north and $&lt;0$ when wind originates from the south.</td>
</tr>
<tr>
<td>$U_y &gt;0$ when wind originates from the west and $&lt;0$ when wind originates from the east.</td>
</tr>
<tr>
<td>$U_z&gt;0$ when wind originates from above and $&lt;0$ when wind originates from below</td>
</tr>
</tbody>
</table>

![Figure 1. The transformation of orthogonal coordinates to spherical coordinates.](image)

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>
<thead>
<tr>
<th>Table 4: Meteorology Data Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 4a: Electronic compass for Met Alignment</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>Min</td>
</tr>
<tr>
<td>Max</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4b: Hourly WD &amp; WS Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>09/22/2010</td>
</tr>
<tr>
<td>09/22/2010</td>
</tr>
<tr>
<td>09/22/2010</td>
</tr>
<tr>
<td>09/22/2010</td>
</tr>
<tr>
<td>09/22/2010</td>
</tr>
</tbody>
</table>

Figure 2a: Wind Direction Comparison
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-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.

![Graph showing black carbon response to trains passing the site.](image)

**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.
Attachments: 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.
Photo 2: RW trailer with all analytical probes deployed.
Photo 3: Cassville site trailer.
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 (PM$_{\text{fine}}$) 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 (SCI0PS) located on the southeast side of Madison. The RWM/PAMS trailer was operated at the SCI0PS 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>
<thead>
<tr>
<th>Table 1: Aethalometer Comparison Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyzer</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>805</td>
</tr>
<tr>
<td>805</td>
</tr>
<tr>
<td>301</td>
</tr>
<tr>
<td>301</td>
</tr>
<tr>
<td>301</td>
</tr>
</tbody>
</table>

19
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 Aethalometers. 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 3

Daily PM$_{2.5}$, SO$_4$, and NO$_3$ Measurements: Comparisons of Cassville and Ashland Sites with Nearby PM$_{2.5}$ Sites

As part of the biomass study - a major effort was made to measure PM$_{2.5}$ – both unspeciated and speciated constituents – at both the Cassville and Ashland monitoring sites in order to estimate a baseline of PM$_{2.5}$ levels in the vicinity of the biomass plant in each city. The purpose of this appendix is to present and compare summaries of the 24-hr averaged PM$_{2.5}$ measurements during the period of the biomass field study (July 2010 –July 2011). These sites include not only the Cassville and Ashland sites, but also PM$_{2.5}$ sites in the vicinity of either site. These comparisons offer some perspective on how the PM$_{2.5}$ levels relate between the two biomass sites and also between the biomass sites and other to nearby sites.

Figure 3-2: The Ashland and Cassville sites, separated by 270 miles – have an expectedly poor correlation regarding PM$_{2.5}$ concentrations ($r^2 = 0.285$). The Ashland site, often with clean Lake Superior air blowing towards it - has noticeably lower PM$_{2.5}$ levels (ave: 7.0 ug/m$^3$) than at Cassville (ave: 11.6 ug/m$^3$).

Figure 3-3: As expected, Cassville’s co-located SASS (filter-based) and BAM (continuous) monitoring instruments yield highly-correlated 24-hr PM$_{2.5}$ concentrations ($r^2 = 0.864$).

Figure 3-4: Cassville and Potosi, separated by 12 miles, are highly correlated for 24-hr PM$_{2.5}$ concentrations from filter-based instruments ($r^2 = 0.922$), which would be expected.

Figure 3-5: Even though the Cassville and LaCrosse sites are separated by 90 miles and the LaCrosse site is in a much more populated location – the sites have reasonably good PM$_{2.5}$ correlation ($r^2 = 0.652$). The Cassville site actually has noticeably higher overall PM$_{2.5}$ concentrations (ave: 11.6 ug/m$^3$) than at LaCrosse (ave: 9.5 ug/m$^3$).

Figure 3-6: Cassville and Backbone Lake State Park, separated by 30 miles – have a very good correlation of 24-hr PM$_{2.5}$ concentrations from filter-based instruments ($r^2 = 0.84$) – albeit based only on 6 months data.

Figure 3-7: Ashland’s co-located SASS (filter-based) and BAM (continuous) monitoring instruments yield 24-hr PM$_{2.5}$ concentrations that are noticeably less correlated ($r^2 = 0.544$) than for Cassville’s co-located SASS and BAM monitors (Fig XX-2: $r^2 = 0.864$). The BAM PM$_{2.5}$ levels are generally higher than for the SASS.

Figure 3-8: Ashland Biomass’s 24-hr PM$_{2.5}$ concentrations are almost always higher than the same day PM$_{2.5}$ levels at the nearby (Bad River) site, even though the sites are separated by only 11 miles. This difference may largely be due to exposure. Ashland Biomass is in a city setting and next to a power plant. The Bad River site is in a much-less developed area that is part of the Bad River reservation.

Figure 3-9: Ashland Biomass site’s 24-hr PM$_{2.5}$ concentrations are almost always higher than the same day PM$_{2.5}$ values at the Trout Lake site – but are still well correlated with one another ($r^2 = 0.72$). Both the relatively large separation distance (70 miles) and the mostly pristine area around the Trout Lake site may help explain why the Trout Lake’s PM$_{2.5}$ concentrations are lower than Ashland biomass.
Figure 3-10: There is a noticeable variability in the spread of day-to-day PM$_{2.5}$ between the Ashland Biomass and Perkinstown sites. However, collectively, the Ashland site’s ave PM$_{2.5}$ (7.51 ug/m$^3$) is quite similar to Perkinstown (7.96 ug/m$^3$). The relatively large distance separating the sites (110 miles) may help explain the sizable spread in day-to-day measurements between the sites.

Figure 3-11: Ashland Biomass’s 24-hr PM$_{2.5}$ concentrations are almost always higher than the same day PM$_{2.5}$ values at the Duluth WDSE site – even though the latter is in a much more highly populated area.

Figure 3-12: Perkinstown’s 24-hr nitrate (NO$_3$) PM$_{2.5}$ levels are almost always higher than the same day NO$_3$ levels at the Ashland Biomass site. These data sets are reasonably well-correlated ($r^2 = 0.734$) with one another.

Figure 3-13: Perkinstown’s average 24-hr sulfate (SO$_4$) concentration (1.31 ug/m$^3$) is higher than that for Ashland (1.07 ug/m$^3$). The correlation between Perkinstown and Ashland biomass for 24-hr SO$_4$ PM$_{2.5}$ levels ($r^2 = 0.364$) is much weaker than for NO$_3$ (Fig XX-12: $r^2 = 0.734$).
Figure 3-1
Ashland and Cassville Biomass Monitoring Sites
Nearby PM$_{2.5}$ Monitoring Sites

Figure 3-2
Scatterplot: SASS 24 Hr PM$_{2.5}$ Concentrations
Ashland vs. Cassville Biomass Sites
104 Sampling Days
During July 2010 - June 2011

<table>
<thead>
<tr>
<th>Cassville (550435500)</th>
<th>Ashland (550035500)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean SASS 24hr PM$_{2.5}$</td>
<td>5.4</td>
</tr>
<tr>
<td>Mean sampling days</td>
<td>104</td>
</tr>
<tr>
<td>Median (ug/m3):</td>
<td>10.5</td>
</tr>
<tr>
<td>Max (ug/m3):</td>
<td>28.1</td>
</tr>
</tbody>
</table>

Regression line equation:
y = 0.37x + 2.92
y = Ashland SASS 24-hr PM$_{2.5}$
x = Cassville SASS 24-hr PM$_{2.5}$

$R^2 = 0.285$
Figure 3-3

Scatterplot: Ave 24 Hr PM$_{2.5}$ Concentrations
Continuous, 24-Hr (BAM) Aves vs Integrated Daily Filter (SASS) Measurements

Cassville (WI) Biomass Monitoring Site
115 Sampling Days during July 2010 - June 2011

Regression line equation:
y = 0.98x + 2.09
y = BAM 24-hr PM$_{2.5}$
x = SASS 24 hr PM$_{2.5}$
Sq of corr. coeff. ($r^2$) = 0.864

1:1 line

Figure 3-4

Scatterplot: Integrated 24 Hr PM$_{2.5}$ Concentrations

Cassville Biomass (SASS) vs. Potosi (FRM) Sites
106 Sampling Days
During July 2010 - June 2011

Regression line equation:
y = 0.99x + 0.82
y = Cassville Biomass SASS 24-hr PM$_{2.5}$
x = Potosi FRM 24 hr PM$_{2.5}$
Sq of corr. coeff. ($r^2$) = 0.922

Potosi FRM 24-hr PM$_{2.5}$ (ug/m$^3$)

---

The Potosi FRM site is located approximately 10 miles to the south west of Cassville.
**Figure 3-5**

Scatterplot: Integrated 24 Hr PM$_{2.5}$ Concentrations

Cassville Biomass (SASS) vs. LaCrosse (FRM/FEM)$^{(a),(b)}$
108 Sampling Days
During July 2010 - June 2011

<table>
<thead>
<tr>
<th>LaCrosse</th>
<th>Cassville-Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRM/FEM 24-Hr PM$_{2.5}$</td>
<td>SASS 24-Hr PM$_{2.5}$</td>
</tr>
<tr>
<td># FRM PM$_{2.5}$ obs.</td>
<td>108</td>
</tr>
<tr>
<td>Ave (ug/m$^3$)</td>
<td>9.5</td>
</tr>
<tr>
<td>Median (ug/m$^3$)</td>
<td>7.0</td>
</tr>
<tr>
<td>Max (ug/m$^3$)</td>
<td>27.7</td>
</tr>
</tbody>
</table>

Regression line equation:
\[ y = 0.78x + 3.24 \]
\[ y = \text{Cassville Biomass SASS 24-hr PM$_{2.5}$} \]
\[ x = \text{LaCrosse FRM/FEM 24 hr PM$_{2.5}$} \]
Sq of corr. coeff. $(r^2) = 0.652$

$^{(a)}$ LaCrosse PM$_{2.5}$ data Jul-Dec 2010 from FRM, sampling every 3rd day. PM$_{2.5}$ data Jan-Jun 2011 from a BAM/FEM sampler, 24h PM$_{2.5}$ aves every day.

$^{(b)}$ LaCrosse site 90 mi from Cassville.

**Figure 3-6**

Scatterplot: Integrated 24 Hr PM$_{2.5}$ Concentrations

Cassville Biomass (SASS) Site vs. Backbone (IA) State Park (FRM)$^{(b)}$
57 Sampling Days
During Jan - June 2011$^{(a)}$

<table>
<thead>
<tr>
<th>Backbone (IA)</th>
<th>Cassville-Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRM/FEM 24-Hr PM$_{2.5}$</td>
<td>SASS 24-Hr PM$_{2.5}$</td>
</tr>
<tr>
<td># FRM PM$_{2.5}$ obs.</td>
<td>57</td>
</tr>
<tr>
<td>Ave (ug/m$^3$)</td>
<td>11.35</td>
</tr>
<tr>
<td>Median (ug/m$^3$)</td>
<td>10.20</td>
</tr>
<tr>
<td>Max (ug/m$^3$)</td>
<td>28.0</td>
</tr>
</tbody>
</table>

Regression line equation:
\[ y = 0.88x + 1.37 \]
\[ y = \text{Cassville Biomass SASS 24-hr PM$_{2.5}$} \]
\[ x = \text{Backbone (IA) FRM 24 hr PM$_{2.5}$} \]
Sq of corr. coeff. $(r^2) = 0.840$

$^{(a)}$ There are only Backbone FRM PM$_{2.5}$ data available for the period Jan - June 2011.

$^{(b)}$ The Backbone FRM site is approximately 30 miles SW of the Cassville Biomass site.
Figure 3-7

Scatterplot: Ave 24 Hr PM$_{2.5}$ Concentrations
Continuous, 24-Hr (BAM) Aves vs Integrated Daily Filter (SASS) Measurements

Ashland (WI) Biomass Monitoring Site
113 Sampling Days during July 2010 - June 2011

Regression line equation:
\[ y = 0.81x + 2.45 \]
\[ y = \text{BAM 24-hr PM2.5} \]
\[ x = \text{SASS 24 hr PM2.5} \]
\[ \text{Sq of corr. coeff. (r$^2$)} = 0.554 \]

Figure 3-8

Scatterplot: Ashland Integrated 24 Hr PM$_{2.5}$ Concentrations

Biomass (SASS) vs. Bad River (FRM) Sites
52 Sampling Days
During July 2010 - June 2011

Regression line equation:
\[ y = 1.10x + 1.76 \]
\[ y = \text{Biomass SASS 24-hr PM2.5} \]
\[ x = \text{Bad River FRM 24-hr PM2.5} \]
\[ \text{Sq of corr. coeff. (r$^2$)} = 0.606 \]

---

*(a) The Bad River FRM site is located approximately 11 miles east of the Ashland Biomass site.*
Figure 3-9

Scatterplot: Integrated 24 Hr PM$_{2.5}$ Concentrations

Ashland Biomass SASS (550035500) vs. Trout Lake FRM (551250001)$^{(a)}$

47 Sampling Days
During July 2010 - June 2011

<table>
<thead>
<tr>
<th></th>
<th>Trout Lake</th>
<th>Ashland Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td># FRM PM$_{2.5}$ obs</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>Ave (ug/m$^3$)</td>
<td>6.10</td>
<td>7.39</td>
</tr>
<tr>
<td>Median (ug/m$^3$)</td>
<td>5.1</td>
<td>5.8</td>
</tr>
<tr>
<td>Max (ug/m$^3$)</td>
<td>21.0</td>
<td>22.3</td>
</tr>
</tbody>
</table>

Regression line equation:

$y = 0.91x + 1.86$

$y = $ Ashland SASS 24-hr PM$_{2.5}$

$x = $ Trout Lake FRM 24-hr PM$_{2.5}$

Sq of corr. coeff. ($r^2$) = 0.720

(a) The Trout Lake FRM site is located approximately 70 mile southeast of the Ashland Biomass site.

Figure 3-10

Scatterplot: Integrated 24 Hr PM$_{2.5}$ Concentrations

Ashland Biomass SASS (550035500) vs. Perkinstown FRM (551198001)$^{(a)}$

52 Sampling Days
During July 2010 - June 2011

<table>
<thead>
<tr>
<th></th>
<th>Perkinstown</th>
<th>Ashland Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td># FRM PM$_{2.5}$ obs</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Ave (ug/m$^3$)</td>
<td>7.56</td>
<td>7.51</td>
</tr>
<tr>
<td>Median (ug/m$^3$)</td>
<td>6.00</td>
<td>6.0</td>
</tr>
<tr>
<td>Max (ug/m$^3$)</td>
<td>36.2</td>
<td>22.3</td>
</tr>
</tbody>
</table>

Regression line equation:

$y = 0.59x + 2.78$

$y = $ Ashland SASS 24-hr PM$_{2.5}$

$x = $ Perkinstown FRM PM$_{2.5}$

Sq of corr. coeff. ($r^2$) = 0.630

(a) The Perkinstown FRM site is located approximately 112 miles south of the Ashland Biomass site.
Figure 3-11

Scatterplot: Integrated 24 Hr PM$_{2.5}$ Concentrations

Ashland Biomass SASS (5500335500) vs. Duluth WDSE FRM (2713775500)$^{(*)}$

105 Sampling Days
During July 2010 - June 2011

<table>
<thead>
<tr>
<th>Duluth WDSE</th>
<th>Ashland-Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2713775500)</td>
<td>(5500335500)</td>
</tr>
<tr>
<td>Sam. Stats</td>
<td>ERU 24hr PM2.5</td>
</tr>
<tr>
<td>105 obs.</td>
<td>105</td>
</tr>
<tr>
<td>Ave (ug/m3)</td>
<td>7.22</td>
</tr>
<tr>
<td>Median (ug/m3)</td>
<td>5.8</td>
</tr>
<tr>
<td>Max (ug/m3)</td>
<td>22.3</td>
</tr>
</tbody>
</table>

Regression line equation:
y = 0.93x + 2.38

y = Ashland SASS 24-hr PM2.5
x = Duluth WDSE FRM PM2.5
Sq of corr. coeff. ($r^2$) = 0.824

$^{(*)}$ The Duluth WDSE site is located approximately 60 miles west of the Ashland Biomass site.
Figure 3-12

Scatterplot: Integrated 24 Hr NO₃ PM₂.₅ Concentrations

Ashland Biomass (550035500) vs. Perkiomenville (551198001)

57 Sampling Days
During July 2010 - June 2011

<table>
<thead>
<tr>
<th></th>
<th>Ashland Biomass</th>
<th>Perkiomenville</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site No.</td>
<td>(550035500)</td>
<td>(551198001)</td>
</tr>
<tr>
<td>Sum Stats.</td>
<td>NO₃ 24h. PM₂.₅</td>
<td>NO₃ 24h. PM₂.₅</td>
</tr>
<tr>
<td># NO₃ PM₂.₅ obs.</td>
<td>57</td>
<td>57</td>
</tr>
<tr>
<td>Ave (µg/m³)</td>
<td>0.46</td>
<td>0.75</td>
</tr>
<tr>
<td>Median (µg/m³)</td>
<td>0.43</td>
<td>0.28</td>
</tr>
<tr>
<td>Max (µg/m³)</td>
<td>13.50</td>
<td>5.26</td>
</tr>
</tbody>
</table>

Regression line equation:
y = 0.44x + 0.102

(a) The Perkiomenville site is approximately 110 miles from the Ashland Biomass site.

Figure 3-13

Scatterplot: Integrated 24 Hr SO₄ PM₂.₅ Concentrations

Ashland Biomass (550035500) vs. Perkiomenville (551198001)

57 Sampling Days
During July 2010 - June 2011

<table>
<thead>
<tr>
<th></th>
<th>Ashland Biomass</th>
<th>Perkiomenville</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site No.</td>
<td>(550035500)</td>
<td>(551198001)</td>
</tr>
<tr>
<td>Sum Stats.</td>
<td>NO₄ 24h. PM₂.₅</td>
<td>NO₄ 24h. PM₂.₅</td>
</tr>
<tr>
<td># NO₄ PM₂.₅ obs.</td>
<td>57</td>
<td>57</td>
</tr>
<tr>
<td>Ave (µg/m³)</td>
<td>1.31</td>
<td>1.07</td>
</tr>
<tr>
<td>Median (µg/m³)</td>
<td>1.63</td>
<td>0.80</td>
</tr>
<tr>
<td>Max (µg/m³)</td>
<td>3.97</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Regression line equation:
y = 0.56x + 0.34

(4) The Perkiomenville site is approx. 110 miles south of the Ashland Biomass site.
APPENDIX 4
Cassville Train Impact Analysis

The Cassville biomass air monitoring site (AIRS ID # 550435500) was located next to the Burlington Northern Santa Fe (BNSF) railroad tracks (near Front St and Wisconsin St) about 1.35 km southeast of the Nelson Dewey plant, and about 1.2 km northwest of the Stoneman plant (Figure 4-1).

Figure 4-1 Cassville Air Monitoring Site

On a typical calendar day during the biomass field stud, approximately 30-40 trains passed through Cassville (Gunderson, 2011a). Consequently, it is speculated that the smoke plumes from these trains had many brief, but significant impacts on the measured concentrations for various species of nitrogen oxides (NO, NO₂, NOₓ) as well as black carbon (BC) at this monitor.

Analyzing certain measurement data could help identify these plume impacts. One assessment of Cassville train plume impacts was constructing a 12-month pollution rose for NOₓ during the field study (July 2010 – June 2011) - Figure 4-2, superimposed over a Google Earth image. This pollution rose shows that the highest NOₓ concentrations (represented by the light blue and dark green colors) are clearly coming from the direction of the railroad tracks.

In order to estimate when the BNSF trains actually passed through Cassville (no stops) - the BNSF railroad provided detailed La Crosse arrival and departure time information for most of the months during the field study (Gunderson, 2011a). There is no direct information on trains passing through Cassville, but BNSF estimated that there was an approximately 100 minute difference between the train being in La Crosse and being in Cassville (Gunderson, 2011b).

Using this train schedule information, it was possible to synchronize the time when trains were present in Cassville with the minute-averaged pollution measurements collected at the Cassville monitoring site. Because of the considerable number of train passages (30-40 per day) and the massive files of minute-averaged data, this analysis focused on the train and pollution data for the month of October 2010 only – representing a typical month.

Using these data, a detailed timeline analysis was conducted of estimated train passes through Cassville and 1-minute NOₓ concentration data at Cassville for the month of October 2010. Several of these daily timeline plots (October 1, 8 and 20) are contained in Figure 4-3.
These timeline graphs reveal that on many occasions during these 3 days - the NOx concentrations (signified with blue circles) spiked from typical levels under 10 ppb to near (and sometimes above) 100 parts per billion (ppb). Most of these excessively high 1-minute NOx concentrations are temporally associated with train passes (signified by red triangles). These graphs further demonstrate that there were generally brief, but sizable impacts of the train plumes on short-term pollutant concentrations at this site.

Figure 4-4 displays – for Cassville, October 2010 - the ratio of the monthly median of 5-minute average concentrations (intervals of train passage / intervals with no train passage) for several pollutants that have concentrations in the train plume: NO₂, NOx, sulfur dioxide (SO₂) and 3 aethalometer constituents (black carbon [BC], ultra-violet [UVPM] and delta-C [DC = UVPM-BC].

This graph shows that, on average, these parameters were noticeably higher when the train was passing through Cassville – compared to when there was no train present. This is especially true for NO₂ and NOx, with “train/no train” ratios of 1.11 and 1.15 respectively. In summary, the smoke plumes from the many trains that passed through Cassville during the field study had many brief, but sizable impacts on pollutant levels at the monitoring site.
Figure 4-3: Time series of 1-min NOx concentrations and train passages
Cassville: Oct 1 (top) Oct 8 (middle) and Oct 20 (bottom)
Figure 4-4

![Bar chart showing the ratio of monthly median of 5-min average concentrations with train passage to those without trains.](image)

(a) In Cassville the monitoring site was located approx. 10 m from railroad tracks.

References

Gunderson, K.D., 2011a: BNSF La Crosse train schedule information. BNSF E-mail. April 11.

Gunderson, K.D., 2011b: BNSF train time adjustment between La Crosse and Cassville. BNSF E-mail. April 4.
APPENDIX 5
Wood Smoke Analysis

A Magee dual wavelength Aethalometer (Model AE21) was operated during the biomass field study at both the Cassville monitoring site (19 July 2010 - 4 Jan 2011) and Ashland monitoring site (27 Jan - 11 July 2011). The monitoring data collected by the aethalometer afforded an opportunity to assess the impact from wood combustion particles, resulting from wood burning both for residential space heating and as a biomass fuel for generating electricity.

The aethalometer principally measures black carbon (BC), which is a fine particulate produced from the combustion of carbon-based fuels. In the aethalometer, the black carbon measurement is made by optical attenuation of ambient air at an optical absorption of 880 nanometers (nm) through a spot on a quartz filter tape (M. Allen, 2011).

The Magee dual wavelength aethalometer also measures at 370 nm and these data are designated as ultra-violet particulate matter (‘UVPM’) concentrations, which are considered fine particulates too. 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 also made on a quartz filter tape as particulate matter loads (M. Allen, 2011).

It has been suggested that certain organic aerosol components of wood smoke have enhanced UV absorption at 370 nm relative to 880 nm in two-wavelength aethalometer black carbon (BC) measurements (Wang, et.al., 2011). This enhanced absorption could serve as an indicator of wood combustion particles (“Delta-C” [“DC”] = UVPM$_{370nm}$ minus BC$_{880nm}$). A positive DC value can be more closely associated with wood combustion, a negative DC value suggests impacts are dominated from burning fossil fuels, especially diesel.

Figure 5-1 reveals that at both biomass monitoring sites for temperatures below approximately 30 °F displays a strong trend towards steadily, sizably increasing DC values as the temperature decreases, especially at the Cassville site. This feature suggests that residential wood burning increases with increasingly colder weather in the vicinity of both sites.

Figure 5-2 attempts to identify any increase in the impacts from wood burning (i.e., higher DC values) on Saturday and Sunday, when this activity might be expected to be more popular - relative to during the other days of the week.

For the Cassville site, the substantial increase in DC from Friday to Saturday, continuing a rapid climb to the peak on Sunday, followed by a sizable descent in DC levels by Monday certainly supports this speculation. The day-of-week average DC profile for Ashland is a bit more muted. Nevertheless, the combined highest 2 day period of DC values for Ashland is on Saturday-Sunday, which suggests a modest increase in residential wood burning on weekend for the area.

Figure 5-3 combines features of the previous two graphs. Namely, for both biomass monitoring sites this graph profiles the average day-of-week DC concentrations for hours when the temperature was less than 40 °F, when the likelihood of residential wood combustion is increased. Cassville’s has highest average DC levels during Tuesday-Thursday, while Ashland’s peak day-of-week DC averages are on Thursday and Saturday. Consequently, these profiles appear to be largely inconclusive with respect to trends in day-of-week wood combustion.
Wood smoke may be a significant contributor to overall ambient levels of PM$_{2.5}$, especially during the winter months, when wood combustion is most active. A study by Babich, (2011) found that on an annual average, PM$_{2.5}$ markers identified with wood smoke contributed to total PM$_{2.5}$ levels ranging from 1.7 to 17.3% for six Connecticut sites.

Figure 5-4 details how average hourly DC relates to increasing average hourly PM$_{2.5}$ at biomass monitoring sites in Cassville and Ashland. Ashland experienced a gradual, slightly irregular increase in DC from 0.005 ug/m$^3$ at 7 ug/m$^3$ PM$_{2.5}$ to 0.119 ug/m$^3$ at 17 ug/m$^3$ PM$_{2.5}$. For Cassville in this same PM$_{2.5}$ range – witnessed wide swings in average DC levels: minimum: -0.459 and -0.439 ug/m$^3$, maximum: 0.738 ug/m$^3$. This instability in Cassville’s DC profile over this range will require additional study to explain.

However, the trend in DC profiles for both Cassville and Ashland for average PM$_{2.5}$ levels above 17 ug/m$^3$ is bit clearer. Cassville’s DC levels increase sharply from -0.011 ug/m$^3$ at PM$_{2.5}$ = 18 ug/m$^3$ to 0.595 ug/m$^3$ at PM$_{2.5}$ > 22 ug/m$^3$. For the same PM$_{2.5}$ range, Ashland’s average DC rapidly rises from 0.119 ug/m$^3$ to 0.887 ug/m$^3$. Consequently, it appears from this graph that the impact of wood combustion (as identified with DC data) on PM$_{2.5}$ levels is most apparent at higher concentrations.

References
Allen, M.K., 2011: Comparison of Roadway Trailer Aethalometer with the Biomass Study Aethalometer. Wis DNR memo, 7pp, 10 Feb.


Figure 5-1
Ave Hrly Delta-C
(UVPM-Bin minus BC-Bin)
vs. Increasing Ambient Temperature

Ashland Site: 3680 Hrs During 27 Jan - 11 Jul 2011
Cassville Site: 4075 Hrs During 19 Jul 2010 - 4 Jan 2011

Figure 5-2
Day-Of-Week Ave Hrly Delta-C
(UVPM-Bin minus BC-Bin)

Ashland Site: 3874 Hrs During 27 Jan - 11 Jul 2011
Cassville Site: 4050 Hrs During 19 Jul 2010 - 4 Jan 2011
Figure 5-3

(UVPM-Bin minus BC-Bin)
During Hours When Temperature < 40 F

Ashland Site: 1877 Hrs During 27 Jan - 11 Jul 2011
Cassville Site: 1342 Hrs During 19 Jul 2010 - 4 Jan 2011

Figure 5-4

Ave Hrly Delta-C
(UVPM-Bin minus BC-Bin)
vs. Increasing Fine Particulates (PM$_{2.5}$) Levels

Ashland Site: 3601 Hrs During 27 Jan - 11 Jul 2011
Cassville Site: 4043 Hrs During 19 Jul 2010 - 4 Jan 2011
December 16, 2011

Mr. Michael Koerber  
Executive Director  
Lake Michigan Air Directors Consortium  
9501 West Devon Avenue, Suite 701  
Rosemount, IL 60018

Re: Northern States Power Company (NSP), a Wisconsin Company  
Response Letter for Testing Performed at the Bay Front Generating Plant, Ashland, WI.

Dear Mr. Koerber,

In response to the test report submitted to the Lake Michigan Air Directors Consortium (LADCO), for testing performed at its Bay Front Generating Plant, Northern States Power Company (NSP) is submitting the enclosed attachment detailing concerns with the accuracy of the data being reported.

As with all emissions monitoring and testing, the ultimate usefulness of the data from any individual test may depend significantly on the adequacy of the Quality Assurance (QA) Project Plan and its effective implementation through the testing process. EPA test methodology specifies QA requirements that must be met in order to validate the data. Any deviations from the methodology must be accounted for in the plan, otherwise the data from an individual test should be considered suspect and possibly invalid.

For the reasons explained in the attachment, NSP believes that the quality of the data derived from the test performed at the Bay Front Generating Plant has many shortcomings. The failure to meet QA requirements, in NSP's view, should result in the data from this individual test not being used as a basis for subsequent environmental or regulatory decision-making.

Given the issues encountered during the data gathering phase of this study, and understanding the value in the information being sought, NSP invites LADCO to repeat the testing provided appropriate testing procedures are followed by an accredited testing body.

If you have any questions concerning this submission, please contact me (612) 330-7879.

Sincerely,

Richard A. Rosvold  
Manager, Air Quality  
Xcel Energy

Enclosure:

cc: William Zawacki  
    David Fulweber  
    David Hillesheim  
    Tina Ball  
    Wayne Storck  
    Environmental Services Record Center
Xcel Energy’s Environmental Policy and Services Department (EP&S) has completed a review of the emission test report titled, “Wisconsin Focus on Energy, Biomass Emissions Testing,” prepared by MACTEC Engineering for the Lake Michigan Air Directors Consortium (LADCO). The testing was conducted on Boiler #2 at Northern States Power Company’s¹ (NSP’s) Bay Front Generating Plant in Ashland, Wisconsin. Based on its review, Xcel Energy believes the emissions data included in this test report should be considered invalid because of several Quality Assurance (QA) issues associated with the field work performed. Accuracy of the data is tied to its validity. Without being able to assess the validity of the data, it is not possible to assure data accuracy.

This paper details the issues observed, breaking them into three categories:

- **Field Observations** – Notes documenting the quality of work performed onsite during the testing.
- **Gaseous testing** – Detailing the QA issues associated with the Continuous Emissions Monitoring System (CEMS) testing performed.
- **Wet Chemistry** – Detailing the QA issues associated with the PM (Method 5, OTM 27 and OTM 28), and HCl (Method 26A) testing performed.

**Field Observations**

Mr. John Buresh of EP&S represented Xcel Energy while the testing was performed at the Bay Front Generating Plant. Mr. Buresh noted the following observations of the work performed onsite:

- The trailers and equipment seemed to be rather worn, and the testers had difficulties with calibrations of the equipment, spending much time taking apart the sample system, as well as the analyzers themselves.
- Degradation of the SO₂ signal for each run following each calibration. During the third run, the analyzer signal was lost completely due to questionable equipment. All of the SO₂ data should be disregarded, as the quality assurance did not meet the standards of Method 6C.
- Signal degradation of CO analyzer through the run was also apparent but less pronounced than that of the SO₂ analyzer. Since both of these analyzers are sensitive to sample pressure, it is possible to have had sample system plugging or pump failure during the test.
- The testers exhibited frustration with the equipment during testing and appeared to have difficulty obtaining required test data.

---

¹ Northern States Power Company, a Wisconsin Corporation
**Gaseous Testing**
The test report documents several instances of test vendor analyzer malfunction, and poor agreement with target gas concentrations during calibrations. Per the test method, Xcel Energy believes the tests should have been aborted and the issues resolved. Because this did not occur, the results from this particular stack test should be considered invalid. The issues observed are detailed below. It should be noted that while a unique test method exists for each gas, the QA requirements for all the Methods tested are consistent, and defer to the procedures outlined in Method 7E (Determination of Nitrogen Oxides Emissions From Stationary Sources (Instrumental Analyzer Procedure)).

Additionally, the test vendor CEMS testing performed at the Bay Front Generating Plant was done using a dry-extractive sampling system, which employs a gas chiller to remove the moisture from a heated sample prior to analysis, and subsequently presents emissions on a dry basis. The sampling system employed at the Bay Front Plant is a dilution extractive system that dilutes the sample at a 100:1 ratio, and is considered a wet basis sample. The percent error reported in the test report between the samples taken, and the plant CEMS, does not take into account the moisture component, which can vary significantly, between 12% and 20% depending on the type and quality of the fuel being combusted. A run by run moisture analysis via Method 4 should have been performed to correct each run’s dry measurement back to wet.

**CO Testing**
Method 7E requires that the sample system be checked with a 3-level calibration injection matrix. This is to be performed using a low level gas (<20% span), a mid level gas (40 to 60% of span), and a high level gas (value determines span). The pre-test checks performed during the testing at Bay Front on 9/15/10 and 9/16/10 consisted of 0.0 ppm (low), 89.24 ppm CO (mid), and 287.10 ppm CO (high) calibration gases. The mid range bottle equates to 31.1% of the calibration gas span. This does not meet Method 7E requirements for the pre-test calibration to verify analyzer linearity. Because of this, the results of this testing should be considered invalid.

**NO\textsubscript{x} Testing**
Prior to testing for NO\textsubscript{x} emissions on 9/15/10, the mid level calibration error check of 54.02 ppm NO\textsubscript{x} response was 56.28 ppm – 2.3% error. Method 7E requires that the calibration error be within ±2.0% at each level. The testing should not have proceeded until the analyzer linearity issues were addressed. The results of this testing should be considered invalid due to non-linear response. The bias check does not resolve this issue, as explained in the CO\textsubscript{2} discussion below.

**SO\textsubscript{2} Testing**
While the report shows decent calibration response for SO\textsubscript{2}, it is a concern that the responses were slow, to the point that a calibration gas cylinder was expended during the bias checks. This issue is a result of SO\textsubscript{2} scrubbing within the gas sample system,
common with dry-extractive systems running a gas conditioner (chiller), with cold spots within the heated sample line. This issue would result in sample runs biased low as the SO$_2$ in the gas sample is “scrubbed,” and slowly off-gassed as the sample system is dried during calibration checks. Any system response to calibration in excess of 15 minutes is considered a failed calibration. Because responses to calibrations are not documented in the test report, the timing cannot be verified. However, the amount of calibration gas used to “dry” the system indicates the response time necessary was significant.

**CO$_2$ Testing**

Prior to testing for CO$_2$ emissions on 9/15/10 the mid level calibration error check of 10.92% CO$_2$ response was 10.44% - 2.48% error (report states 2.18% error). Method 7E requires that the calibration error be within ±2.0% at each level. As with the NO$_x$ sampling, the results of the tests should be considered invalid.

The test report makes the statement that because the bias test results (-1.03%) were less than the allowed 5% that the testing is valid. Xcel Energy disagrees with this statement due to the fact that the bias test is a comparative test between the analyzers direct response to the target calibration gas value, and the full system’s response to the calibration gas. It does not represent the analyzer’s accuracy, but instead reflects the integrity of the sampling system. As an example, the analyzer’s response to calibration gas could have been 6% when injecting a 10% CO$_2$, or 20.7% error, if this gas was then injected through the sample system with a response of 5.8%, the bias response would be 1.0% error, while the analyzer’s true response to the calibration is 21.7% error. The results of the bias test therefore do not resolve concerns about the calibration error being outside the required range.

The test report describes large differences in data between the results of the emission testing and emission data being reported from the Continuous Emissions Monitoring System (CEMS) on Boiler 2. Plant logbooks and emissions data generated by the plant Data Acquisition and Handling System (DAHS) show no issues with plant CEMS during the period of time that testing was conducted. The report mentions on page 3-3 that the Bay Front SO$_2$ monitor malfunctioned during test runs 3 and 4 on 9/16/10. There is no indication of this in the minute data reported from the plant CEMS.

**Wet Chemistry Testing**

Emission rates are consistently calculated throughout the test report based on a stack area of 49.2 ft$^2$. The actual stack area of Boiler #2 is approximately 40.3 ft$^2$. This error has a significant impact on the emissions reported. A larger stack area for a particular flue gas velocity would indicate a higher volumetric stack flow, and therefore a higher emission rate, than actually occurred. It could also indicate that incorrect sample points were used during the testing which could have an impact on the emission rates reported.
Method OTM-27 filters were received at the laboratory in a damaged condition. This raises questions about the care and handling of the filters and whether the filters were contaminated or contained all the particulate captured during testing. In either case, an accurate measurement of filterable particulate could not be made.

Sampling with OTM-27 requires isokinetic conditions to ensure representative emission samples are collected. Sampling above the isokinetic rate would indicate more particulate than was actually present; all runs were sampled above isokinetic conditions. The report attempts to validate the data based on research work by others; the method makes no allowance for sampling outside isokinetic conditions and the data therefore should not be considered valid. The field data sheets, which are filled out during testing, indicate sampling above isokinetic rates. This should have indicated an issue with sampling.

Method OTM-28 post CPM impinger catches were discarded, this is not allowable unless catches were analyzed on site prior to disposal; there is no documentation of this analysis in the report. The method requires analysis of reagent blanks, field reagent blanks, and field train blanks. The laboratory report contains a reagent blank analysis, but the test report does not indicate if this was a field reagent blank. There is no documentation that a field train blank was obtained or analyzed. Without this information it is not possible to assess the validity of the condensable particulate samples. For example, if the reagents used to rinse filter holders and glassware were contaminated, test results would indicate more particulate matter than was actually present during testing.

The test report states that the plant uses a carbon based F-factor based on historical fuel analysis. This is incorrect, the Fc-Factor (1830) used is derived from 40 CFR Part 60 Method 19 default value for wood fuel. The Fc-Factor is used to determine emission rates in lb/mmBTU. An incorrect factor will cause the rates to be incorrectly reported.