FINAL FEASIBILITY REPORT

Field Demonstration of a Near-Real-Time Multi-Metals Ambient Fence Line Monitor

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EPA Contract EP-D-05-096, Work Assignment 4-07

MACTEC Work Order No.: 200812509
MACTEC Project No.: 8708S407

Submitted to:
MACTEC Federal Programs
Research Triangle Park, NC

Prepared by:
Cooper Environmental Services LLC
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Executive Summary

National emissions standards for hazardous air pollutants (HAPs) are required under Section 112 of the Clean Air Act to limit the release of specified HAPs. Permitting, monitoring and enforcement of these emission limits are an integral part of managing air quality to protect human health and the environment. However, this is difficult and highly uncertain in the case of fugitive emissions because of the lack of appropriate monitors. This is of particular concern for fugitive metal emissions because metals represent 8 of 33 pollutants identified by the EPA as posing the greatest potential health threat, and these fugitive emissions may represent dominate exposure pathways in some airsheds. Fence line monitoring, or monitoring in a neighborhood near the perimeter of a metals emission source, offers the potential to not only greatly increase the accuracy of estimating the local impact of fugitive metal emissions, but also has the potential to eliminate the need for costly monitoring of poorly defined emissions from many possible area and fugitive permitted sources. Near-real-time ambient monitoring could also provide hourly or shorter feedback to plant operators to minimize emissions before they become a problem.

Cooper Environmental Services LLC (CES) is currently working on an ambient multi-metals monitoring program in coordination with MACTEC and EPA sponsorship. The overall objectives of this program are to: develop a near-real-time multi-metals ambient monitor, demonstrate its potential utility for permitting and compliance demonstration, and develop reference procedures for its application.

An ambient-optimized version of a CES continuous emissions monitor based on reel-to-reel filter tape sampling with X-ray fluorescence analysis of metals has recently been used to evaluate the feasibility of near-real-time metals measurement as well as the feasibility of apportioning these metals to potential fugitive emission sources. In this field test, the monitor was installed near a metals manufacturing facility and operated for a period of about one month. The monitor (CES Xact 620) recorded hourly concentration (ng/m^3) data for the following 24 elements: K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Mo, Cd, Sn, Sb, Ba, Hg, Pb, and Bi. Local wind speed and wind direction were also recorded during this same period. A key, new and unique aspect introduced with the Xact 620 multi-metals monitor is its ability to generate large, multi-element data sets applicable to receptor oriented source apportionment models. The resulting database from this field study was evaluated for its applicability to receptor-oriented source apportionment models such as chemical mass balance and multivariate models. These models are well established, validated models having been used for over 30 years as the basis of permitting and compliance demonstration. This capability of defining near-real-time source impacts is expected to be particularly useful in implementing new particulate matter and lead National Ambient Air Quality Standards that require defining source impacts as the basis for further monitoring and development of state implementation plans.

These field tests demonstrated that the Xact 620 ambient metals monitor is field ready by providing metals concentration data over the course of the field test. This conclusion is further supported with the deployment of six similar ambient metals monitors at various locations around the world. The monitor detected real world concentrations of various metals from low background levels to high concentration events. Not only did it respond timely to rapidly

changing concentrations of elements from an expected source, but it recorded “hits” from two unexpected sources, one dominated by Pb and Zn and the other dominated by As. In addition, the data generated by the monitor was determined to be adequate for application to EPA’s Chemical Mass Balance 8.2 source apportionment model. Thus, both the measurement and modeling technologies are available for permitting and enforcement applications. The monitor provided all of the required ambient data for the model. It could provide source profile information through multivariate analysis if source profiles are not available from the EPA source profile library or through direct measurements of emissions that might be required as part of a permitting and enforcement plan.

It is important to note that this field-ready feasibility evaluation study has clearly shown that with near-real-time monitoring, events may be observed that might otherwise be obscured with 24 hour integrated sampling with laboratory analysis. If these events can be observed, it should be possible to regulate and/or eliminate them through permitting, enforcement and improved plant management. In addition, measured short-term peak impacts may be directly related to specific fugitive emission events and/or processes, which again may be eliminated through improved plant management.

The following tasks still need to be completed prior to using this technology in a permitting and enforcement setting:

1. Validate FLM analytical results by comparing to EPA federal reference methods
2. Automate and integrate CMB 8.2 source apportionment model into the FLM
3. Develop protocol for permitting and compliance demonstration
4. Field demonstrate total system protocol

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1.0 Introduction

The U.S. Congress amended the federal Clean Air Act (CAA) in 1990 to address a large number of hazardous air pollutants (HAPs) that are known to cause adverse effects to human health. Section 112 of the CAA governs the federal control program for HAPs. National emissions standards for HAPs (NESHAPs) are issued to limit the release of specified HAPs. These standards are "technology-based" meaning that they represent the maximum achievable control technology (MACT). The CAA requires EPA to review and revise MACT standards as necessary every eight years, and directs the EPA to assess the risk remaining (residual risk) after the application of the MACT standards. The EPA is further directed to promulgate additional standards if required to provide an ample margin of safety to protect public health. The EPA is in the process of promulgating residual risk standards for HAPs following its promulgation of MACT standards.

Permitting, monitoring and enforcement of emission limits for HAPs (MACT or residual risk related) are an integral part of managing air quality to protect human health and the environment. Emissions from stacks can be relatively easily permitted, their emissions accurately monitored with continuous emissions monitoring systems (CEMS), and limits enforced based on these measurements. However, it is difficult to permit and enforce fugitive emission limits because of the lack of monitors for fugitive emissions and/or their impacts at a fence line or in the local community. Current permitting and enforcement of fugitive emission sources are based on crude estimates of emissions (uncertainties generally ranging from about 100 to 1,000 percent) and good management practices. This uncertainty and management difficulty is of particular concern because fugitive emissions are often highly variable and may be responsible for the dominate exposure to hazardous pollutants for nearby residents.

Although progress is being made in the development of fugitive emissions monitors for some gaseous pollutants such as ammonia, little progress has been made for other pollutants such as metals. Metals and metal compounds are of particular concern because they are included in EPA's list of 188 HAPs and represent 8 of the 33 pollutants identified by the EPA as posing the greatest potential health threat in urban areas. Hazardous metals are unique in that they will not biodegrade; once released into the environment, they will always be potentially available for re-introduction into the air, water and food chain. This persistence is particularly important in the context of environmental justice and areas where hand-to-mouth type pathways can represent significant exposure. In these local airsheds, area/fugitive HAP emissions can make a significant contribution to total HAP emissions and impacts in local communities. Perimeter or nearby ambient air monitoring programs to evaluate these contributions have become increasingly valuable. Fence line or nearby ambient monitoring offers the potential to not only greatly increase the accuracy of measurement and enforcement, but also the potential to eliminate the need for costly monitoring of poorly defined emissions from many possible area/fugitive compliance sources within a facility. This near-real-time monitoring may also provide timely feedback to plant operators to identify sources and minimize their emissions before they become a problem.

Cooper Environmental Services LLC (CES) is currently working on a multi-metal ambient monitoring program in coordination with MACTEC and EPA sponsorship. The overall

objectives of this program are to demonstrate the potential utility of a near-real-time metals monitor for permitting and compliance demonstration, and develop reference procedures for application of this technology in a compliance setting. This program has taken a phased approach to achieving these goals.

The objectives of Phase I were to:

1. Modify CES' existing multi-metal continuous emissions monitor (CEM) to meet the requirements of an ambient metals monitor.
2. Evaluate this modified monitor in CES' laboratory for its potential applicability to ambient metals monitoring.
3. Develop a protocol to demonstrate its practical applicability in the field.

The first two objectives of Phase I were completed in September of 2006. The results of Phase I demonstrated that the CEM technology could be modified to accurately monitor emission impacts at a fence line and achieve detection limits adequate for modeling high impact periods.[1]

The overall objective of Phase II is to demonstrate feasibility/availability of a continuous ambient metals monitoring technology for use in permitting and enforcing fugitive emission limits. The specific objectives for Phase II are to:

1. Demonstrate that measurement technology is field ready; i.e. demonstrate it can practically provide accurate and reliable near-real-time measurements of metals in the field.
2. Evaluate the applicability of the field data for models that might be used to quantify either fugitive emission rates and/or impacts at a monitor.
3. If applicable, determine the adequacy of this field data to quantify either source emission rates and/or source impacts to ambient metal concentrations that can be used in permitting and compliance demonstrating situations.
4. Develop procedures for applying this technology in a permitting and compliance demonstration situation.
5. Validate the monitor and procedures developed in the above tasks.

To date, the first three objectives of Phase II have been completed, the results of which are reported herein. The last two objectives are expected to be achieved in the second part of Phase II. To achieve these first three objectives, the following tasks were performed during the first part of Phase II:

- A testing site was located in the vicinity of a source likely to produce measurable metal concentrations near the fence line of the source.
- Historical patterns of wind speed and wind direction were reviewed and used to select a site to install and operate a multi-metals ambient monitor.
- A multi-metals ambient monitor was installed and operated for a period of three weeks.
- A meteorological monitoring site was also established near the multi-metals monitoring site to record local wind speed and wind direction during the field tests.
- A database of elemental and meteorological data was developed and evaluated.

- The resulting database was used to evaluate 1) the field readiness of the monitoring technology, 2) its model applicability and 3) its appropriateness for permitting and enforcement.

2.0 Experimental

2.1 Overview

In Phase I, the feasibility of using an elemental monitoring platform similar to CES' continuous emissions monitor (CEM) was evaluated. It was anticipated that a modified CEM would be used in Phase II. However, in the interim between Phase I and Phase II, CES developed an ambient-optimized version of the CEM (Xact 620) independent of this program and used it in this initial part of Phase II. This Xact 620 was installed near a metals manufacturing facility and operated for a period of three weeks. The instrument recorded hourly concentration (ng/m^3) data for the following 24 elements: K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Mo, Cd, Sn, Sb, Ba, Hg, Pb, and Bi. Local wind speed and wind direction were also recorded during this same period. The resulting database was then used to evaluate the applicability of the instrumentation and models to permitting and enforcement. The following describes this instrumentation and its field deployment.

2.2 Xact 620 Instrument

The Xact 620 ambient multi-metals monitor is a reel-to-reel filter tape sampling system with an integrated metals analyzer based on X-ray fluorescence (XRF) and EPA's Compendium Method IO 3.3.[2] A schematic of the monitor is illustrated in Figure 1. It consists of a PM inlet and temperature sensor, a sampling and analysis module and a flow control module. It operates by drawing 16.7 lpm through a PM size-selective inlet and a filter tape located in the sampling and analysis module. At the end of a sampling interval that can last from 15 minutes to 4 hours (operator defined), the resulting filter tape deposit is advanced approximately 2 inches for analysis. While this sample is being analyzed for metal content, the next sample is being collected. The only dead time in the sampling and analysis system is about 20 seconds required to advance the tape and prepare for the next sample. The average metal concentration for each sampling interval is calculated by dividing the XRF-determined metal mass by the sampled volume. The resulting concentration (ng/m^3) is automatically stored in a computer and/or reported to a central monitoring location. The Xact 620 has been optimized for ambient toxic metals monitoring and has interference-free detection limits in the low pg/m^3 range.

The monitor as deployed in the field for this testing is shown in Figure 2. The two modules are mounted on a table as illustrated in this photograph. The far left module is the sampling and analysis module where the aerosol was sampled through about a one cm^2 area of PTFE filter tape. The flow control module located on the table to the right of the sampling and analysis module contains a laptop computer for system control and XRF analysis. One-hour sampling and analysis periods were used in these tests. The computer visible in Figure 2 was used for diagnostic and special testing. Hourly average metal concentrations were automatically stored in the computer. Key features of the Xact 620 include: automated leak and XRF calibration check with each sample collected and analyzed, daily automatic energy calibration, automatic alarming, and MS Excel- and DAS-compatible data reports. The non-destructive XRF analysis allows for

possible sample archiving and re-analysis of filter deposits. A PM_{10} inlet was used in these tests and a sampling flow maintained at 16.7 lpm. A $PM_{2.5}$ or a TSP inlet could also be used with this instrument.

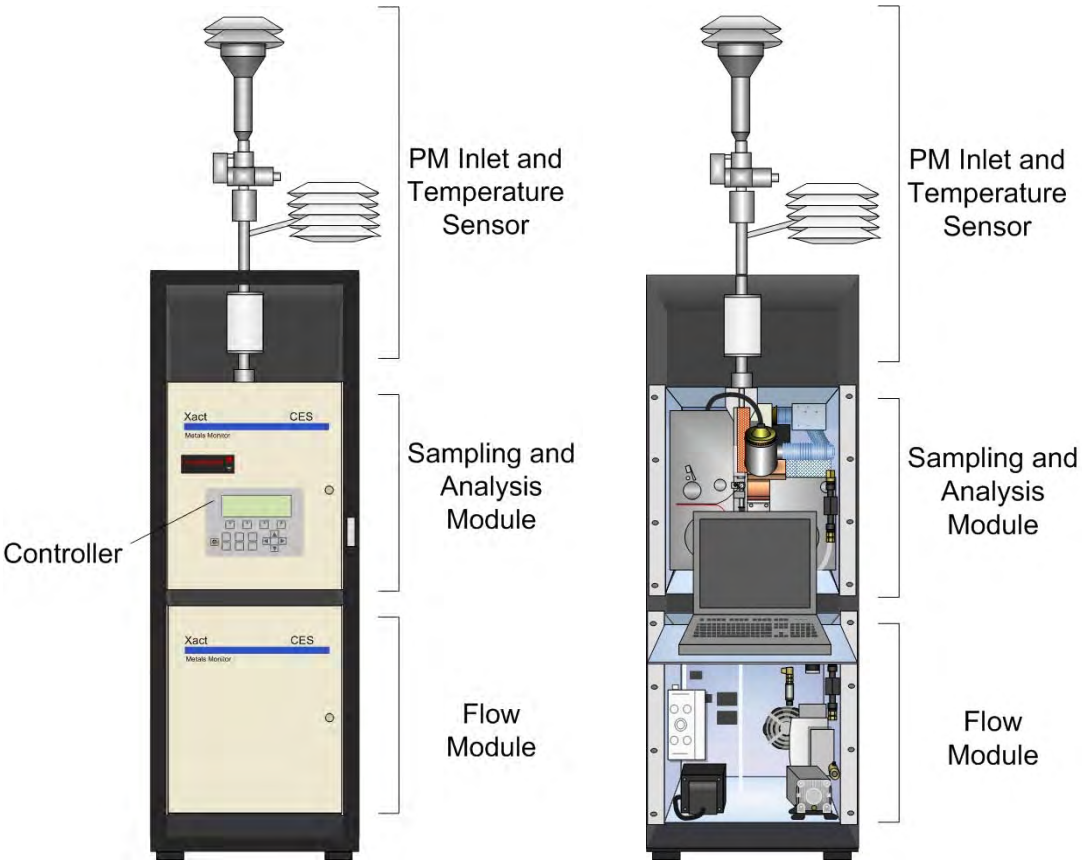

Figure 1. Schematic illustration of the Xact 620 ambient metals monitor and its major components.

The Xact 620 was installed on August 19, 2008 and operated for three weeks until September 9, 2008. It was calibrated at CES prior to field deployment using thin film standards traceable to NIST. In addition, after field deployment, the Xact was checked for flow and X-ray calibration accuracy and checked for leaks. It was then operated using one-hour sampling and analysis times for the entire test period.

Data from the instrument was periodically downloaded during the testing period. Although the Xact is capable of remote polling, it was not possible in this case because the instrument was located in a hotel room and all communication lines had to pass through the hotel switchboard, which prevented direct communication with the instrument from outside the hotel.

Figure 2. The Xact 620 experimental setup as deployed for this experiment.

The Xact experienced several unscheduled events during the course of this test in which it went into standby mode due to firmware/software communication problems. To minimize data loss, the instrument was checked daily during the course of the study to confirm that it was operating and restarted if it was found in standby mode. Data from the meteorological instrumentation was collected on a weekly basis. Upon completion of field testing, all elemental and meteorological data was assembled into a single database.

2.3 Xact 620 Monitoring Site

The multi-metal monitoring site was located in an industrial section in the northwest of Portland, Oregon. This location was selected in part because of its proximity to a potential source of fugitive metal emissions, which was expected to challenge the monitor with a wide range of metals concentrations. The magnitude and variability of the concentrations expected from this site offered the potential to evaluate the responsiveness of the Xact 620. In addition, this particular source had been previously characterized as part of a 1979 Portland aerosol characterization study and it was conveniently located relative to CES. The Xact 620 was set up in a hotel near the potential source as indicated in the aerial photograph in Figure 3.[3] Although the monitor could not be located on the perimeter of the metals processing facility due to security requirements, it was placed in a location in which emissions from the metals processing facility were expected to impact the monitor at high concentration levels.

Figure 3. Aerial view of the relative location of the metals processing facility and the ambient and meteorological monitors.

The source is a metal recycling and manufacturing facility located approximately 0.2 miles from the monitoring site in a northwest sector (approximately 280-325°) relative to the Xact 620 monitoring site.

The monitor was located on the fourth floor of the hotel in a room with a balcony on the north facing side of the building. Locating the monitor in a hotel room ensured its security and controlled its operating environment. The PM_{10} inlet was located approximately 40 feet off the ground and about three feet above the roof line as illustrated in the photograph shown in Figure 4. This photograph looking east from the monitoring site shows the PM_{10} inlet supported on the balcony and extending above the roof of the hotel. Although this arrangement would not meet EPA monitoring site requirements, it was adequate to meet the instrument feasibility and evaluation objectives of this study. The metals processing facility as viewed from the monitoring site is shown in Figure 5.

Figure 4. Xact 620 field study inlet configuration

Figure 5. Metals processing facility as viewed from the monitoring site

2.4 Meteorological Monitoring Site

The Xact 620 monitoring site was located downwind from the plant based on historical prevailing winds for August and September as measured by the National Weather Service at the Portland International Airport about four miles from the study area. The average wind speed and direction as measured at the Portland airport during 2007 is plotted in Figure 6.[4] Meteorological data from 2004-2006 can be seen in Appendix A. All of this historical data shows that wind speeds are typically low and predominantly from the northwest throughout the summer and early fall.

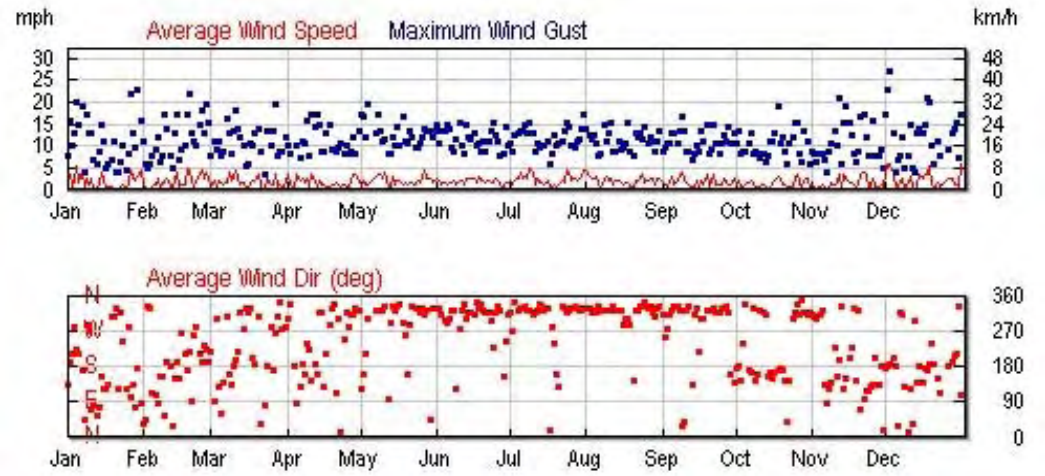

Figure 6. Plot showing wind speed and direction during 2007 as measured at the Portland International Airport by the National Weather Service

Although the airport wind speed and direction are considered to be generally representative of the region, it is not necessarily representative of the specific wind speed and direction at the study site. To obtain local meteorological data for the study site, a site-specific meteorological monitor was established by CES about three blocks southwest of the monitoring site for the duration of the study. The meteorological monitor could not be located at the same site as the Xact 620 due to building restrictions. The relative location of the meteorological monitoring station to the Xact 620 and metals processing facility locations is also illustrated in Figure 3 above. The monitoring station consisted of a Met One Instruments Wind Sensor model 034B mounted on a tripod and connected to a data logger. The monitor reported wind speed in miles per hour (mph) and wind direction in degrees. Hourly average wind speed and direction data acquired from this local monitor during the study was coordinated with the metals monitor sampling cycle and is summarized in Appendix B along with the corresponding metals data.

3.0 Modeling Approach

The Xact 620 measures the concentrations of metals in the ambient air where the Xact is located. Assuming that the metal mass is additive, the concentration of a metal in the air at a sampling location will be a combination of emissions from a large number of natural, anthropogenic, regional, local, ducted and fugitive sources. Clearly, simply measuring the concentration of metals is insufficient to regulate and enforce emission limits. Simultaneous up wind and down wind sampling would help to isolate the contributions from a specific source. However, to use the Xact data in an enforcement situation, the resultant concentrations need to be either related to emission rates based on highly uncertain estimates of plume volume and assumptions such as the representativeness of the concentrations, or use receptor-oriented source apportionment methods. The first alternative represents a classic source-oriented dispersion or deterministic modeling approach to relating a measured metal concentration to a fugitive emission rate at a specific moment in time and would be expected to have uncertainties on the order of 100 to 1000%. On the other hand, the second alternative is a receptor-oriented source apportionment approach such as chemical mass balance (CMB), which has successfully apportioned ambient measured metal concentrations during specific sampling periods with uncertainties on the order of 5 to 30%.

Receptor modeling of peak measured concentrations that might represent a permit exceedance is clearly the preferred modeling approach for enforcement because of the potential for significantly lower uncertainties. This latter approach is used here to evaluate the feasibility of the Xact metals monitor for permitting and enforcement applications. A more extensive discussion of modeling tools considered is provided in Appendix C.

A key and unique aspect introduced with the Xact 620 is its ability to quantify up to 25 elements simultaneously. Other monitors typically measure only a single species and as such would not provide the necessary multi-species data set required for receptor modeling methods such as CMB and multivariate analysis modeling approaches. Without multiple species measurements, monitors of species such as CO, SO_2, NH_3, etc. require estimates of plume volume and average concentration to estimate emissions or a dispersion model to predict impacts. As noted below, the uncertainties in these model input estimates can be substantial (>100%) and may represent the limiting aspect of any single-species monitor. However, with a monitor like the Xact 620 that measures multiple species simultaneously, it is possible to use other modeling approaches that do not require input estimates of plume volume and average plume concentration to accurately estimate fugitive emission impacts at a receptor to within 5 to 30%. These estimated source impacts could be used in permitting and enforcement situations. This capability is expected to be particularly useful in such applications as the new PM and lead NAAQS that require defining source impacts as the basis for further monitoring and state implementation plans (SIP).

This emphasizes a key metals monitor evaluation criterion: accuracy of model results. Because it is difficult to accurately monitor fugitive emissions directly, it is generally necessary to relate other measurements to either a source's emission rate (mass/time) or its ambient impact (mass/volume) at a monitoring site with mathematical models. In the case of emission models, this may be as simple as an equation relating the number of tons of material handled per time interval to emissions through a previously determined emission factor (mass of emissions/tons handled). On the other hand, these models can be quite complex as in the case of predictive impact models such as source-oriented dispersion models that use similar emission factors with complex mathematical models to simulate dispersion of the emissions and/or back trajectory models that rely on impact measurements and dispersive parameters to estimate emissions. A key limitation of these models is the accuracy of required input information such as emissions and/or dispersive factors at any specific location and hour of the day. Models relying on short-term fugitive emission rates and dispersive factors are inherently inaccurate because of the high uncertainty in these emission factors and specific dispersive factors over a trajectory for a specific time period (about 100 to 1,000% uncertainties). To realistically establish emission limits or source impact limits in a permit and to aggressively enforce these limits on fugitive emission sources, it will be necessary to accurately estimate either a source's emissions or its impact. As such, accuracy is a key model evaluation parameter for this study.

Only the CMB receptor model 1) has the potential to accurately quantify hourly source impacts, 2) is generally accepted by the EPA, 3) is available as an approved EPA model and 4) has been used as the basis for permit development and enforcement of state implementation plans for over 30 years. The CMB model relies on only two types of input data:

- Aerosol concentration data that can usually be determined to an accuracy of about 5 to 10%, and
- Representative relative source profiles (normalized to parameter being apportioned such as PM, Pb, As, etc), with accuracies on the order of 5 to 30%.

Typical accuracies of CMB source contribution estimates are on the order of 10 to 30%, but have the potential to be as low as about 5% over short sample averaging times of about 30 to 60 minutes. As such, our model adequacy evaluation has focused primarily on the CMB model and the supporting possibilities of multivariate analysis, particularly in light of the large quantity of time variable data that can be provided by the Xact 620.

Characterization of emissions for CMB analysis (source profile determination) requires the determination of relative chemistry of the emissions, which can be far more accurate and less variable than determination of emission factors for source-oriented models. It should also be noted that it is possible to use multivariate analysis of the Xact 620-generated data to develop source profile information. As with all models, there are limitations to the CMB modeling approach, but this model has proven to be a useful tool over the past 30 years for permitting and enforcement of such species as PM, Pb and volatile organic compounds. In addition, the model and its application are well documented and readily available from the US EPA.[5] Finally, it should be possible to automate the US EPA CMB model on an ambient monitoring platform such as the Xact 620 so that source contribution impacts might be automatically reported in addition to elemental concentrations. The model would identify the major sources that contributed to the metal concentration of interest collected during the preceding sampling interval. The contribution of each of the identified sources to the total metal concentration could be reported in terms of the absolute concentration (mass/volume) or percent of total metal measured and used both for enforcement as well as by the plant to manage its emissions.

4.0 Results

4.1 Elemental Data

The Xact 620 reported concentrations in ng/m^3 for the following elements: Potassium (K), Calcium (Ca), Scandium (Sc), Titanium (Ti), Vanadium (V), Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Gallium (Ga), Arsenic (As), Selenium (Se), Bromine (Br), Molybdenum (Mo), Cadmium (Cd), Tin (Sn), Antimony (Sb), Barium (Ba), Mercury (Hg), Lead (Pb) and Bismuth (Bi). The results are listed in Appendix B. There were 348 samples collected and measured with the Xact 620 after QA data checks were conducted. Data from six hours were not included in the final data set because they did not meet QA requirements. As noted earlier, software issues that put the instrument into standby mode were responsible for the remainder of data gaps during the test period.

The field study period beginning August 19, 2008, at 18:00 through September 9, 2008, at 10:00 lasted a total of 497 hours. The instrument uptime during this period was 70%. Although this uptime is far from adequate for enforcement monitoring, the unit used in this study was an early production model with software “bugs”, which have since been corrected. Even though it was not demonstrated during this series of tests, uptimes approaching 100% are being demonstrated with units currently in the field.

The concentrations (ng/m^3) recorded for eight key elements are plotted for the test period in Figure 7. The results illustrated in Figure 7 as well as those in Appendix B ranged from about 0.1 ng/m^3 for As to over 10,000 ng/m^3 for Fe. It is clear from this plot that there were numerous times when the Xact recorded rapidly changing concentrations of elements such as Fe, Mn, Pb and Zn. These periods of rapid changes in concentration are thought to be periods when a source plume impacted the monitor and are considered plume "hits." Figure 8 shows an expanded example of one of these hits. In this example, the concentrations of Fe and Mn show a rapid increase while the concentration of Br is low and reasonably constant. This suggests that factors such as meteorology that influence the concentration of all elements are not the source of the rapid increase in Mn and Fe. If a simple increase in suspended particulate matter were responsible for the increase in Mn and Fe, the Br would increase by the same relative amount as the Mn and Fe. The rapid increase in Mn and Fe is most likely due to a significant impact from a source emitting those elements.

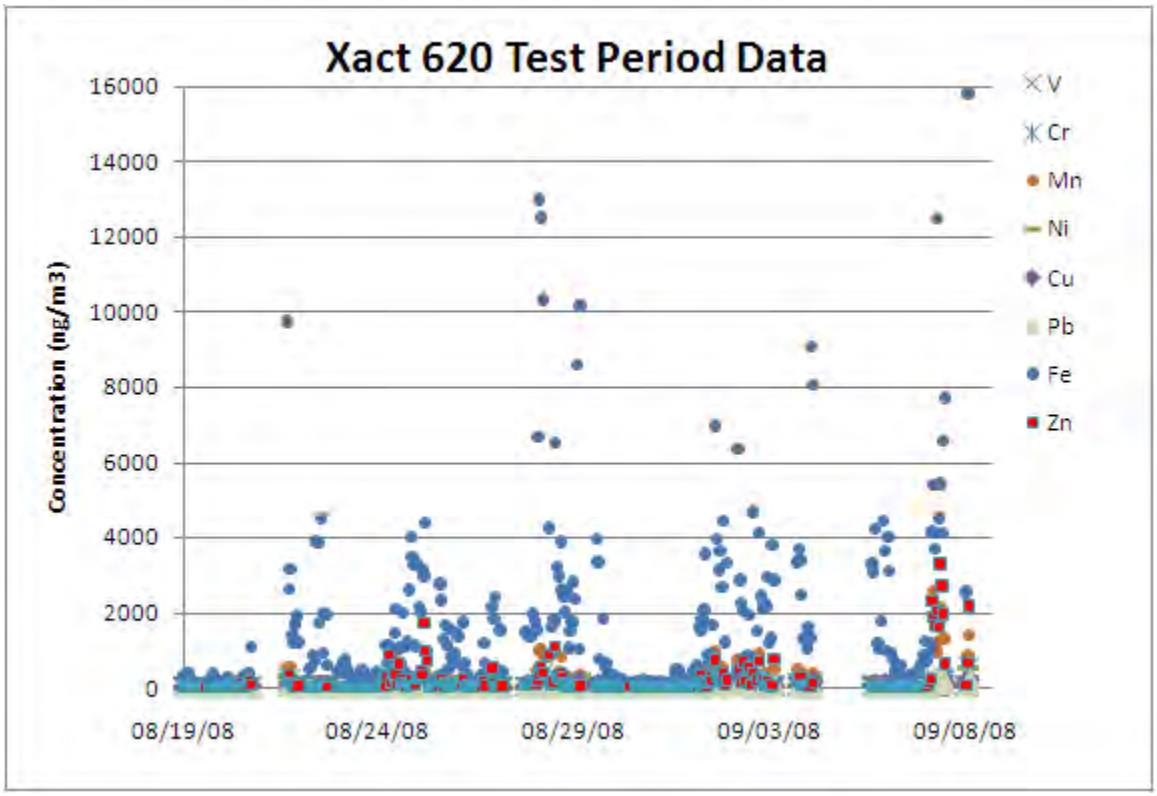

Figure 7. Plot of representative elemental concentration results from the Xact 620 during study period.

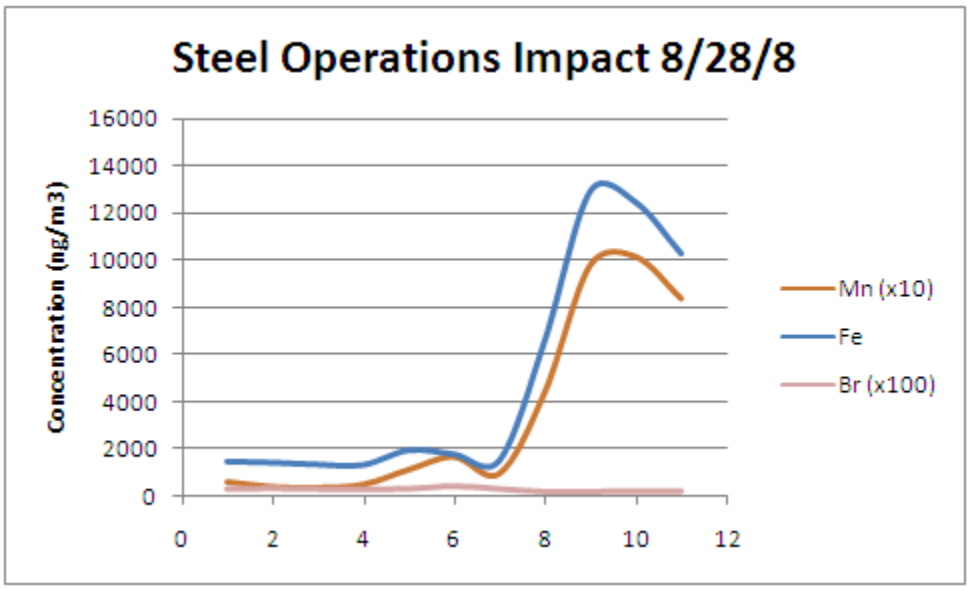

Figure 8. Expanded plot of selected elemental concentrations during a period of high source impact or 'Hit'.

This data set clearly shows the Xact 620 monitor has more than adequate detection limits to not only identify hits, but also clearly define background concentrations. In addition, it is also obvious that the instrument is responsive to these rapid changes in concentration.

4.2 Meteorological Data

Meteorology during this test period was typical of the historical data illustrated in Figure 6 for 2007. Wind speeds and directions during each sampling period of this study are listed in Appendix B and illustrated in Figure 9. In general, the period was characterized as low wind speeds predominantly from the northwest, which is consistent with historical trends.

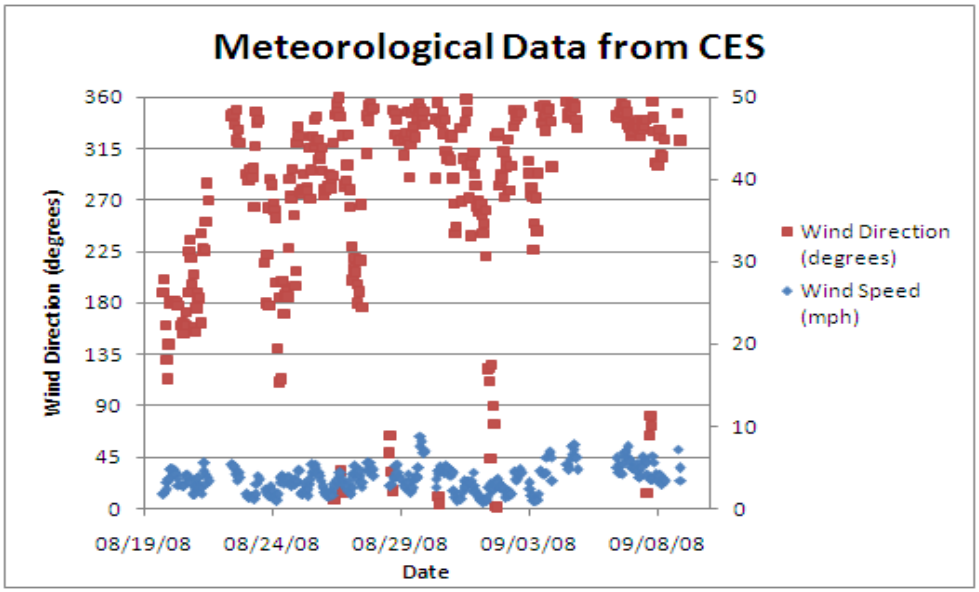

Figure 9. Wind data from Northwest Portland meteorological monitoring site during August-September 2008 test period.

Figure 10 shows an expanded section of the wind direction plot overlapped with the concentration plots for Fe, Mn and Br that were illustrated in Figure 8. During this 12-hour period, the wind direction changed from generally out of the northeast to generally out of the northwest. During this rather modest change in wind direction, the Br concentration was relatively constant. After the change in wind direction, the Fe and Mn had only a small increase in concentration. But later, even though the wind direction and Br concentration remained reasonably constant, the concentration of Fe and Mn increased about eight to ten fold, suggesting an increase in source emissions rather than a wind direction-related increase.

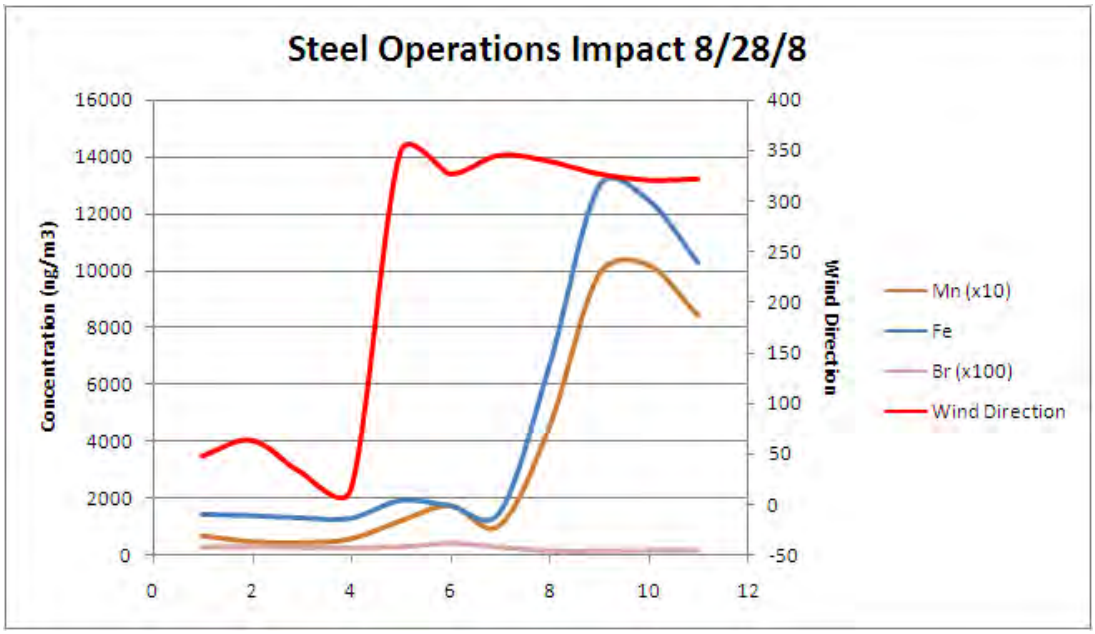

Figure 10. Example of an expanded wind direction and elemental plot from the test period.

5.0 Discussion

5.1 Overview

As noted in the introduction, this first portion of Phase II addressed primarily the first three objectives:

1. Demonstrate measurement technology is field ready.
2. Evaluate field data applicability to possible models.
3. Determine adequacy of field data for quantifying either source emission rates and/or impacts in a permitting and enforcement setting.

The following three subsections address these three objectives in the context of the data and model evaluation developed as part of this project.

5.2 Field Ready Instrumentation

The general objective of this task was to demonstrate that the monitor could operate effectively in the field and provide adequate sensitivity to real world emissions and meteorological variability; i.e. demonstrate it can practically provide accurate and reliable near-real-time measurements of metal concentrations applicable to potential source apportionment models. The original test plan called for using a modified CEMS to demonstrate feasibility of multi-metals monitoring. The availability of the new Xact 620 ambient monitor provided an opportunity to take two steps forward in the evaluation process; i.e. not only being able to field test its feasibility and model readiness, but also using a monitor of which six units are now in the field.

Five criteria were used to evaluate if the technology is field ready: reliability, detection limits, accuracy, model adequacy and remote polling. These criteria are discussed below relative to the Xact 620 evaluated in these tests.

- Reliability of monitor

The monitor uptime during the test period was about 70%. This is not adequate for fence line monitoring. However, the monitor was a new prototype production monitor, which would be expected to have more down time than a proven production model. The down time generally fell into two categories: one category included voluntary periods for special instrument testing to de-bug the unit. However, the larger portion of down time was due to the instrument unexpectedly going into standby mode. This has since been determined to have been caused by poor software/firmware communications and has since been rectified. The unit has since demonstrated a 98% uptime over an 18-day period. Although this test did not clearly demonstrate that the monitor was field ready from an uptime perspective, its prototype nature and the post-resolution of the problem as well as six units already operating in the field clearly suggests that the instrumentation is now field ready with respect to this criterion.

- Minimum detection limits

The four hour interference free detection limits for the monitor used in this test were about 0.01ng/m^3 as defined in EPA Compendium Method IO 3.3.[2] In the real world encountered in northwest Portland, the detection limits were more than an order of magnitude below the measured background concentrations for all of the elements reported in Appendix B except for As. In the case of As, the one hour sampling times used in this test had a detection limit of about 0.1 ng/m^3 due to Pb interferences. However, this interference did not restrict or limit the monitor

from clearly defining several As “hits” that exceeded 1 ng/m^3 as illustrated in the example shown below in Figure 11. Using 24-hour EPA reference methods of sampling, As hits like this would not be observable. As illustrated with this plot and the data in Appendix B, this field-ready criterion was clearly achieved.

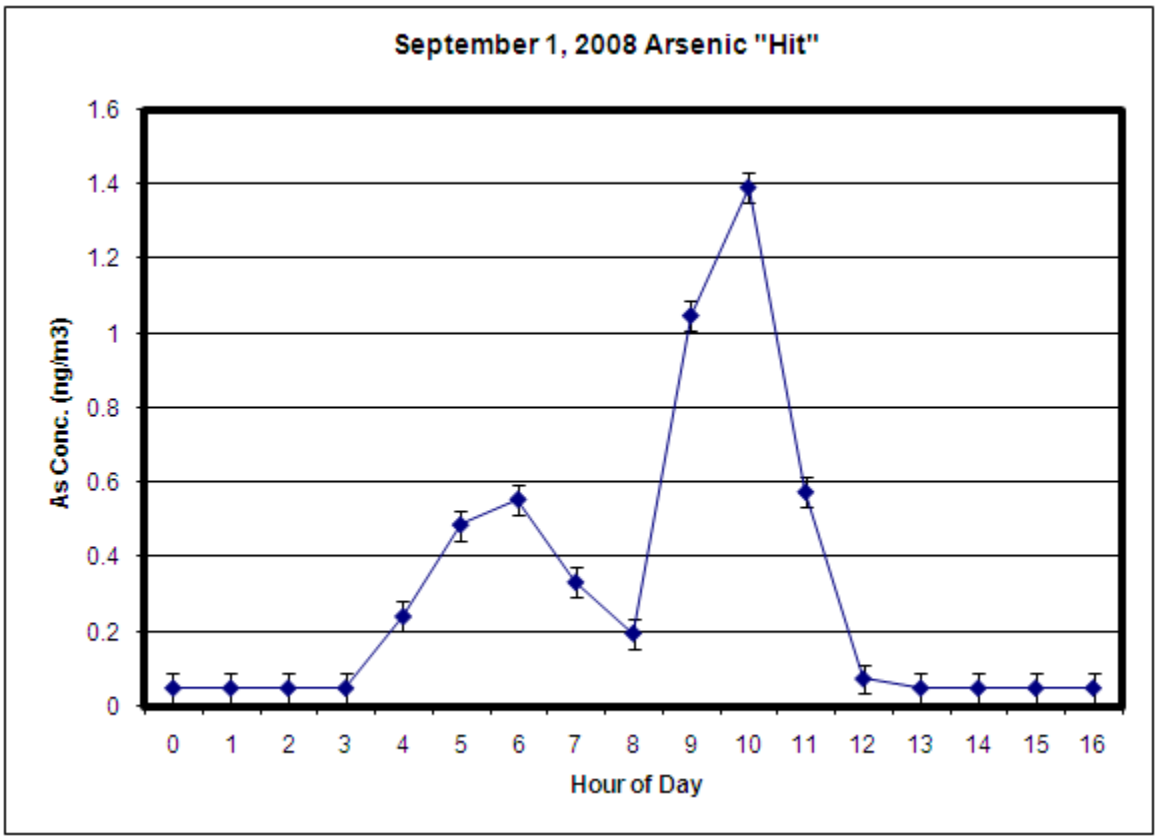

Figure 11. Plot of arsenic concentration during a ‘hit’.

- Accuracy of results

The accuracy of the reported elemental concentrations are expected to be on the order of the accuracy reported with typical low volume samplers and laboratory XRF analysis systems. In this case, the XRF analyzer component was calibrated with thin film standards similar to those used with CES’ laboratory XRF analyzer. The flow control module was calibrated with a NIST traceable reference flow meter. It is also important to note that the XRF analyzer calibration is checked with each measurement using an internal standard (Pd) and an energy calibration is performed daily. As such, the accuracy of the elements reported in the appendix is expected to be similar to the accuracy achievable with EPA Compendium Method IO 3.3[2] and sufficient for model applications.

- Adequate for model input

There are two types of CMB model input data: one is source profile data and the other is ambient receptor concentration data. This field demonstration test deals with only the latter ambient receptor concentration data. In this case, the adequacy of the ambient data is determined by the elements measured and the accuracy of the measurements. The accuracy is adequate as noted above. A general statement as to the adequacy of the elements measured is not possible because

it is site/source specific. That is, it will depend on the characteristics of the source emissions as well as the characteristics of possible interfering sources in the area and their elemental composition. The Xact 620 measures most of the elements commonly associated with typical sources as well as all of the hazardous elements except for Be, which is relatively rare in source emissions. In this particular test case, the elements measured were more than adequate to identify the likely sources and quantify their impacts as discussed in the following examples. This criterion has been demonstrated with these tests.

- Remote polling

The FLM used in these tests (Xact 620) is capable of remote polling. However, it was not possible to demonstrate this in these tests because the instrument was located in a hotel room. As such, all communication had to pass through the hotel switchboard, which prevented direct communication with the instrument from outside the hotel. Even though remote polling was not demonstrated in this test, it has been demonstrated by one Xact 620 user (State of Missouri) who is posting the measurements online in near-real-time.

In summary, these tests and current Xact 620 users have demonstrated the field readiness of the metals monitor by meeting all of the evaluation criteria, either during these tests or in other party tests.

5.3 Applicability and Adequacy of Field Data for Modeling

The objective of this subsection is to evaluate the applicability and adequacy of the field data for models that might be used to generate source emission and/or impact data that could be used in permitting and enforcement applications. As discussed in Section 3.0, the only model appropriate for this application is the CMB receptor model. The criteria used in this evaluation are therefore based on the requirements of the CMB receptor source apportionment model. As noted in Section 3, the CMB model requires two categories of input information: source profiles or fingerprints and ambient receptor chemistry. The Xact 620 used in these tests can provide the required ambient chemistry but not the source profile information directly. In the case of ambient chemistry, the Xact 620 used is clearly able to provide the required data as discussed above in Subsection 5.2.

Several approaches can be used to develop site-specific source profiles for the CMB model:

- Source profile libraries – For example, the USEPA provides an extensive database of source profiles available for CMB modeling on its website.[5]
- New source measurements such as those that might be developed as part of a permitting process
- Use of ambient data and multivariate analysis along with wind sector restrictions

All of the above are reasonable and relatively easy to implement as part of a procedure that might be developed in the second part of Phase II. The reasonableness of these expectations is illustrated with the following applications and illustrations. At the outset, it is important to note several points:

- Source profiles consist of normalized concentrations. The normalizing parameter can be PM, Pb, As or other parameter of interest. In this case, concentrations were normalized

to Fe in part because PM was not measured, but also because Fe is a key element in emissions from the source of interest.

- If the source causing the emissions is a process controlled by the plant, the emissions are likely to be reasonably constant with regards to their relative composition, even though the absolute emissions (mass/time) can vary from zero to orders of magnitude greater.
- The shape of a logarithmic plot of relative elemental composition of source emissions is much like a fingerprint; i.e. unique and constant.

The above points can be illustrated with the following example that compares the relative composition measured with the Xact 620 during a one hour sample collected at the peak of a 'hit' from the suspected source (Figure 12), with a source profile developed for a steel electric arc furnace in a metals processing facility some 30 years earlier (Figure 13).

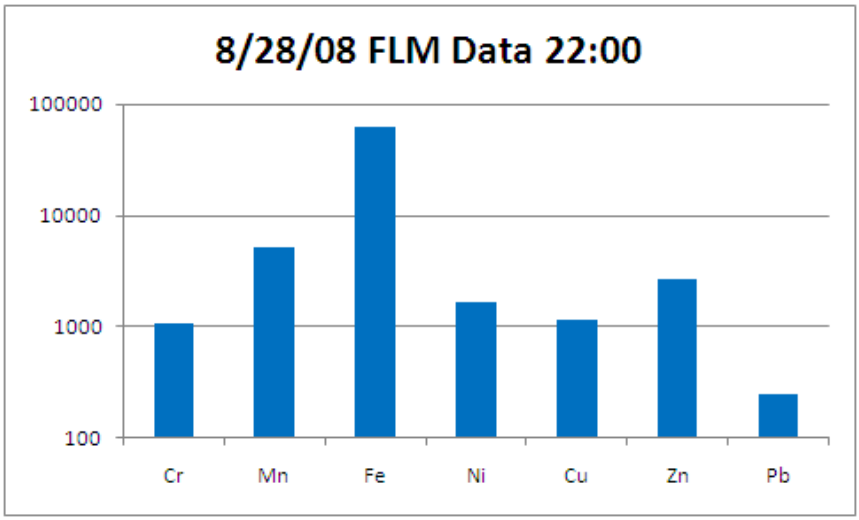

Figure 12. Plot of measured concentrations for selected elements.

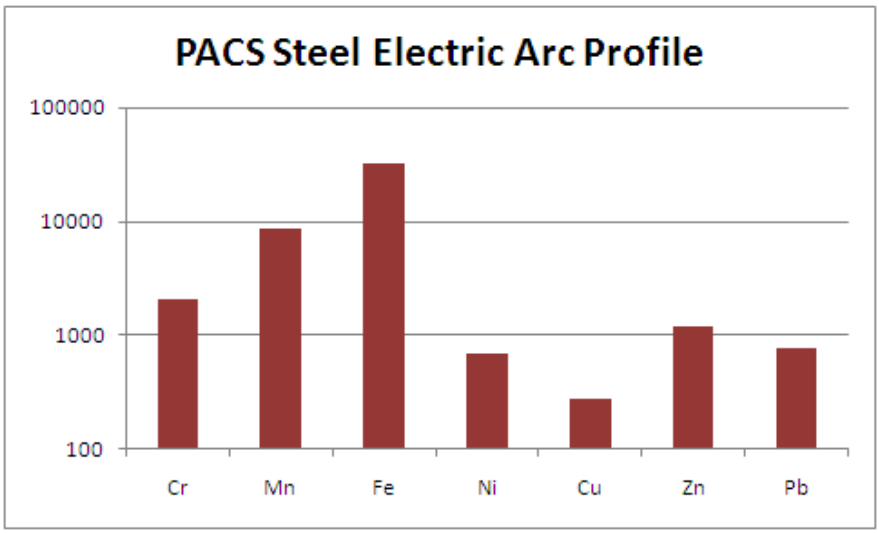

Figure 13. Relative source profile measured in 1978.

The important point to note in this comparison is the similarity of the shapes of these two plots. Although the comparison is not perfect, there is a clear implication of causality, particularly when one takes into account the 30-year interim and specific controls implemented to reduce Pb emissions as well as the wind direction being from the metals processing facility to the monitor.

To illustrate the applicability of the data to the CMB model, the ambient data collected in this study was applied to the CMB model using a source profile library acquired during a 1979 Portland Aerosol Characterization Study (PACS).[6] The PACS source data for 20 source types are listed on the USEPA website.[5] The above "steel electric arc" profile is an example of a source profile developed during this earlier study and illustrates the potential applicability of other profiles for this demonstration. The elemental concentrations for the three profiles used in this illustration are listed in Table 1. The concentrations are adjusted for the discontinued use of leaded gasoline. Although the limited number of sources used in this illustration would not be adequate for a realistic CMB study, it will serve the purpose of demonstrating data adequacy for this study.

Table 1. PACS source profiles used in this CMB model data evaluation

Source Description	Elemental Concentration (Percent)									
	Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	Br	Pb
Road Dust	0.0101	0.00027	5E-04	0.001	0.0573	4E-05	0.0003	0.0011	8E-07	4E-05
Steel Electric Arc	0.002	0.0006	0.021	0.087	0.32	0.007	0.0028	0.012	0	0.008
Ferro-manganese	0.00046	0.00024	4E-04	0.173	0.021	0.001	0.00036	0.0058	0.0016	5E-04

The CMB model was applied to a small subset of ambient data generated by the Xact 620. Four samples were selected to represent different conditions as noted in Table 2. The ambient elemental concentrations used in this evaluation are also listed in Table 2.

Table 2. Xact 620 ambient data used to evaluate applicability to CMB model

Date	Hour	Impact Characterist	Elemental Concentration (ng/m^3)									
			Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	Br	Pb
09/01/08	18	Background Level	11.02	1.92	1.34	3.15	153.77	1.54	2.65	5.81	5.36	4.96
08/25/08	2	Fe:Mn Ratio ~ 1	9.28	3.39	16.99	724.98	587.16	4.50	20.11	115.55	1.08	13.59
08/25/08	5	Fe:Mn Ratio ~2	18.91	6.20	61.26	981.97	2088.00	38.29	21.43	344.57	1.92	40.62
08/28/08	21	Fe:Mn Ratio ~13	55.59	23.59	231.59	984.12	12974.00	237.01	236.85	350.12	1.62	43.40

The output of the CMB model is a source contribution estimate (SCE), which is the portion of the measured Fe concentration the model attributed to a particular source. The results of this modeling are listed in Table 3. The first three columns list the sample identifying information while the next three columns list model "goodness-of-fit" statistical evaluation parameters. The

source identifying code, and SCE expressed in ng/m^3 as well as percent of explained Fe mass are listed in the three columns to the right. As noted above, four distinctly different ambient samples were selected to evaluate the adequacy of the data generated by the monitor. The first sample was a background sample. In this case, most of the Fe mass was apportioned to road dust. However, in this case, the goodness-of-fit parameters are not acceptable; e.g. Chi^2 should be less than four, R^2 should be greater than 0.9.[7] Mass should be within ± 20% of 100%. This poor fit may be due to a more significant difference between typical road dust today as compared to the road dust characterized 30 years ago. The complete CMB results can be seen in Appendix D, including which species were used for fitting each sample.

Table 3. CMB results for selected ambient data sets

Sample Information			CMB Results					
Sample Date	Sample Hour	Impact Characteristic	R^2	Chi^2	% Fe Mass Explained	Source Contribution Estimate		
						Source Code	ng/m^3	% of Explained Fe Mass
09/01/08	18	Background Level	0.9	6.36	87.3	UDUST	130.54	97.3
						STEEL	3.69	2.7
08/25/08	2	Fe:Mn Ratio ~ 1	0.98	1.03	102.2	UDUST	26.37	4.4
						STEEL	500.17	83.4
						FERMN	73.34	12.2
08/25/08	5	Fe:Mn Ratio ~2	0.98	1.1	98.1	UDUST	32.71	1.6
						STEEL	1957.69	95.6
						FERMN	57.74	2.8
08/28/08	21	Fe:Mn Ratio ~13	0.85	7.68	62.7	UDUST	38.68	0.5
						STEEL	8092.35	99.5

Using the limited number of source profiles, the CMB model apportioned the Fe measured with the Xact 620 to road dust (UDUST), a steel electric arc furnace (STEEL) and a ferromanganese source (FERMN) in varying amounts. The steel electric arc furnace source was estimated to be the highest contributor for the periods during which the Fe was above background. The road dust source was estimated to be the highest contributor to the ambient Fe during the period in which Fe was at background level. The fits obtained using the CMB model do not fulfill all of the EPA goodness-of-fit criteria for all of the samples. However, this illustrative example clearly shows that the Xact 620 ambient concentration data is adequate for CMB modeling applications. The relatively poor performance of the model with the available data set is more a limitation of the available source profile information, not the ambient data. This source profile limitation can be addressed in the permitting process following procedures to be developed that will suggest source testing, ambient monitoring with multivariate analysis, etc. This example does illustrate the utility of the Xact 620 data in a CMB quantitative source apportionment study. The large number of elements measured on a near-real-time hourly basis can be applied to the CMB model and any of these elements can be apportioned. In an actual airshed study, all of the significant sources of pollutants would be included in the source profile library for application to the CMB model.

The data and model results clearly demonstrate applicability of the ambient field data generated by the Xact 620. However, the model requires both source and ambient data. The Xact 620 provides only a direct measure of the ambient concentrations. Source profile data can come from either direct source emissions measurements, existing source profile libraries, or as discussed in the following section, multivariate analysis of the ambient data from the ambient monitor. The large amount of time-variable concentration data developed by the Xact 620 is expected to be a realistic option for developing relevant source profiles for the CMB model, particularly when accompanied with wind speed and direction data.

5.4 Multivariate Analysis

As noted in Section 3.0, multivariate analysis methods such as factor analysis can provide valuable insight into source profiles and supporting information for CMB SCE. Illustrations of this potential on a two-dimensional basis are presented in this subsection.

In this study, a multivariate receptor approach was used as a qualitative tool to identify species measured at the Xact 620 that may have originated from a common source as determined by their common variability with time. The large amount of Xact 620 data generated during the study period was more than adequate to fulfill the minimum number of measurements required for a reliable multivariate analysis. One hundred samples or more are generally acceptable for reliable results for multivariate analysis.[8] Each ambient element measured by the Xact 620 was correlated with every other element measured. This resulted in 276 inter-element correlations. Elements with significant correlation are discussed below.

Elements with the highest observed correlation (R^2 of 0.96) were Pb and Zn. Figure 14 below shows a scatter plot of the entire Xact 620 study data set of Zn and Pb concentrations.

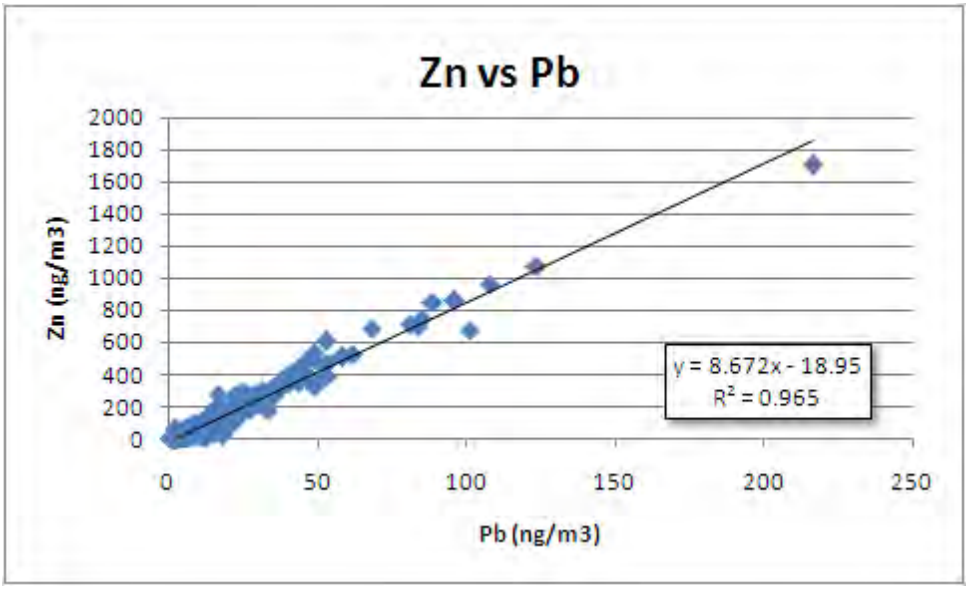

Figure 14. Scatter plot illustrating the high degree of correlation between Zn and Pb concentrations measured with the Xact 620 at the receptor site.

The high R-squared (R^2) value indicates a high correlation between the two elements and that most of the elemental variability is likely due to a single source. The slope of the trend line suggests the ratio of these two elements in the source emissions is about 8.7. Figure 15 below shows an event in which the higher Pb and Zn concentrations were observed. The wind was from the same direction as the metals processing facility (270 – 360^o), yet Pb and Zn are clearly not correlated with Fe. This suggests the Pb and Zn are from either a different fugitive emission source within the same facility or emissions from a different plant in the same wind sector as the metals processing facility.

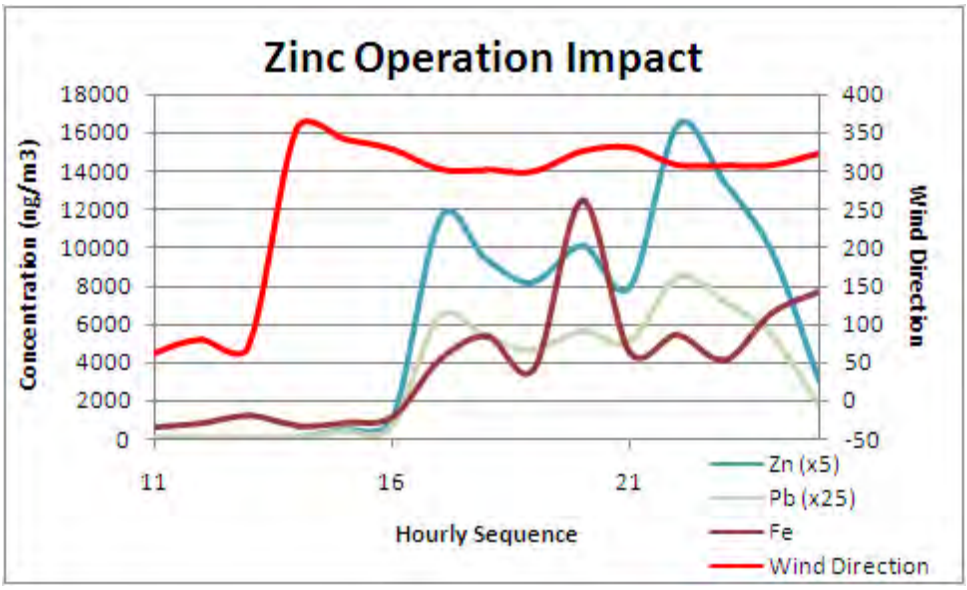

Figure 15. Plot of Pb, Zn and Fe concentrations and wind direction during a Zn and Pb 'hit' period.

Further investigation into the emission inventory of the plant and surrounding sources might qualitatively identify the common source for the Pb and Zn. One possibility for the origin of the Pb and Zn within the metals processing facility is in the initial stage of a metals recycling process. If there is Pb-based material in the recycled metal (solder, body repair fill), it might be vaporized in the initial melting process. This vaporized Pb/Zn might be emitted only during this initial heating and separation step, in which case it would not be correlated with other emissions that might occur during such steps as alloy formation.

In a second example, the expanded plot of Fe and Mn shown in Figure 8 suggests that these two elements might be highly correlated. However, if all of the data acquired during the study period is compared, the correlation is quite poor as illustrated in Figure 16. On the other hand, if the data is selected for those periods when there is a 'hit' and the wind was from the direction of the metals processing facility, a high correlation between these two elements is observed, as illustrated in Figure 17. This suggests a common source for Fe and Mn for this particular impact event. The slope of the correlation would lead an investigator to seek out sources with an Fe:Mn ratio around 12:1 for use in CMB modeling.

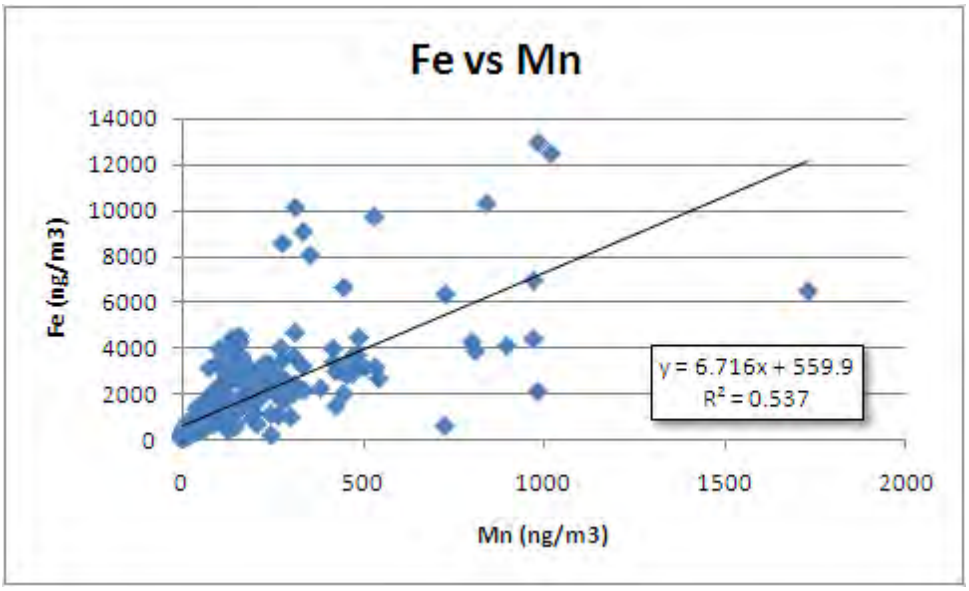

Figure 16. Scatter plot of entire Xact 620 Fe and Mn concentrations showing little correlation between these two elements.

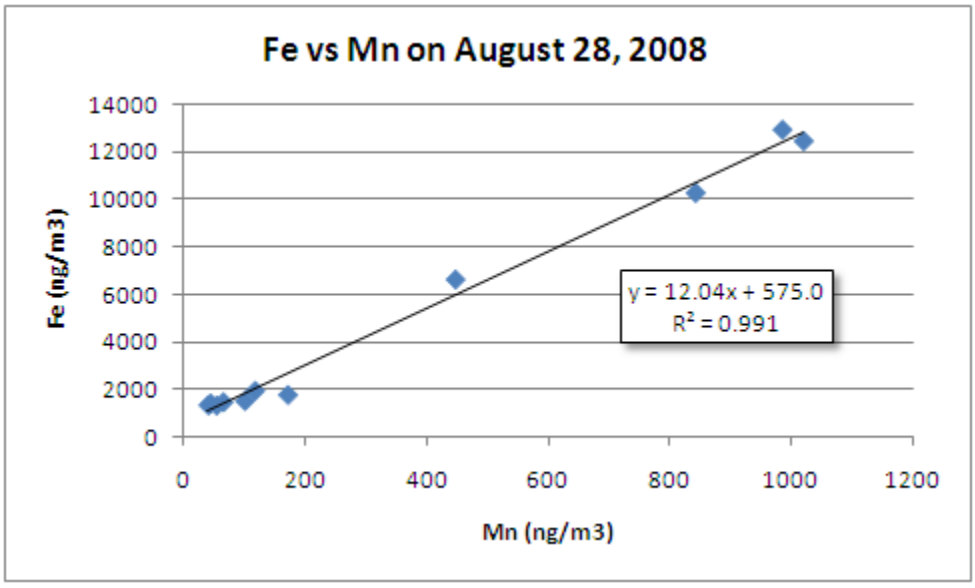

Figure 17. Scatter plot of Fe and Mn during a steel plant hit showing a high degree of correlation between these two elements.

The examples discussed above demonstrate the contribution simple two-dimensional multivariate analysis can make to our understanding of sources that contribute to ambient chemistry. The qualitative information learned about an airshed from multivariate analysis compliments the quantitative source contribution estimates provided by CMB modeling. In addition, multivariate tools like factor analysis can be used to develop source profiles if they are not available from direct emissions measurements.

6.0 Conclusions

Results from this preliminary field evaluation have clearly demonstrated not only the feasibility of near-real-time multi-metals monitoring of ambient air at typical concentrations, but also that the instrumentation is field ready. This conclusion is strongly supported with the deployment of six monitors at various locations around the world. The instrument was responsive to rapidly changing concentrations of elements from an expected source and detected impacts from an unexpected source of Pb and Zn as well as an unexpected source of As. The data generated by the Xact 620 was adequate for application to the CMB source apportionment model. This model has been approved by the EPA, is available from the EPA, and has been used extensively for permitting and enforcement over the past 30 years. Thus, both the measurement and modeling technologies are available for permitting and enforcement applications.

7.0 Recommendations

The following recommendations are based on the successful demonstration of the field readiness of the Xact 620 ambient metals monitor and the applicability of the data it generates to EPA approved source apportionment models. It is recommended that the following major tasks be implemented to complete the validation of the instrumentation and development of procedures for routine use of the technology in a permitting and compliance monitoring situation for fugitive metal emissions:

1. FLM validation

Although the quantitative accuracy of the ambient monitor is implied based on its calibration, automated QA and field checks, the total system accuracy still needs to be validated by comparing the Xact 620 results with results measured using EPA federal reference sampling methods and EPA analytical protocols such as EPA Compendium Method IO 3.3.[2]

2. Model integration

Modeling results presented in this report were developed using analytical results from the Xact 620 and off-line source apportionment modeling of this data using EPA CMB 8.2. The time lag between developing concentration data sets and off-line source apportionment modeling might be days to months depending on the local monitoring expertise. To take full advantage of the monitoring technology's potential to provide half hour to hourly source impact results, the monitor needs to integrate and automate the source apportionment model so as to provide near real time quantitative source contribution estimates as well as metals concentration results.

3. Develop protocol

A third task that must be completed prior to this technology being integrated into routine permitting and enforcement is the development of a protocol for the use of this technology. This protocol would include such procedures as how to identify monitoring sites, how to determine the number of instruments required to adequately monitor a facility or whether a single instrument could be moved from site to site depending on prevailing wind and meteorological data. Procedures for identifying sources within the plant and procedures for developing a site-specific source profile library with appropriate concentration uncertainties would also be part of the protocol.

4. Demonstrate protocol

The protocol developed above should be applied to a real permitting and compliance demonstration situation prior to release as a general-purpose tool.

8.0 References

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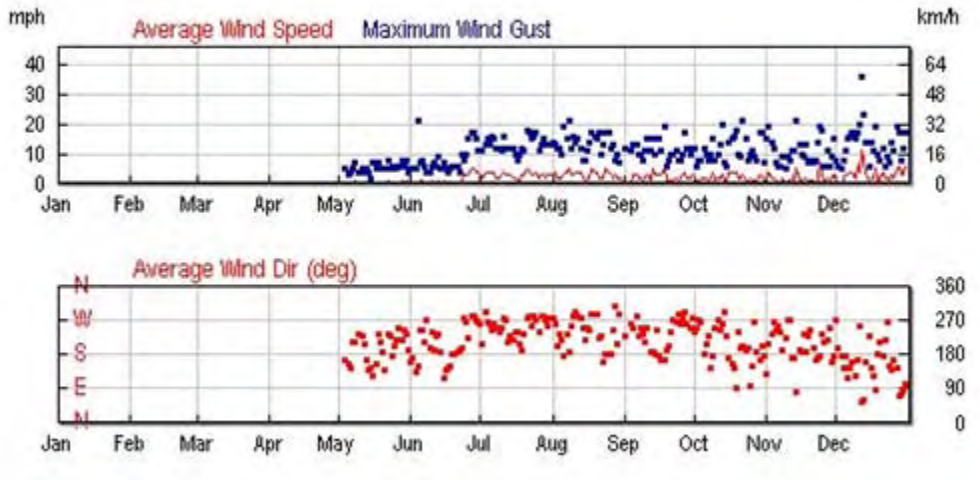
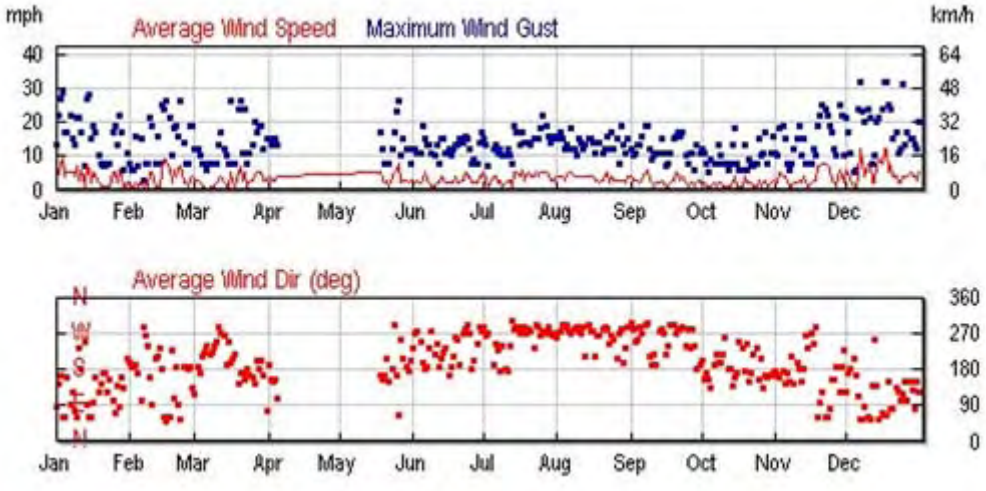
Appendix A: Historical Wind Trends

Local Prevailing Winds 2004-2006

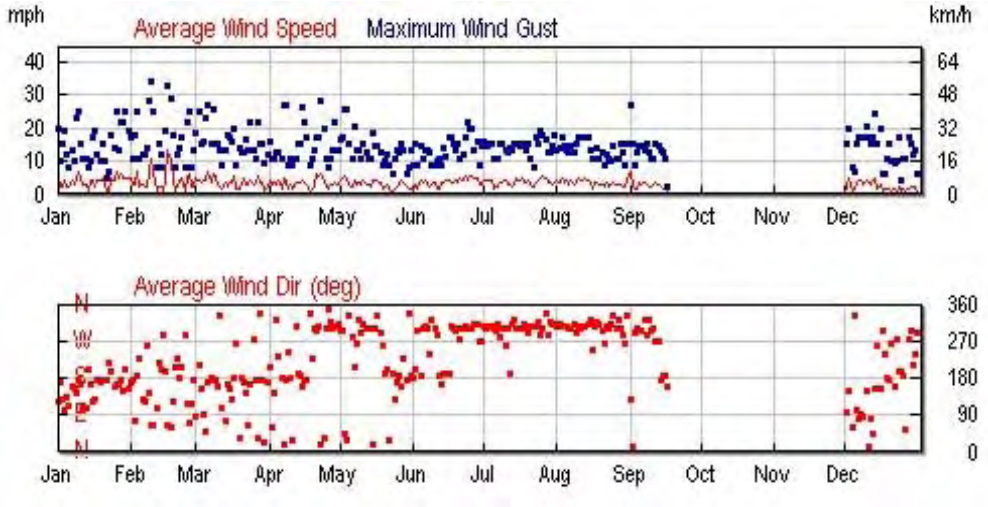
2004



2005



2006


mph
Average Wind Speed
Maximum Wind Gust
km/h
40
30
20
10
0
64
48
32
16
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Average Wind Dir (deg)
N
W
E
N
360
270
180
90
0

Appendix B. Database of Meteorological and Xact 620 Data

Met Time	Wind Speed (mph)	Wind Direction (°)	Elemental Concentration (ng/m^3)													
			Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	As*	Se	Br	Pd	Hg	Pb
8/19/08 18:00	1.7	188.1	14	8.61	24.4	14.5	289	9.62	30.2	34.5	1.8	2.45	1.57	19000	6.61	5.38
8/19/08 19:00	2	200.4	18.4	2.36	9.72	8.55	255	2.54	14.8	37.2	0.98	1.16	1.25	22800	2.87	0.84
8/19/08 20:00	2.3	160.1	18.4	1.52	9.79	6.93	293	1.29	13.1	12.1	<0.03	0.57	1.61	22000	1.33	2.01
8/19/08 21:00	3.2	129.7	22.9	1.79	7.59	8.03	347	1.81	10.8	11.2	<0.03	0.87	1.83	20800	1.5	3.35
8/19/08 22:00	3.5	113	29.1	2.45	6.66	7.72	380	4.91	11.7	23.4	0.38	0.76	1.52	21800	1.41	6.03
8/19/08 23:00	3.6	143.4	11.6	1.01	3.1	5.42	200	1.19	5.95	9.18	0.9	0.52	1.03	22700	1.13	1.36
8/20/08 0:00	4.7	178.2	4.52	0.87	2.01	2.63	66.5	0.86	2.57	4.35	0.01	0.52	1.07	20400	1.14	1.23
8/20/08 1:00	4.7	181.2	6.8	1.42	2.25	3.04	78.7	1.85	3.34	7.27	<0.03	1.2	1.19	21700	2.45	1.89
8/20/08 2:00	4.7	180.5	5.34	0.8	3.1	2.6	34.5	1.34	2.95	3.27	<0.03	0.81	1.35	20600	1.51	1.55
8/20/08 3:00	4.8	178	2.01	0.83	2.52	1.85	23	1.02	2.12	2.3	<0.03	0.69	1.36	21200	1.38	1.29
8/20/08 4:00	4.2	178.4	1.53	0.71	1.79	1.66	23	0.75	1.76	4.29	0.43	0.47	0.94	22600	1.1	0.02
8/20/08 5:00	4.3	180.5	2.48	0.49	1.91	1.91	35	0.81	1.9	2.53	0.17	0.54	1.24	22200	1.24	0.58
8/20/08 6:00	4.1	179.7	2.17	0.63	2.45	2	36.5	0.87	2	3.19	<0.03	0.82	1.77	20700	1.44	1.42
8/20/08 7:00	3.6	179.3	3.79	0.84	2.35	2.04	56.3	0.93	3.52	3.26	<0.03	0.67	1.3	21300	1.29	1.06
8/20/08 8:00	2.8	177.2	4.78	0.95	3.55	3.18	107	1.04	6.89	5.4	0.45	0.45	0.89	22700	1.09	0.15
8/20/08 11:00	2.8	160.2	10.1	1.24	5.28	4.8	217	1.27	9.54	10.5	<0.03	0.79	1.29	19300	1.48	2.1
8/20/08 12:00	2.7	161.7	9.43	0.8	3.72	4.66	229	1.13	9.61	11.6	<0.03	0.87	1.87	20700	1.49	2.53
8/20/08 13:00	2.8	152.1	21.7	0.92	3.23	6.02	375	1.28	13.8	16.8	<0.03	0.82	1.81	20700	1.54	3.34
8/20/08 14:00	3.9	161.2	11.6	1.07	2.98	4.13	242	1.11	9.72	12.2	0.24	0.82	1.57	20400	1.55	4.58
8/20/08 15:00	4.2	159.3	8.06	0.96	3.26	2.8	160	1.19	7.33	9	<0.03	0.83	1.21	20500	1.5	2.65
8/20/08 16:00	4	171.7	6.93	0.74	2.76	2.46	113	0.96	5.28	6.31	<0.03	0.82	1.04	20600	1.44	2.15
8/20/08 17:00	3.4	188.9	3.26	0.47	2.53	2.59	76.5	0.95	4.97	3.73	<0.03	0.79	0.81	20400	1.42	1.52
8/20/08 18:00	3.7	224.4	4.15	0.58	2.83	2.23	106	0.87	6.38	3.69	<0.03	0.66	0.34	21300	1.33	0.97
8/20/08 19:00	3.3	234.6	6.7	0.74	2.18	2.24	117	0.87	6.46	5.53	<0.03	0.83	0.7	20500	1.4	1.44
8/20/08 20:00	3.1	219.1	4.06	0.15	1.91	1.65	75.9	0.84	3.73	3.47	<0.03	0.84	0.84	20700	1.45	1.2
8/20/08 21:00	1.7	195.5	7.1	0.56	4.51	3.09	115	1	5.76	3.98	<0.03	0.86	0.92	20600	1.39	1.41
8/20/08 22:00	1.7	203.9	7.99	0.83	5.84	8.31	250	1.38	7.68	28.5	<0.03	0.9	1.2	20500	1.47	3.58
8/20/08 23:00	2.5	158.1	4.52	0.57	2.17	2.13	86.6	0.87	4.63	3.1	<0.03	1.03	3.05	20600	1.5	1.52
8/21/08 0:00	2.7	154	6.04	0.89	1.63	3.75	111	0.9	4.35	11.1	<0.03	0.94	3.13	19200	1.44	2.06
8/21/08 1:00	3.5	174.9	11.6	1.4	3.07	3.27	92.4	2.15	4.06	5.74	<0.03	2	3.91	20500	3	3.06
8/21/08 2:00	2.5	188.7	2.52	0.69	2	1.9	41.3	0.92	1.64	2.49	<0.03	1.09	3.84	20500	1.55	1.37
8/21/08 3:00	3.7	182.6	1.54	0.38	1.17	1.19	25.9	0.81	1.12	4.19	<0.03	1.03	2.54	20700	1.47	1.46
8/21/08 4:00	2.8	184.1	1.27	0.5	1.56	2.82	26.2	0.83	0.99	3.23	<0.03	0.98	1.92	20500	1.47	1.29
8/21/08 5:00	1.8	161.9	1.72	0.45	1.91	1.47	30	0.87	1.29	1.83	<0.03	0.98	2.18	20600	1.45	1.3
8/21/08 6:00	2.5	240.2	1.78	0.84	20	246	179	2.78	5.43	83.5	<0.03	2.85	1.23	20800	1.39	8.84
8/21/08 7:00	4.5	227.6	0.89	0.59	1.81	1.89	47.1	1.04	2.89	3.72	<0.03	0.85	1.14	20400	1.45	1.27
8/21/08 8:00	5.5	224.2	2.91	0.66	3.3	2.74	80.9	1.07	5.39	4.43	<0.03	0.9	1.69	20600	1.47	1.89
8/21/08 9:00	4.2	225.8	2.92	0.67	1.75	1.61	87	0.92	5.44	5.47	<0.03	0.88	1.67	20600	1.46	2.02
8/21/08 10:00	3	250.8	5.89	1.1	8.89	33.2	346	3.37	7.02	43.3	<0.03	0.91	2	20500	1.58	6.37
8/21/08 11:00	3.7	284.1	10.9	1.67	16.1	129	373	5.29	7.42	151	<0.03	1.06	2.35	20400	1.4	14.3
8/21/08 12:00	3.4	268.9	15.7	2.4	42.9	142	1070	22.3	20.7	63.5	<0.03	3.51	2.1	20500	1.82	14.3
8/22/08 10:00	5.3	343.2	38.9	21.4	160	531	9730	294	99.6	326	<0.03	1.48	2.2	20400	3.17	49.3
8/22/08 11:00	4.9	342.4	54.8	14.1	71.8	284	2610	25.8	25	329	0.17	1.34	2.67	20900	1.78	35.9
8/22/08 12:00	5.1	344.7	36.6	8.6	230	534	3150	99.8	58.3	122	0.21	1.28	2.18	21000	1.93	22.3
8/22/08 13:00	4.2	335	38	5.7	46.4	138	1380	26.3	20.2	44.4	<0.03	1.12	2.29	20500	1.72	16.5
8/22/08 14:00	3.4	348	39.6	5.48	21.5	95.4	1170	20.3	19.4	28.4	<0.03	1	2.45	20700	1.6	6.9
8/22/08 15:00	4.3	321.7	45.8	6.43	37.7	135	1680	38	26	55.1	<0.03	1.17	2.32	20600	1.99	10.7
8/22/08 16:00	4.3	330.5	148	5.73	49.8	87.1	1890	44.1	32.1	42.9	0.16	0.98	2.42	20800	1.66	8.22
8/22/08 17:00	3.7	319.8	40	4.52	23.6	59.7	1210	31.8	18	30.1	<0.03	0.93	2.34	20400	1.75	4.98
8/23/08 0:00	1.7	292	13.6	10.5	17.7	15.8	494	9	8.42	8.38	1.09	0.95	2.99	19600	1.44	3
8/23/08 1:00	1.3	288	16	20.4	10.8	21.6	535	12.6	7.14	11.1	<0.03	1.85	4.12	20500	3.02	4.4
8/23/08 2:00	1.4	285.9	16.1	15.6	33.2	29.6	845	34.6	8.15	9.34	0.05	1.1	3.75	20500	1.67	3.44
8/23/08 3:00	1.4	295.8	20.4	14.7	28.5	20	688	9.96	9.29	13.9	0.27	1.03	3.35	20800	1.53	3.38
8/23/08 4:00	1.6	289.1	18.3	20.8	68	111	3880	132	64.2	17.2	0.54	1.13	3.36	20800	2.02	4.92
8/23/08 5:00	1.4	289.1	49.2	16.2	65.1	126	3850	126	63.5	45.7	0.47	1.35	3.89	20800	2.01	12.9
8/23/08 6:00	1.6	297.3	33.1	19.2	22.2	81	1720	24.7	26.6	32.2	0.25	1.12	4.37	20500	1.84	8.24
8/23/08 7:00	1.1	263.2	55.6	31.1	62.6	160	4500	127	66.5	37.5	0.84	1.15	4.02	20700	2.39	15.3
8/23/08 8:00	1.7	317	37.7	27.7	11.6	95.1	917	17	13.7	29	0.28	1.12	3.73	20800	1.51	8.26

Met Time	Wind Speed (mph)	Wind Direction (°)	Elemental Concentration (ng/m^3)													
			Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	As*	Se	Br	Pd	Hg	Pb
8/23/08 9:00	3	347.2	47.1	20.7	23.7	85.1	1970	54.7	27.2	22.7	0.24	1.06	4.23	20700	1.88	12.1
8/23/08 10:00	4	337.2	38.5	13.8	23.3	77.8	1930	40.7	29.9	18.3	0.13	1.06	3.01	20800	1.95	6.35
8/23/08 11:00	3.5	339.5	41.2	6.78	6.17	36.4	586	6.13	6.7	12.8	<0.03	0.97	2.93	20500	1.46	4.62
8/23/08 17:00	2.4	214.3	33.2	4.27	3.99	9.01	433	2.18	11.3	11.1	<0.03	0.93	3.62	19100	1.44	6.8
8/23/08 18:00	2.1	179	31.9	3.73	2.9	10.7	431	2.87	13.4	10.7	<0.03	0.85	3.47	20400	1.42	5.83
8/23/08 19:00	1.9	221.4	35.3	4.56	3.91	10.3	520	3.3	20.7	13.6	<0.03	0.95	3.64	20500	1.53	6.16
8/23/08 20:00	1.5	262.6	32.4	3.46	3.31	8.48	511	2.59	21.2	12	<0.03	0.93	3.66	20700	1.5	5.07
8/23/08 21:00	1.5	176.7	71.6	3.96	6.1	15.5	707	3.39	12.4	18.6	<0.03	0.98	4.56	20600	1.59	18.3
8/23/08 22:00	2.8	288	59.3	5.67	5.63	17.9	724	3.29	14.1	16	<0.03	1.05	4.13	20400	1.85	10.9
8/23/08 23:00	2.2	282.9	34.1	5.54	4.96	11.7	464	3.21	9.34	11.4	<0.03	1.06	4.33	20500	1.66	7.54
8/24/08 0:00	2.1	283.1	26.7	4.81	6.26	8.64	327	2.75	9.68	8.94	<0.03	0.97	4.15	19300	1.64	5.96
8/24/08 1:00	1.3	265.8	23.3	4.63	16.5	8.69	261	3.35	9.82	9.39	<0.03	1.66	4.44	20600	3.04	5.49
8/24/08 2:00	1.1	260.7	13.4	5.02	16	7.8	221	2.71	9.68	7.87	<0.03	1.04	4.16	20600	1.51	4.4
8/24/08 3:00	1.2	254.1	16.2	4.01	18.6	9.1	242	2.68	9.43	11.4	<0.03	1.1	4.32	20600	1.54	4.63
8/24/08 4:00	0.9	197.1	19.9	2.4	18.6	9.06	273	1.98	9.32	10.3	<0.03	1.11	3.88	20500	1.45	4.24
8/24/08 5:00	1.7	139.2	21.1	2	13.8	9.07	334	1.74	6.83	9.72	0.1	1.13	3.87	20600	1.52	5.79
8/24/08 6:00	3.7	110.3	25	1.75	7.49	7.85	346	2.12	5.14	11.2	0.57	1.04	3.61	20800	1.49	5.24
8/24/08 7:00	3.2	184.2	17.2	1.57	7.33	6.55	193	1.73	3.63	7.29	<0.03	1.04	3.56	20500	1.46	5.2
8/24/08 8:00	3.9	113.2	29.9	1.85	4.48	8.66	454	1.75	8.87	13.2	0.63	1.07	3.65	20600	1.53	6.33
8/24/08 9:00	3.8	197.9	12.3	1.2	2.36	3.37	171	1.2	3.79	7.47	<0.03	0.91	3.09	20700	1.47	2.96
8/24/08 10:00	3	198.7	10.9	1.15	1.22	2.58	137	0.95	3.42	5.23	<0.03	0.99	3.11	20700	1.44	2.77
8/24/08 11:00	3.8	170	13.2	1.09	1.83	3.51	167	1.09	5.51	5.83	<0.03	0.95	3.22	20500	1.52	3.51
8/24/08 12:00	3.8	186.3	18.3	1.22	1.4	3.93	190	0.98	4.38	4.74	<0.03	0.85	2.22	20500	1.43	2.83
8/24/08 13:00	3.7	190.3	28.1	1.87	2.39	5.8	260	1.07	5.91	6.68	<0.03	0.88	2.35	20400	1.41	3.1
8/24/08 14:00	3.3	184.8	37.3	1.72	1.38	6.07	283	0.94	4.46	4.76	<0.03	0.85	2.26	20600	1.43	3.13
8/24/08 15:00	3	227.2	27.9	1.24	0.63	4.5	227	0.91	3.93	5.31	<0.03	0.8	2.19	20800	1.4	3.27
8/24/08 16:00	3.7	288.1	44.5	2.48	2.14	9.46	389	1.42	5.94	17.4	<0.03	0.94	2	20700	1.52	4
8/24/08 17:00	3	273.3	41.8	2.27	4.94	9.43	403	1.33	9.41	9.72	<0.03	0.89	2.02	20300	1.59	4.57
8/24/08 18:00	2.7	270.6	18.4	1.55	5.26	5.83	228	1.2	8.71	7.19	<0.03	0.91	2.24	20500	1.58	2.98
8/24/08 19:00	3.1	296.3	10.5	0.92	5.57	4.27	137	1.39	5.82	13	<0.03	0.97	1.78	20600	1.5	3.11
8/24/08 20:00	3.5	256.4	2.23	0.51	6.9	3.03	44.2	0.99	2.93	2.92	<0.03	0.77	1.04	20400	1.5	1.37
8/24/08 21:00	2.9	194.6	3.04	0.67	5.8	2.68	48.2	0.97	2.49	3.34	<0.03	0.81	0.68	20600	1.41	1.36
8/24/08 22:00	3.2	207	3.23	0.64	3.01	2	34.5	0.86	2.41	3.61	<0.03	0.83	0.77	20600	1.43	1.67
8/24/08 23:00	3.4	319.5	12.2	2.99	25.8	201	1110	18.1	20.8	304	<0.03	1.2	0.99	20400	1.46	35.8
8/25/08 0:00	4.8	333.5	17.4	3.48	13	137	639	8.71	32.3	256	<0.03	1.45	0.87	19100	1.35	24.3
8/25/08 1:00	4.5	325.2	18.9	3.71	24.6	245	1100	12.6	28.1	857	<0.03	2.57	2.71	20400	2.25	96.2
8/25/08 2:00	1.8	276	9.28	3.39	17	725	587	4.5	20.1	116	<0.03	2.89	1.08	20500	1.65	13.6
8/25/08 3:00	1.7	278.8	8.74	2.15	16.4	208	648	10.6	10.8	425	<0.03	2.67	1.28	20600	1.1	43.9
8/25/08 4:00	1.9	274.5	16.4	4.33	23.2	425	1440	13.4	20.4	213	<0.03	2.44	1.21	20700	1.85	24.9
8/25/08 5:00	2.9	292	18.9	6.2	61.3	982	2090	38.3	21.4	345	<0.03	4.11	1.92	21000	1.72	40.6
8/25/08 6:00	2.2	277.5	12.3	2.54	19.7	147	529	4.36	7.84	57.6	<0.03	1.87	1.85	20600	1.54	7.82
8/25/08 7:00	2	278.2	12.3	3.77	22.9	267	1030	30.6	19	606	<0.03	1.22	1.91	20700	1.3	52.8
8/25/08 8:00	1.5	280	12.6	2.11	15.3	89.3	657	7.9	13.4	76.9	<0.03	1.18	1.86	20600	1.46	6.07
8/25/08 9:00	2.3	277.3	27.1	4.9	58.4	447	1990	33.3	24.4	227	<0.03	7.26	2.53	21000	1.65	24.1
8/25/08 10:00	3	315	22.5	3	16.9	142	1080	19.5	23.8	82	<0.03	1.05	2.83	20600	1.54	10.1
8/25/08 11:00	3.5	270.2	10.1	1.95	5.85	58.2	353	4.14	5.97	14.3	<0.03	1.23	3.97	20600	1.52	2.63
8/25/08 12:00	4.4	295.9	13.6	3.13	24.7	152	1200	27.1	22.5	110	<0.03	3.44	2.68	20600	1.58	16
8/25/08 13:00	5.3	325.3	24.7	4.77	46	182	2590	57.1	42.7	64.2	<0.03	1.23	2.28	20500	1.89	10.5
8/25/08 14:00	4.5	324.7	39	6.43	78.6	273	4000	110	57.6	109	<0.03	1.04	2.29	21000	1.97	14.9
8/25/08 15:00	5.4	316.4	27.8	7.2	94.1	278	3450	75.6	40.5	182	<0.03	1.34	2.79	20900	2.19	27.4
8/25/08 16:00	4.9	339.4	43	9.8	77.3	178	3270	67.2	54.3	58.5	<0.03	1.47	2.58	20600	2.33	8.91
8/25/08 17:00	4.2	342.2	30.2	4.47	17	116	1090	18	17.8	66.6	<0.03	1.52	2.53	20600	1.56	7.5
8/25/08 18:00	4.3	321.5	20.9	6.28	81.6	241	3310	84.3	41.2	226	<0.03	1.23	2.36	20800	1.92	26.5
8/25/08 19:00	4.4	322.5	28.3	7.58	46.1	257	2120	31.4	33.3	276	<0.03	1.31	2.45	20600	1.6	30.4
8/25/08 20:00	4	305.4	25.2	4.69	51	293	1990	24.3	21.2	412	<0.03	1.79	2.35	20600	1.48	41.9
8/25/08 21:00	3.4	308.4	28.4	6	57.7	217	3130	59.3	50.9	328	<0.03	1.57	2.1	20800	1.78	37.4
8/25/08 22:00	2.5	295.2	44.2	9.14	73	426	2960	29.4	39.3	1710	<0.03	3.33	2.58	21600	0.81	217
8/25/08 23:00	2.7	315.1	40	10.6	119	970	4390	68.9	41.9	963	<0.03	5.8	3.99	21500	2.11	108
8/26/08 0:00	2	273.8	19.2	4.83	162	300	966	8.11	11.7	686	<0.03	4.75	1.97	19500	0.97	68.5
8/26/08 1:00	1.9	278.3	8.45	1.35	1.57	4.53	188	1.95	3.13	7.31	<0.03	1.66	1.77	20400	2.86	2.17

Met Time	Wind Speed (mph)	Wind Direction (°)	Elemental Concentration (ng/m^3)													
			Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	As*	Se	Br	Pd	Hg	Pb
8/26/08 2:00	1.7	279.5	7.67	1.14	2.18	3.67	132	1.23	2.44	4.41	<0.03	0.92	1.39	20500	1.48	1.38
8/26/08 3:00	1.5	279.6	4.14	0.94	2.42	4.19	64.8	1.11	1.83	15.3	<0.03	0.99	1.28	20600	1.49	2.16
8/26/08 4:00	1.4	281.3	3.26	0.97	2.3	3.83	58.9	1.11	2.05	3.63	<0.03	0.93	1.21	20600	1.43	1.19
8/26/08 5:00	1.9	292	4.21	0.83	1.68	2.1	49.8	1.05	2.01	2.59	<0.03	0.95	1.33	20500	1.47	1.23
8/26/08 6:00	1.9	279.7	7.59	1.05	2.81	3.9	162	1.2	3.67	4.71	<0.03	0.92	1.33	20600	1.54	1.59
8/26/08 7:00	1.9	287.7	17.6	1.35	3.53	11.9	334	1.3	9.67	8.72	<0.03	0.93	1.8	20600	1.47	2.06
8/26/08 8:00	1.6	290.4	72.7	11.9	58	264	2740	61	49.9	164	<0.03	1.29	2.24	20700	1.87	18.4
8/26/08 9:00	2.5	319.8	65.1	23.3	58.4	178	2320	33.5	44.7	199	<0.03	1.12	1.64	20900	1.72	17
8/26/08 10:00	2.9	7.9	31.8	8.74	14.7	111	1290	10.9	18.6	29.2	0.08	1.17	1.98	20600	1.79	7.19
8/26/08 11:00	3.3	343.9	22.8	5.32	27.2	208	1650	31	23	125	<0.03	1.2	1.98	20700	1.64	20.5
8/26/08 12:00	3.6	353.1	23.4	6.96	15.9	104	1130	18.9	17.8	48.8	<0.03	1.52	1.73	20400	1.62	6.16
8/26/08 13:00	3.3	346.9	16.9	3.84	6.49	43	482	3.83	7.72	13.4	<0.03	1.03	1.47	20500	1.5	2.93
8/26/08 14:00	3.9	359.1	20.8	5.76	33.7	145	1540	32.2	17.7	80	<0.03	1.65	1.22	20500	1.69	12.4
8/26/08 15:00	4.3	342.8	37.9	5.51	17.7	117	821	9.06	9.21	63.4	<0.03	1.22	1.74	20500	1.5	8.42
8/26/08 16:00	3.2	32.3	34.5	4.17	16.3	56.1	710	4.22	7.33	40.7	<0.03	1.27	2.22	20500	1.53	6.58
8/26/08 17:00	3.3	13.7	29.2	5.29	22.8	82.1	891	10.6	9.05	80.5	<0.03	1.36	2.42	20500	1.58	10.9
8/26/08 18:00	3	325.8	32.3	5.5	24.2	130	1430	24.8	15.5	104	<0.03	1.44	2.85	20500	1.52	13.4
8/26/08 19:00	2.5	280.8	41.1	5.46	49.2	129	1370	29.1	26.9	117	<0.03	1.83	3.09	20700	1.52	11.2
8/26/08 20:00	2.7	283.5	31.1	6.42	12.8	54.5	629	6.32	18.4	45.9	<0.03	1.53	2.65	20400	1.61	3.71
8/26/08 21:00	2.2	286.8	170	5.39	7.81	51.8	575	3.96	18.6	51.5	<0.03	1.6	2.63	20600	1.46	3.5
8/26/08 22:00	2.8	300.2	41.6	8.5	29.1	204	1730	29.3	27.3	218	<0.03	2.76	2.56	20500	1.63	21.4
8/26/08 23:00	3.4	326.5	64	4.56	11.8	54.4	654	6.22	6.82	10.8	<0.03	2.33	2.27	20700	1.65	3.81
8/27/08 0:00	1.8	263.4	18.6	8.3	6.81	13.2	340	5.25	4.6	6.78	<0.03	1.08	2.38	19200	1.51	2.55
8/27/08 1:00	1.7	278.2	14.1	6.08	6.26	23	319	5.19	6.55	28.3	<0.03	2.12	2.59	20400	3.02	5.12
8/27/08 2:00	2.5	228.9	14.9	3.07	3.42	12.7	244	2.56	3.63	16.1	<0.03	1.61	2.6	20600	1.5	4.03
8/27/08 3:00	4.1	199.5	15.1	1.15	1.4	4.78	174	1.11	1.88	7.79	<0.03	1.02	1.91	20700	1.42	2.44
8/27/08 4:00	4.1	209.2	11.9	1.31	1.83	4.66	134	1.23	2.85	5.7	<0.03	0.9	1.07	20500	1.44	1.62
8/27/08 5:00	5.1	218.5	13	1.2	1.59	5.52	153	1.39	2.33	7.56	<0.03	1	1.17	20500	1.49	1.89
8/27/08 6:00	4.3	206.4	11.9	1.21	1.56	3.56	148	1.1	2.5	4.39	<0.03	1	1.54	20600	1.47	2.04
8/27/08 7:00	4.2	195.5	16.2	1.75	2.23	4.24	166	1.39	4.27	5.13	<0.03	0.91	1.51	20400	1.5	2.82
8/27/08 8:00	3.3	179.2	21.5	1.2	2.35	4.93	249	1.23	6.05	7.59	<0.03	0.93	1.74	20700	1.4	2.42
8/27/08 9:00	3.9	189.3	27.3	1.91	3.15	7.37	312	1.47	7.91	8.61	<0.03	0.95	1.71	20500	1.49	2.74
8/27/08 10:00	4.5	216.4	24.2	1.79	19	18.6	306	7.51	6.5	8.4	<0.03	0.89	1.66	20600	1.5	2.2
8/27/08 11:00	2.6	265.7	46.6	6.53	24.3	128	1190	13.4	18	146	<0.03	1.63	2.15	20600	1.65	16.9
8/27/08 12:00	3.1	175.5	39	2.65	5.73	15.8	629	2.6	14.1	32.2	<0.03	1.04	2.87	20500	1.8	5.21
8/27/08 16:00	4.7	310.2	44	5.74	63.8	337	2150	37.2	28.1	508	<0.03	1.56	4.64	19600	1.66	58.6
8/27/08 17:00	5.5	343.2	41.2	5.8	35.4	161	1820	20.1	20.8	170	<0.03	1.17	3.31	20900	1.6	21.7
8/27/08 18:00	4.4	338.9	70.3	10.8	50.2	187	2380	31.9	41.8	112	<0.03	1.23	2.43	20700	1.7	15.6
8/27/08 19:00	5.6	352.8	72.5	4.86	8.15	17.6	488	4.94	5.56	8.62	<0.03	0.97	2.79	20600	1.55	2.9
8/27/08 20:00	4.6	353.2	44.2	4.79	6.22	16.3	358	3.26	5.07	5	<0.03	0.92	2.56	21100	1.43	2.58
8/27/08 21:00	4.7	347.7	30.2	10.3	21.8	72.6	1520	44	19.1	22.8	<0.03	1.01	2.56	20600	1.69	3.94
8/27/08 22:00	3.9	349.2	27.6	5.39	7.94	58.9	400	4.97	6.82	23.9	<0.03	1.07	2.32	20900	1.57	3.18
8/28/08 13:00	2.8	48.1	77.1	6.53	17.5	66.1	1460	13.5	26.2	61.3	0.3	1.71	2.81	20500	1.78	16.1
8/28/08 14:00	2.7	63.8	86.9	5.79	13.4	45.1	1410	9.31	26	59.8	0.33	1.45	3.01	20600	1.67	14.9
8/28/08 15:00	3	32	120	5.27	12.4	41.2	1330	8.56	24	55.7	0.07	1.46	2.75	20500	1.75	13.3
8/28/08 16:00	3.7	15.2	104	5.51	13.3	55	1320	9.1	20.7	60.7	<0.03	1.32	2.73	20400	1.7	13.6
8/28/08 17:00	3.8	348.4	77.4	7.44	26.1	118	1940	28.6	28.2	72.7	<0.03	1.33	2.85	20500	1.85	13.6
8/28/08 18:00	3.8	326.5	70.7	6.55	28.4	172	1770	26.9	22.9	125	<0.03	1.47	4.01	20600	1.75	17.4
8/28/08 19:00	5.1	345.1	66.2	7.36	26.9	102	1520	24.3	14.2	37.9	<0.03	1.24	2.82	20500	1.67	7.85
8/28/08 20:00	5.4	339.1	53	16.4	95	447	6650	173	74.9	169	<0.03	1.62	1.65	21000	2.58	22.4
8/28/08 21:00	4.3	326.6	55.6	23.6	232	984	13000	237	237	350	<0.03	2.56	1.62	22100	4.86	43.4
8/28/08 22:00	3.7	320.4	63.8	21.2	217	1020	12500	338	231	535	<0.03	2.72	1.85	22300	4.26	48.7
8/28/08 23:00	3.5	321.7	58.1	17.6	344	841	10300	238	118	381	<0.03	2.69	1.9	22100	4.97	47
8/29/08 3:00	2.5	308.6	36.1	11.7	173	800	4250	59.2	43.5	853	<0.03	2.5	2.09	19700	2.64	88.8
8/29/08 4:00	2.8	323	20.9	5.27	85.8	132	1610	14.7	13.2	80.8	<0.03	1.23	1.78	20600	1.73	8.49
8/29/08 5:00	3.2	327.2	13.4	6.65	18.7	77.6	925	14	11	86.4	<0.03	1.01	2.11	20400	1.88	9.74
8/29/08 6:00	4.2	346.5	20.7	5.54	40.2	272	1810	22.9	19.8	130	<0.03	1.36	2.65	20500	1.94	17.1
8/29/08 7:00	3.1	320.6	25.7	15.6	196	1730	6490	151	75.1	1080	<0.03	4.29	3.73	21600	2.95	124
8/29/08 8:00	2.1	289.4	26.7	8.67	123	334	3180	102	48.3	272	0.75	1.96	2.85	20900	1.98	29.1
8/29/08 9:00	1.9	317.5	68.6	8.99	75.9	441	2960	54.8	40.3	240	1.07	1.53	3.04	20900	2	25.5

Met Time	Wind Speed (mph)	Wind Direction (°)	Elemental Concentration (ng/m^3)													
			Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	As*	Se	Br	Pd	Hg	Pb
8/29/08 10:00	2.3	345.5	56.1	11.8	129	811	3860	67.7	54.5	387	1.34	2.3	3.17	20700	2.39	53.3
8/29/08 11:00	2.6	328.5	81.9	7.83	39.4	226	2590	28.4	28.2	277	0.55	1.08	2.28	20700	1.63	16.7
8/29/08 12:00	3.5	333.5	81.7	7.7	43.7	312	2400	19	25	75.7	0.46	1.45	1.5	20700	1.89	11.5
8/29/08 13:00	3.6	324.6	74.3	7.35	35.7	296	2000	14.4	18.4	123	<0.03	1.94	1.33	20300	1.77	18
8/29/08 14:00	4	349.2	45	5.21	44.2	141	2570	37.7	32.8	30.7	<0.03	1.12	1.49	20600	1.96	12.4
8/29/08 15:00	3.8	340.2	40.3	3.31	15.5	105	1040	9.47	11	19.4	<0.03	1.11	1.45	20700	1.55	6.52
8/29/08 16:00	4.9	341.1	59.1	4.99	22.5	92.5	1480	26.2	19.1	20.1	<0.03	1	1.61	20700	1.65	7.69
8/29/08 17:00	7.6	353.6	57.5	4.85	32.6	86.7	1740	37.2	24.6	27.6	<0.03	1.01	1.78	20500	1.77	8.96
8/29/08 18:00	8.8	346.5	59.9	5.81	58.9	122	2800	69.2	39.7	29	<0.03	1.06	1.21	20600	1.79	9.06
8/29/08 19:00	8.1	349.4	35.3	4.81	42.7	104	2350	62.2	37.8	21.2	<0.03	1.19	0.81	20700	1.68	6.74
8/29/08 20:00	7.2	339.4	21	13.2	147	278	8580	274	210	34.3	<0.03	0.74	0.57	21400	2.5	6.79
8/29/08 21:00	6.7	346.4	20.5	2.93	19	47.6	1020	25.8	10.5	15	<0.03	0.9	0.92	20600	1.56	2.9
8/29/08 22:00	7	335.5	24.1	14.5	147	313	10100	300	162	25.7	<0.03	0.86	0.23	21600	2.77	6.92
8/30/08 8:00	2.6	288.5	18.4	6.59	77.8	103	3940	177	58.4	35	<0.03	0.91	4.57	19600	1.87	7.8
8/30/08 9:00	3.6	340.4	8.56	5.72	62.5	99.8	3340	135	72.9	31.1	<0.03	0.96	4.56	20800	1.77	3.32
8/30/08 10:00	4.2	354.5	21.7	2.63	11.3	43.7	751	22.4	15.6	8.56	<0.03	1.07	4.81	20400	1.55	2.73
8/30/08 11:00	4.6	9.8	12.9	1.91	2.36	17.7	161	2.04	5.5	5.65	<0.03	1.04	6.32	20400	1.47	12.5
8/30/08 12:00	5.2	3.7	23.8	3.75	42.7	72.8	1820	79.2	30.6	12.1	<0.03	1.09	3.87	20600	1.69	5.4
8/30/08 13:00	4.7	338.4	13.3	2.09	5.95	37.4	520	7.89	11	8.07	<0.03	0.95	3.38	20500	1.45	2.8
8/30/08 14:00	4.7	337.4	24.1	2.52	6.23	30.8	630	4.23	25.1	14.9	<0.03	0.93	3.41	20700	1.46	11.5
8/30/08 15:00	4.3	327.5	24.6	2.69	4.78	17	301	2.55	7.18	12.8	<0.03	0.88	3.16	21000	1.34	4.19
8/30/08 16:00	4.7	345.8	24.6	2.4	5.33	34	341	3.32	2.95	35	<0.03	0.96	3.37	20600	1.34	3.1
8/30/08 17:00	4.8	339.8	21.2	2.55	12.1	42	331	4.03	3.56	37.9	<0.03	1.06	3.52	20700	1.41	3.38
8/30/08 18:00	5.1	312.2	14.7	1.93	11.4	14.4	270	3.24	3.76	15.3	<0.03	0.88	3.24	20500	1.47	3.45
8/30/08 19:00	4.3	305.3	10.2	1.7	13.2	10.3	325	3.14	2.83	12.6	<0.03	0.82	3.28	20800	1.36	2.33
8/30/08 20:00	5	308	11.3	1.2	6.72	8.11	284	3.24	3.42	9.98	<0.03	0.87	2.34	20600	1.43	3.02
8/30/08 21:00	4	306.7	11.8	1	3.44	3.66	141	1.67	2.46	11.4	<0.03	0.84	2.28	20700	1.34	1.54
8/30/08 22:00	4	304.3	11.6	1.34	4.66	3.66	200	2.05	2.25	4.35	<0.03	0.88	2.59	20800	1.4	1.59
8/30/08 23:00	4.6	324.5	8.62	1.63	6.8	5.01	147	2.47	2.03	3.72	<0.03	0.98	3.09	20500	1.49	1.86
8/31/08 0:00	4.3	326.1	5.59	1.98	17	6.32	185	3.35	2.53	3.08	<0.03	0.99	3.16	19100	1.43	1.71
8/31/08 1:00	2.1	288.5	6.65	2.33	4.83	2.39	67.3	2.8	3.67	2.41	<0.03	1.77	3.61	20200	2.76	2.32
8/31/08 2:00	2	265.8	4.25	1.15	1.79	1.49	33.8	1.4	2.04	2.05	<0.03	1.01	2.97	20400	1.47	1.38
8/31/08 3:00	1.3	240.7	1.74	1.11	1.85	1.8	37.7	1.39	2.32	1.78	<0.03	1.03	2.9	20400	1.5	1.33
8/31/08 4:00	0.9	245.9	2.47	1.35	1.67	1.36	50.5	1.24	2.68	3.03	<0.03	0.99	2.9	20500	1.47	1.68
8/31/08 8:00	1.1	332.3	5.91	1.55	2.63	4.5	139	1.57	4.73	8.34	<0.03	0.98	3.98	19300	1.44	3.2
8/31/08 9:00	1.9	268.3	3.9	0.99	1.24	2.41	88.1	1	3.62	6.14	<0.03	0.99	4.56	20500	1.46	1.96
8/31/08 10:00	3.3	306.8	2.8	0.9	4.98	2.34	57.7	1.4	2.04	2.95	<0.03	0.97	5.3	20400	1.49	1.51
8/31/08 11:00	2.5	305.1	2.52	1.59	2.16	2.17	69.4	1.68	2.1	2.46	<0.03	0.95	5.78	20300	1.58	1.63
8/31/08 12:00	3.1	338	6.76	2.21	1.82	5.93	156	1.79	2.13	7	<0.03	0.91	4.81	20500	1.48	1.66
8/31/08 13:00	2.7	357.7	5.86	3.8	2.94	26.3	214	2.81	4.67	58.4	<0.03	0.95	3.41	20500	1.59	2.11
8/31/08 14:00	3.1	346.4	4.79	9.61	4.82	8.65	140	4.12	3.06	26.5	<0.03	0.95	3.12	20300	1.65	2.06
8/31/08 15:00	3.4	299.4	2.27	5.71	2	2.34	51	2.57	1.86	3.31	<0.03	0.89	2.86	20400	1.41	1.38
8/31/08 16:00	3.2	271	6.64	2.12	2.48	5.12	130	1.79	4.45	6.15	<0.03	0.92	2.71	20300	1.46	2.16
8/31/08 17:00	2.2	238.2	2.27	0.51	0.58	1.12	86.4	0.92	4.85	3.03	<0.03	0.9	2.49	20600	1.53	1.72
8/31/08 18:00	3.4	301.2	4.05	0.84	0.68	1.94	93.9	0.98	2.41	3.19	<0.03	0.87	2.96	20400	1.45	1.59
8/31/08 19:00	4.4	308.5	6.55	2.47	2.7	11.9	146	2.13	2.83	3.95	<0.03	1	3.83	20500	1.49	4.31
8/31/08 20:00	2.8	310.9	4.14	3.03	2.03	2.57	82.1	1.87	1.5	3.67	<0.03	0.9	2.5	20600	1.41	1.44
8/31/08 21:00	2.1	292.4	3.54	5.13	1.65	1.71	91.8	2.6	2.45	3.78	<0.03	0.87	2.19	20500	1.41	1.67
8/31/08 22:00	1.9	282	3.43	4.82	1.52	2.05	105	2.24	5.31	4.14	<0.03	0.99	2.78	20500	1.5	1.67
8/31/08 23:00	1.5	263.5	3.04	9.8	2.34	2.18	105	3.69	5.34	3.73	<0.03	0.96	2.69	20300	1.48	1.71
9/1/08 0:00	1.2	259.3	3.23	9.98	2.94	3.66	143	3.94	5.29	4.73	<0.03	0.89	2.65	19100	1.45	2.09
9/1/08 1:00	1.6	268.7	1.45	2.3	0.83	1.14	45.5	1.95	2.81	2.91	<0.03	1.78	3.22	20400	2.81	2.16
9/1/08 2:00	1.4	262.6	2.73	2.7	0.92	1.49	72.2	1.67	3.21	3.47	<0.03	0.99	2.82	20500	1.46	2.42
9/1/08 3:00	1	265.3	4.53	3.36	2.98	2.24	108	3.25	6.59	6.34	0.24	0.95	2.65	20400	1.5	4.93
9/1/08 4:00	1	256.4	5.06	3.48	2.83	1.86	115	3.59	6.72	8.59	0.49	0.96	2.74	20500	1.48	5.38
9/1/08 5:00	0.7	240.4	5.76	3.16	3.38	2.2	115	3.35	7.54	7.97	0.56	0.98	2.84	20300	1.64	5.32
9/1/08 6:00	1	249.4	4.71	3.25	1.57	1.76	102	2.45	5.44	6.95	0.33	0.96	2.89	20400	1.58	4.51
9/1/08 7:00	0.9	220	8.98	3.76	2.11	2.81	194	2.35	7.35	9.9	0.2	0.93	2.88	20400	1.5	4.64
9/1/08 8:00	1.1	260.4	12.3	2.59	2.48	3.53	331	2.22	8.62	15.2	1.05	1.07	3.65	20600	1.47	7.91
9/1/08 9:00	1.6	121.8	18.8	2.57	3.94	5.22	496	2	14.9	25.6	1.39	0.95	3.77	20500	1.5	5.47

Met Time	Wind Speed (mph)	Wind Direction (°)	Elemental Concentration (ng/m^3)													
			Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	As*	Se	Br	Pd	Hg	Pb
9/1/08 10:00	2.6	122.5	16.3	2.44	3.27	5.1	456	1.72	17.9	24.6	0.58	0.95	4.56	20200	1.49	9.56
9/1/08 11:00	2.9	111	13.6	1.98	2.5	3.98	352	1.46	12.6	12.5	0.08	0.99	4.71	20400	1.53	4.06
9/1/08 12:00	2.3	42.8	7.78	1.56	2.05	2.88	207	1.28	7.1	6.54	<0.03	1	5.14	20200	1.46	3.17
9/1/08 13:00	2.3	125.2	8.04	1.66	1.92	3.14	203	1.41	5.95	5.83	<0.03	1.07	5.19	20400	1.48	2.9
9/1/08 14:00	2.4	89.7	11.4	1.52	1.74	2.78	190	1.64	6.66	7.75	<0.03	1.12	5.42	20300	1.53	3.62
9/1/08 15:00	2.3	73.1	13.1	1.67	2.03	3.62	210	1.57	7.54	9.65	<0.03	1.12	5.29	20300	1.45	3.57
9/1/08 16:00	2.7	1.5	10.5	1.24	1.55	2.94	168	1.36	6.61	8.43	<0.03	1.02	5.15	20400	1.49	4.05
9/1/08 17:00	3.3	325.5	9.71	1.09	0.82	2.6	122	1.29	2.79	7.17	<0.03	1.03	5.55	20500	1.49	6.34
9/1/08 18:00	3.5	0.8	11	1.92	1.34	3.15	154	1.54	2.65	5.81	<0.03	1.02	5.36	20400	1.47	4.96
9/1/08 19:00	3.1	327.8	14.3	2.7	3.68	5.66	345	2.12	4.85	11.8	<0.03	1.16	5.01	20300	1.59	5.38
9/1/08 20:00	2.5	282	14.7	3.04	3.97	6.46	458	2.19	6.01	19.5	<0.03	1.2	4.84	20600	1.44	5.92
9/1/08 21:00	2.7	284.8	155	3.17	0.88	2.58	134	1.74	4.63	5.22	<0.03	1	4.25	20400	1.39	2.5
9/1/08 22:00	2.4	292.3	64.5	4.25	6.11	16.1	593	5.91	9.8	20.3	<0.03	1.04	7.24	20500	1.53	5.41
9/1/08 23:00	2.3	288.4	28.8	6.2	58.2	182	1600	22.3	18.8	140	0.12	1.57	4.25	20700	2.09	18.8
9/2/08 0:00	2.6	311.5	19.4	6.59	59	116	1510	25.7	16.4	53.1	0.01	1.13	4.32	19600	1.6	8.48
9/2/08 1:00	1.3	271.6	19.8	7.6	41.2	181	1830	31.1	18.7	301	<0.03	2.07	4.25	20400	3.08	36.9
9/2/08 2:00	1.8	297.7	17	5.5	51.2	229	2050	41.9	27.6	129	0.25	1.33	3.77	20800	1.72	17.5
9/2/08 3:00	2	303.6	19.7	8.2	57	468	3550	68.8	58.4	98.6	<0.03	1.65	4.01	20800	1.99	12.8
9/2/08 4:00	2.2	321.9	7.28	5.19	10.4	69.9	848	15.1	10.4	8.11	<0.03	1.02	4.26	20800	1.5	2.99
9/2/08 5:00	1.5	277.6	16.5	8.94	7.31	41.9	625	10.3	7.68	91	0.13	1.21	4.36	20700	1.48	21.1
9/2/08 6:00	1.7	277.8	31.6	8.82	16.6	195	878	18.4	14.6	280	<0.03	3.26	3.54	20600	1.45	25.8
9/2/08 7:00	1.7	299.3	65	12.9	25.9	281	1640	37.8	27.1	157	0.43	1.71	3.96	20700	1.62	19.8
9/2/08 9:00	4.4	333.4	44.9	18.9	173	972	6950	187	102	711	<0.03	3.73	4.73	21700	2.76	81.2
9/2/08 10:00	4.6	348.1	39.6	12.9	80.7	418	3960	81.6	79	260	0.08	1.66	3.87	21000	2.28	26
9/2/08 11:00	3.4	340.2	57.6	12.6	69.5	505	3130	45	34	352	0.07	2.04	4.79	20900	1.89	43.4
9/2/08 12:00	3.5	343	44.9	11.7	63.6	310	3630	72.7	49.9	215	<0.03	2.92	3.99	20900	1.86	30.2
9/2/08 13:00	4.1	342.9	49.4	10.4	62.1	544	2660	55.8	31.1	301	<0.03	1.94	3.73	20800	1.63	31.8
9/2/08 14:00	4.3	345.7	56.9	11.8	89.4	489	4440	90.1	50.8	383	<0.03	2.37	3.76	21200	1.96	42
9/2/08 15:00	4.7	347.3	56.3	5.81	24.5	130	1210	23.2	15.3	40.6	<0.03	1.41	3.68	20900	1.59	6.78
9/2/08 16:00	4.3	344.9	55.6	10.1	70.7	231	3310	96.7	42.7	182	<0.03	1.5	13.4	21000	1.93	21.6
9/2/08 23:00	3.1	303.6	33.3	17.6	127	728	6340	175	83	478	<0.03	2.04	4.46	20100	2.4	53.7
9/3/08 0:00	2.4	292.9	33.4	13.5	60.2	455	2850	37.2	22.4	471	<0.03	1.76	4.37	19700	1.91	45.4
9/3/08 1:00	1.6	275.1	31.4	9.36	59.4	225	2240	53.1	22.4	93.2	<0.03	2.34	4.33	20900	3.19	13.3
9/3/08 2:00	1.6	280.2	22.9	10.3	42.1	312	2030	29.5	16.3	672	<0.03	1.58	4.15	21100	1.14	101
9/3/08 3:00	1.5	271.6	21.4	6.05	14.5	146	756	11	8.53	264	<0.03	1.6	3.96	20900	1.21	30.8
9/3/08 4:00	0.9	225.8	25.5	7.41	14.9	146	785	10.6	9.63	176	<0.03	2.22	3.68	20600	1.65	33.4
9/3/08 5:00	0.9	249	15.6	8.19	20.6	133	846	12.7	9.1	473	<0.03	1.48	3.38	21100	1.02	50.4
9/3/08 6:00	1.1	271.1	26.3	11.6	52.8	263	1910	42.9	28.5	525	<0.03	2.67	3.27	20900	1.34	62
9/3/08 7:00	1	242.5	22.6	9.04	20.6	98.2	814	16.9	16.8	37.3	<0.03	1.15	2.74	21000	1.51	6.46
9/3/08 8:00	1.8	293	42.5	21.1	180	313	4660	183	107	357	0.2	1.48	3	21200	1.96	38.5
9/3/08 11:00	4.5	351.3	34.6	6.55	21.2	161	1490	35.9	28	188	<0.03	1.29	2.95	19700	1.41	15.4
9/3/08 12:00	4.2	336.6	47.4	16	96.6	897	4090	86	59.9	701	<0.03	4.35	3.66	21500	1.57	83.7
9/3/08 13:00	4.2	342.5	55.3	12.1	39.5	255	2420	45.8	24.8	278	<0.03	1.79	3.2	21300	1.58	23.2
9/3/08 14:00	4.2	351.8	66.9	10.7	30.9	268	2080	35.6	27.3	150	<0.03	1.87	3.4	21300	1.62	15.7
9/3/08 15:00	4.4	330.3	59.6	9.78	50.6	383	2230	52.1	37.7	195	0.21	1.92	4.12	21800	1.71	26.1
9/3/08 16:00	6.2	343.8	47.5	5.63	30	91.3	2120	63.2	27.4	41.4	<0.03	1.12	3.11	21400	1.62	8.82
9/3/08 17:00	6.4	349.5	35.8	6.38	58.3	188	2930	88	46.3	131	<0.03	1.17	2.71	21400	1.75	23.6
9/3/08 18:00	6.7	349.4	40.8	4.19	30.6	66.1	1180	27.6	17.5	35.2	<0.03	1.19	3.04	21300	1.59	10.1
9/3/08 19:00	7	348	43.5	4.63	39.4	92.2	1300	25.7	21.3	26.6	<0.03	1.07	3.3	21400	1.55	8.97
9/3/08 20:00	6.2	338.5	34.8	21.3	55.5	140	3790	124	53.7	47.5	0.04	1.17	3.42	21500	2.07	8.14
9/3/08 21:00	3.3	298.4	68.4	9.17	55.7	470	2850	27.1	36.6	750	0.14	2.08	4.17	21900	2.09	85.2
9/4/08 11:00	5.4	355.5	36.5	10.1	75.3	481	3330	46	44	190	<0.03	1.4	2.52	20100	1.81	24.8
9/4/08 12:00	5.1	340.6	56	13.2	79.7	484	3680	52.6	39.5	260	<0.03	2.96	2.75	21300	1.97	35.1
9/4/08 13:00	4.7	344.8	58.8	14.1	79.6	420	3380	48.7	28.8	268	<0.03	2.36	2.92	21300	1.83	31.1
9/4/08 14:00	6	346.2	73	10.5	52.1	120	2440	33.4	37.5	71.6	<0.03	1.22	2.93	21300	1.99	10.8
9/4/08 15:00	6.6	347.1	64.9	5.87	22.2	82.4	1270	13.3	11.4	57.3	<0.03	1.13	5.37	21400	1.62	15.6
9/4/08 16:00	7.6	354.1	64.7	5.84	33.3	74.4	1340	18.3	19.9	53.6	<0.03	1.24	2.79	21300	1.8	14.5
9/4/08 17:00	7.2	353.1	59.2	5.96	16.3	65.2	1040	12	10.8	49.1	<0.03	1.09	2.92	21200	1.5	8.86
9/4/08 18:00	7.7	351.9	58.5	7.12	23.6	71.9	1600	28.6	29.1	57.2	<0.03	0.97	3.29	21500	1.46	14.1
9/4/08 19:00	6.4	350.5	50.3	8.15	18.4	57.6	1310	29.1	26.1	25.1	<0.03	0.88	2.8	21400	1.57	7.51

Met Time	Wind Speed (mph)	Wind Direction (°)	Elemental Concentration (ng/m^3)													
			Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	As*	Se	Br	Pd	Hg	Pb
9/4/08 20:00	6.1	340	40.2	31.6	169	336	9080	261	158	152	<0.03	1.08	3.28	22300	2.9	16.9
9/4/08 21:00	4.7	331.9	61.3	35.7	144	354	8050	222	126	98.5	<0.03	1.18	3.66	21700	2.83	13.7
9/6/08 9:00	6.1	343.8	19.1	6.56	62.2	148	3280	71.5	59	42	0.41	0.84	1.47	19900	1.95	8.99
9/6/08 10:00	5	342.3	28.5	7.15	52.3	152	3060	65.2	49.2	34.4	<0.03	1.11	1.42	21100	1.92	7.5
9/6/08 11:00	5.4	341.4	39	7.97	51.1	162	4220	106	86.5	53.8	<0.03	0.94	1.33	21400	1.91	5.98
9/6/08 12:00	4.3	342.1	31.4	4.64	22.7	74.1	1180	23.4	25.1	27.2	<0.03	1.21	1.52	21200	1.85	11.5
9/6/08 13:00	4.3	346.5	24.1	4.57	14.4	55.4	1180	25.6	17.1	16.1	<0.03	0.99	1.97	21300	1.64	5.95
9/6/08 14:00	4.2	353	25.7	4.52	12.4	56.3	997	15.6	14.3	20.9	<0.03	1.02	2.13	21300	1.62	5.1
9/6/08 15:00	5.4	345.9	46.6	6.06	23.9	135	1750	35.4	29.9	29.7	<0.03	1.07	2.72	21300	1.69	6.57
9/6/08 16:00	6.3	347	39.1	10.4	59.3	139	4430	144	77.9	25.7	<0.03	1.07	2.62	21500	1.97	6.94
9/6/08 17:00	6.7	350.8	40	9.15	47.7	166	3610	110	76.2	24	<0.03	1.04	3.2	21500	1.9	11.5
9/6/08 18:00	7	352.8	59	6.88	14.4	72	976	15.7	11.4	31.1	<0.03	1.31	2.56	21200	1.64	10.4
9/6/08 19:00	7.5	345.9	38.8	9.75	53.5	135	4000	91	66.1	40.4	0.09	0.99	2.69	21600	1.98	7.26
9/6/08 20:00	6.2	336.1	50.7	7.79	51.8	75.4	3110	59.9	37.2	53.8	<0.03	1.03	2.86	21400	2.26	7.55
9/6/08 21:00	5.9	334.2	32.7	4.32	12.3	31	897	7.03	11.7	23.7	<0.03	1.12	2.35	21200	2.43	7.43
9/6/08 22:00	5.8	332.4	31.4	4.84	9.45	29.2	753	4.85	11	20.6	0.02	1.02	2.15	21300	1.85	6.02
9/6/08 23:00	4.9	324.9	24.3	3.71	10.3	18	456	4.53	6.4	17.5	0.15	0.86	2.02	21500	1.48	5.62
9/7/08 0:00	5	328.1	16.2	2.94	11.6	9.28	397	4.57	4.7	11.5	<0.03	0.82	1.74	20000	1.39	3.93
9/7/08 1:00	4.8	330.4	14.4	5.43	14.5	8.97	277	7.17	4.33	7.52	<0.03	1.66	2.05	21400	2.86	3.99
9/7/08 2:00	4.7	334.2	11	6.2	10.7	7.11	236	6.5	3.33	6.43	<0.03	0.85	1.72	21300	1.48	3.02
9/7/08 3:00	4.9	335.7	15.7	7.91	12.1	11.4	601	6.79	8.28	20.2	0.09	0.89	1.92	21400	1.46	4.5
9/7/08 4:00	5.3	334.6	10.3	8.48	9.19	4.94	208	6.29	3.92	6.16	0.14	0.95	2.02	22000	1.4	4.64
9/7/08 5:00	4.5	336	8.48	15.3	9.3	5.58	244	8.64	4.03	7.51	<0.03	1.08	2.52	21300	1.49	5.56
9/7/08 6:00	3.8	339.8	9.98	16.8	7.56	6.05	281	9.66	3.68	7.45	<0.03	1.13	2.69	21300	1.48	5.48
9/7/08 7:00	3.8	332.7	10.8	18.1	8.56	7.9	269	9.99	4.29	11.4	0.15	1.19	2.85	21400	1.51	5.86
9/7/08 8:00	4.9	325.8	16.7	13.9	9.85	11.7	295	7.59	6.51	17.1	0.58	1.15	3.32	21500	1.56	6.16
9/7/08 9:00	6.2	331.7	13.9	11.1	5.61	6.71	259	5.42	5.65	11.3	1.14	1	2.75	22100	1.27	5.34
9/7/08 10:00	6.4	337.5	14.1	9.76	4.68	8.97	266	5.72	5.18	14.4	0.69	1.01	2.76	21800	1.35	5.52
9/7/08 11:00	5.7	333.8	22	12.2	5.96	15.6	337	6.44	4.22	14.7	0.37	1.06	2.57	21500	1.51	5.81
9/7/08 12:00	5.8	339.9	23.9	9.77	4.74	18.9	365	5.3	4.91	12.1	0.3	0.95	2.08	21900	1.34	4.95
9/7/08 13:00	5.5	339.1	35.5	7.72	4.19	19	426	4.82	6.57	11.5	<0.03	0.95	2.13	21300	1.5	5.66
9/7/08 14:00	4.2	12.8	39.2	2.66	3.3	10.7	454	1.66	5.15	7.1	<0.03	0.72	1.44	21800	1.45	3.12
9/7/08 16:00	3.5	63.2	56.6	2.71	3.83	12.8	619	1.35	5.42	6.94	<0.03	0.81	1.6	21300	1.47	2.76
9/7/08 17:00	3.6	80.7	74.4	3.61	4.56	16.8	864	2.03	7.71	8.44	<0.03	0.86	1.73	21300	1.54	3.42
9/7/08 18:00	3.5	72.1	97.3	4.74	6.13	32.7	1210	1.89	6.83	10.5	<0.03	0.81	1.52	21400	1.67	4.55
9/7/08 19:00	6.4	355.3	57.1	6.94	5.34	45.9	726	3.52	19.6	16.5	<0.03	0.97	2.24	21500	1.53	4.97
9/7/08 20:00	5.6	341.9	59.4	9.61	10.4	84.5	872	6.98	8.3	103	<0.03	1.18	3.04	21400	1.56	14.9
9/7/08 21:00	3.7	329.4	54.6	10.7	16.9	136	1140	9.13	10.1	208	<0.03	1.44	2.99	21400	1.57	26.9
9/7/08 22:00	4.1	302.6	57.5	20.8	94.8	949	4120	44.3	29.2	2300	<0.03	4.67	4.9	22500	1.08	259
9/7/08 23:00	3.5	301.2	64.8	33.7	124	2560	5380	93.2	67.3	1870	<0.03	5.68	4.54	22800	1.95	214
9/8/08 0:00	3.3	299.2	49	29.1	71.3	1620	3660	33.7	33.8	1640	<0.03	7.89	3.49	20700	0.77	186
9/8/08 1:00	4.2	325.5	29.2	30	202	940	12500	357	187	2020	<0.03	4.62	4.68	22200	3.21	226
9/8/08 2:00	3.9	331	33.8	33.6	159	1210	4510	145	47.5	1590	0.08	5.02	3.97	22400	1.69	204
9/8/08 3:00	3.1	308.7	30.9	44.3	154	2130	5410	132	78.5	3290	<0.03	7.32	6.42	23000	0.52	339
9/8/08 4:00	2.9	307.6	32.3	64.6	158	1880	4100	79.6	65.6	2700	<0.03	14.2	5.94	22400	0.65	289
9/8/08 5:00	3.5	307.4	63.8	71.2	251	1320	6550	123	67.3	1950	<0.03	7.78	4.44	22600	2.67	217
9/8/08 6:00	3.3	322.1	69.7	42.1	207	1290	7700	169	85.6	613	<0.03	3.94	3.23	22200	4.08	72.7
9/8/08 19:00	7.2	344.9	99.3	9.38	71.4	102	2540	92.4	32.5	45.2	0.12	1.02	2.37	19500	2.04	11.8
9/8/08 20:00	4.9	322.5	103	32.8	293	860	15800	505	188	649	<0.03	2.05	2.26	23000	5.44	83.7
9/8/08 21:00	3.4	321.4	95.6	38.8	502	1400	18600	542	227	2150	<0.03	5.49	3.93	21300	9.69	267
9/11/08 11:00	5.5	350	110	26.4	170	859	5900	119	79.6	266	<0.03	3.83	3.76	20000	2.52	36.6
9/11/08 12:00	4.9	343.9	114	27	192	805	9950	220	151	462	<0.03	10.2	3.22	22000	3.16	46.6
9/11/08 13:00	4.7	338.4	118	19.8	107	444	5060	100	82.4	350	<0.03	2.48	2.89	21400	2.2	29.1

* Less than values are interference-free detection limits defined by EPA Compendium Method IO 3.3

Appendix C. Alternative Model Evaluation

Four models in three general categories were evaluated as part of this program as noted below:

- Receptor-oriented, most-probable source impact models
  - Chemical mass balance
  - Multivariate analysis
- Source-oriented, predictive source impact dispersion models
- Source-receptor hybrid model

There are two subcategories in the receptor-oriented source impact model category: multivariate analysis and mass balance models. Multivariate analysis models such as principal component and factor analysis models are used to identify sources responsible for common variability of measured species. Although multivariate models can provide powerful indications of possible source impacts and elemental relationships as defined by multiple filter analyses, they cannot quantify impacts without incorporating a mass balance subcomponent. The second receptor-oriented model is a chemical mass balance (CMB) model that can quantify most probable source impacts at a receptor based on chemical analysis of deposits on a single filter and previously determined chemical profiles ("fingerprints").
Source-oriented dispersion models typically predict a source's impact at a receptor based on estimates of emission and dispersion factors.[9] More recently, dispersion models have been used with estimates of source impacts at the receptor and back trajectory dispersion to estimate emissions. The fourth model category evaluated is a source-receptor hybrid that incorporates aspects of both receptor- and source-oriented models.

These four models are compared below in Table 4 with regards to model input requirements, output products and regulatory acceptance. Source-receptor hybrid models such as Ondov's pseudo-deterministic receptor model are relatively new. Ondov's model, for example, combines mass balance and Gaussian plume dispersion equations to determine average source emission rates and meteorological dispersion factors for each source. The model takes into account the number and location of stationary sources, wind direction, source emission parameters, and meteorological plume dispersion parameters. This new model was demonstrated for stack emissions with highly time-resolved ambient data in 2005.[10] There is currently no generic software publicly available for this model. In addition, its application to and performance for fugitive emission sources has not yet been established, and has not yet been used for permit writing and enforcement. As such, this model was not considered further for this application.

Table 4. Comparison of Fugitive Emission Model Requirements, Products and Acceptance

Model objective: quantitative measurement of fugitive emission rate or impact applicable to permitting and enforcement

Model evaluation parameters	Receptor Oriented		Source Oriented	Source-Receptor Hybrid
Input requirements	**CMB**	**Multivariate**	**Dispersion/BT***	**Pseudo-deterministic Receptor***
Source profiles	R	NR	NR	R
Single filter chemistry	R	NA	NR	R
Multiple filter chemistry	NR	R	NR	R
Meteorology	NR	NR	R	R
Source impact	NR	NR	NR/R	R
Emission factor	NR	NR	R/NR	NR
Products/outputs				
Specific period SCE	Yes	No	Not quantitative	Yes
Long term average SCE	Yes	No	No	Yes
New Source profiles	No	Yes	No	No
Emission rates	No	No	No/yes	Yes, Limited Accuracy*
Accuracy (% relative)	5 to 30	NA	100 to 1,000	Not yet demonstrated
Quantitative (accuracy better than 30%)	Yes	NA	No	Not yet demonstrated
Applicable to permitting & enforcement	Yes	No	Not quant.	Not yet demonstrated
Regulatory acceptance				
State implementation plans	Yes	No	Yes	No
New lead NAAQS	Yes	No	Yes	No
EPA Model availability	Yes	No	Yes	No

*Back trajectory analysis
NR: not required
NA: not applicable
R: required

Source-oriented dispersion models are well established models commonly used by the EPA in permitting and enforcement, but are of limited applicability to fugitive emissions because of large uncertainties (100 to 1,000%) not only in required emission factors but also in dispersion factors for specific short (hours) time periods. Because of these large uncertainties and the models' dependence on source impacts and back trajectory analysis, this modeling approach was not considered further for this fugitive emission and/or source impact application.

Multivariate receptor models, on the other hand, require little input data and can identify factors whose components exhibit common variability. If there is source profile information available, these factors can be related to sources and the component variability apportioned to these sources. However, the mass cannot be apportioned without a mass balance calculation such as provided with the CMB model. On the other hand, multivariate methods can be valuable tools for identifying missing sources and defining source profiles for CMB modeling.[8] These models can also provide confirming support for CMB source contribution estimates (SCE). Multivariate models will not be considered further as a primary source apportionment tool, but will be considered as a secondary supportive tool to the CMB model as discussed below. Because of the large amount of hourly chemical data that can be generated with the Xact 620, this supportive tool is expected to make major contributions to identifying fugitive emission sources and improving source profiles, as well as reconciling CMB model results.

Only the CMB receptor model 1) has the potential to quantify hourly source impacts, 2) is generally accepted by the EPA, 3) is available as an approved EPA model and 4) has been used as the basis for permit development and enforcement of state implementation plans for over 30 years. The CMB model relies on only two types of input data:

- Aerosol concentration data that can usually be determined to an accuracy of about 5 to 10%, and

- Representative relative source profiles (normalized to parameter being apportioned such as PM, Pb, As, etc), with accuracies on the order of 5 to 30%.

Typical accuracies of CMB source contribution estimates are on the order of 10 to 30%, but have the potential to be as low as about 5% over short sample averaging times of about 30 to 60 minutes. As such, our model adequacy evaluation has focused primarily on the CMB model and the supporting possibilities of multivariate analysis, particularly in light of the large quantity of time variable data that can be provided by the Xact 620.

The physical model on which receptor modeling is based is similar to that of the source-oriented approach. Material emitted by a source is acted upon by meteorological and atmospheric influences that dilute and modify the characteristics of the emitted material. The primary difference in the two models is their starting point and the measurable parameters on which they focus. Whereas the source-oriented deterministic modeling approach starts from the source and focuses on measurable characteristics of the source and transport influences (dispersion), the receptor-oriented probabilistic modeling approach starts with the receptor and focuses on measurable characteristics of the material collected at the receptor. In the receptor modeling approach, the total mass concentration (PM) or the mass concentration of a particular feature such as Pb, As, etc., as measured at the receptor is the dependent variable and the mass contributed by each source impacting the receptor become the independent variables. Simply put, the receptor model assumes that the measured mass collected at the receptor (PM, Pb, As, etc.) is the sum of the mass contributed by all possible sources. Implicit in this model are several assumptions such as:

- The masses of species used in the model are linearly additive.
- The species used in the model are non-reactive as the material arrives at the receptor.
- The relative composition of species used in the model (source profile or fingerprint) is conserved in transport from the source to the receptor (monitoring site).

Although these assumptions are not satisfied perfectly, they can be satisfied to a matter of degree that meets the needs of many source apportionment applications and are expected to be adequately satisfied for fugitive emissions with appropriate source characterization methods. Characterization of emissions for CMB analysis (source profile determination) requires the determination of relative chemistry of the emissions, which can be far more accurate and less variable than determination of emission factors for source-oriented models. It should also be noted that it is possible to use multivariate analysis of the Xact 620-generated data to develop source profile information. As with all models, there are limitations to the CMB modeling approach, but this model has proven to be a useful tool over the past 30 years for permitting and enforcement of such species as PM, Pb and volatile organic compounds. In addition, the model and its application are well documented and readily available from the US EPA.[5] Finally, it should be possible to automate the US EPA CMB model on a FLM platform such as the Xact 620 so that source contribution impacts might be reported in addition to elemental concentrations. The model would identify the major sources that contributed to the metal concentration of interest collected during the sampling interval. The contribution of each of the identified sources to the total metal concentration could be reported in terms of the absolute concentration (mass/volume) or percent of total metal measured.

Appendix D. CMB 8.2 Results

CMB 8.2 Model applied to "Background Level" ambient sample measured 09/01/08 at 18:00.

	Chemical	Mass	Balance	Version	EPA-CMB8.2						
	Report	Date:	11/13/2008								
SAMPLE:	OPTIONS:	INPUT	FILES:								
SITE:	FLM	BRITT	&	LUECKE:	No	INFLMTI.in8					
SAMPLE	DATE:	9/1/2008	SOURCE	ELIMINATION:	No	*******					
DURATION:	1	BEST	FIT:	No	*******						
START	HOUR:	18	*******								
SIZE:	COARS	ADFLMTI.csv									
	PRFLMTIHIUNC.cs										
Species	Array:	1									
Sources	Array:	1									
FITTING	STATISTICS:										
	R	SQUARE	0.9	%	MASS	87.3					
	CHI	SQUARE	6.36	DEGREES	FREEDOM	3					
SOURCE	CONTRIBUTION	ESTIMATES:									
SOURCE											
EST	CODE	NAME	SCE(ng/m3)	Std	Err	Tstat					

YES	FLM3	UDUST	130.53624	13.97389	9.34144						
YES	FLM12	STEEL	3.68752	1.82157	2.02437						

	134.22375										
MEASURED	CONCENTRATION	FOR	SIZE:	COARS							
	153.8+-	15.4									
	Eligible	Space	Collinearity	Display							
==========											
ELIGIBLE	SPACE	DIM.	=	2	FOR	MAX.	UNC.	=	30.7544	(20.%	OF
1	/	Singular	Value								

	1.47862	14.01433									

NUMBER	ESTIMABLE	SOURCES	=	2	FOR	MIN.	PROJ.	=	0.95		
	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.	SOURCE	

1	FLM3	1	FLM12								

ESTIMABLE	LINEAR	COMBINATIONS	OF	INESTIMABLE	SOURCES						
COEFF.	SOURCE	COEFF.	SOURCE	COEFF.	SOURCE	COEFF.	SOURCE	SCE	Std	Err	

==========											
SPECIES	ONCENTRATIONS:										
	CALCULATED	RESIDUAL									
	---	---									
SPECIES	FIT	MEASURED	CALCULATED	MEASURED	UNCERTAINTY						

TMAC	TMAU	153.77200+-15.37720	134.22375+-13.00086	0.87+-	0.12	-1					
TIC	TIU	*	11.01600+-	1.1016	23.03205+-	4.10062	2.09+-	0.43	2.8		
VC	VU	1.92400+-	0.1924	0.62201+-	0.11391	0.32+-	0.07	-5.8			
CRC	CRU	*	1.33600+-	0.1336	1.26715+-	0.41954	0.95+-	0.33	-0.2		
MNC	MNU	*	3.15200+-	0.3152	3.28066+-	0.27121	1.04+-	0.14	0.3		
FEC	FEU	*	153.77200+-15.37720	134.22375+-	6.61558	0.87+-	0.1	-1.2			
NIC	NIU	1.54300+-	0.1543	0.17179+-	0.06882	0.11+-	0.05	-8.1			
CUC	CUU	2.64700+-	0.2647	0.71570+-	0.2734	0.27+-	0.11	-5.1			
ZNC	ZNU	*	5.81300+-	0.5813	2.64421+-	0.84302	0.45+-	0.15	-3.1		
BRC	BRU	5.35900+-	0.5359	0.00182+-	0.0117	0.00+-	0	-10			
PBC	PBU	4.96300+-	0.4963	0.17187+-	0.34181	0.03+-	0.07	-8			

CMB 8.2 Model applied to "Fe:Mn Ratio~1" ambient sample measured 08/25/08 at 02:00.

	Chemical	Mass	Balance	Version	EPA-CMB8.2				
	Report	Date:	11/13/2008						
SAMPLE:	OPTIONS:	INPUT	FILES:						
SITE:	FLM	BRITT	&	LUECKE:	No	INFLMTI.in8			
SAMPLE	DATE:	8/25/2008	SOURCE	ELIMINATION:	No	*******			
DURATION:	1	BEST	FIT:	No	*******				
START	HOUR:	2	*******						
SIZE:	COARS	ADFLMTI.csv							
	PRFLMTIHIUNC.cs								
Species	Array:	1							
Sources	Array:	1							
FITTING	STATISTICS:								
	R	SQUARE	0.98	%	MASS	102.2			
	CHI	SQUARE	1.03	DEGREES	FREEDOM	5			
SOURCE	CONTRIBUTION	ESTIMATES:							
SOURCE									
EST	CODE	NAME	SCE(ng/m3)	Std	Err	Tstat			

YES	FLM3	UDUST	26.37023	7.80183	3.38001				
YES	FLM12	STEEL	500.16788	60.64923	8.2469				
YES	FLM13	FERMN	73.3405	10.28481	7.13095				

	599.8786								
MEASURED	CONCENTRATION	FOR	SIZE:	COARS					
	587.2+-	58.7							
	Eligible	Space	Collinearity	Display					
==========									
ELIGIBLE	SPACE	DIM.	=	3	FOR	MAX.	UNC.	=	********
1	/	Singular	Value						
	7.2271	9.84617	60.79307						
NUMBER	ESTIMABLE	SOURCES	=	3	FOR	MIN.	PROJ.	=	0.95
	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.

1	FLM3	1	FLM12	1	FLM13				

ESTIMABLE	LINEAR	COMBINATIONS	OF	INESTIMABLE	SOURCES				
COEFF.	SOURCE	COEFF.	SOURCE	COEFF.	SOURCE	COEFF.	SOURCE	SCE	Std
---									
==========									
SPECIES	CONCENTRATIONS:								
	CALCULATED	RESIDUAL							
	----------	----------							
SPECIES	FIT	MEASURED	CALCULATED	MEASURED	UNCERTAINTY				

TMAC	TMAU	587.15503+-58.71550	599.87860+-56.08823	1.02+-	0.14	0.2			
TIC	TIU	*	9.28200+-	0.9282	9.38071+-	0.91854	1.01+-	0.14	0.1
VC	VU	*	3.38900+-	0.3389	1.90025+-	0.68211	0.56+-	0.21	-2
CRC	CRU	*	16.99100+-	1.6991	34.49742+-21.88273	2.03+-	1.3	0.8	
MNC	MNU	*	724.98199+-72.49820	740.62939+-37.32702	1.02+-	0.11	0.2		
FEC	FEU	*	587.15503+-58.71550	599.87860+-67.75775	1.02+-	0.15	0.1		
NIC	NIU	*	4.50100+-	0.4501	14.45199+-17.49627	3.21+-	3.9	0.6	
CUC	CUU	20.10600+-	2.0106	5.77180+-	0.49238	0.29+-	0.04	-6.9	
ZNC	ZNU	115.54600+-11.55460	39.51848+-	8.93183	0.34+-	0.08	-5.2		
BRC	BRU	*	1.07900+-	0.1079	5.58822+-	7.84066	5.18+-	7.29	0.6
PBC	PBU	*	13.59100+-	1.3591	13.46760+-	1.23049	0.99+-	0.13	-0.1

CMB 8.2 Model applied to "Fe:Mn Ratio~2" ambient sample measured 08/25/08 at 05:00.

	Chemical	Mass	Balance	Version	EPA-CMB8.2				
	Report	Date:	11/13/2008						
SAMPLE:	OPTIONS:	INPUT	FILES:						
SITE:	FLM	BRITT	&	LUECKE:	No	INFLMTI.in8			
SAMPLE	DATE:	8/25/2008	SOURCE	ELIMINATION:	No	*******			
DURATION:	1	BEST	FIT:	No	*******				
START	HOUR:	5	*******						
SIZE:	COARS	ADFLMTI.csv							
	PRFLMTIHIUNC.cs								
Species	Array:	1							
Sources	Array:	1							
FITTING	STATISTICS:								
	R	SQUARE	0.98	%	MASS	98.1			
	CHI	SQUARE	1.1	DEGREES	FREEDOM	6			
SOURCE	CONTRIBUTION	ESTIMATES:							
SOURCE									
EST	CODE	NAME	SCE(ng/m3)	Std	Err	Tstat			
YES	FLM3	UDUST	32.70684	15.24344	2.14563				
YES	FLM12	STEEL	1957.68591	162.49541	12.04764				
YES	FLM13	FERMN	57.746	15.43979	3.74008				
	2048.13867								
MEASURED	CONCENTRATION	FOR	SIZE:	COARS					
	2088.0+-	208.8							
	Eligible	Space	Collinearity	Display					
ELIGIBLE	SPACE	DIM.	=	3	FOR	MAX.	UNC.	=	********
1	/	Singular	Value						
12.91393	14.88901	********							
NUMBER	ESTIMABLE	SOURCES	=	3	FOR	MIN.	PROJ.	=	0.95
	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.
1	FLM3	1	FLM12	1	FLM13				
ESTIMABLE	LINEAR	COMBINATIONS	OF	INESTIMABLE	SOURCES				
COEFF.	SOURCE	COEFF.	SOURCE	COEFF.	SOURCE	COEFF.	SOURCE	SCE	Std
SPECIES	CONCENTRATIONS:								
	CALCULATED	RESIDUAL							
	---	---							
SPECIES	FIT	MEASURED	CALCULATED	MEASURED	UNCERTAINTY				
TMAC	TMAU	*********+-********	*********+-********	0.98+-	0.12	-0.2			
TIC	TIU	*	18.91100+-	1.8911	19.26553+-	1.60928	1.02+-	0.13	0.1
VC	VU	*	6.19900+-	0.6199	4.48473+-	0.80502	0.72+-	0.15	-1.7
CRC	CRU	*	61.26200+-	6.1262	129.88492+-85.64886	2.12+-	1.41	0.8	
MNC	MNU	*	981.97400+-98.19740	*********+-61.42228	1.03+-	0.12	0.2		
FEC	FEU	*	*********+-********	*********+-********	0.98+-	0.13	-0.1		
NIC	NIU	*	38.29100+-	3.8291	45.59702+-14.40055	1.19+-	0.39	0.5	
CUC	CUU	*	21.43100+-	2.1431	18.29092+-	1.8399	0.85+-	0.12	-1.1
ZNC	ZNU	344.57300+-34.45730	89.99001+-10.05976	0.26+-	0.04	-7.1			
BRC	BRU	*	1.92400+-	0.1924	4.40015+-	8.60375	2.29+-	4.48	0.3
PBC	PBU	*	40.62000+-	4.062	47.75357+-	4.30583	1.18+-	0.16	1.2

CMB 8.2 Model applied to "Fe:Mn Ratio~13" ambient sample measured 08/28/08 at 21:00.

	Chemical	Mass	Balance	Version	EPA-CMB8.2				
	Report	Date:	11/13/2008						
SAMPLE:	OPTIONS:	INPUT	FILES:						
SITE:	FLM	BRITT	&	LUECKE:	No	INFLMTI.in8			
SAMPLE	DATE:	8/28/2008	SOURCE	ELIMINATION:	No	*******			
DURATION:	1	BEST	FIT:	No	*******				
START	HOUR:	21	*******						
SIZE:	COARS	ADFLMTI.csv							
	PRFLMTIHIUNC.cs								
Species	Array:	1							
Sources	Array:	1							
FITTING	STATISTICS:								
	R	SQUARE	0.85	%	MASS	62.7			
	CHI	SQUARE	7.68	DEGREES	FREEDOM	6			
SOURCE	CONTRIBUTION	ESTIMATES:							
SOURCE									
EST	CODE	NAME	SCE(ng/m3)	Std	Err	Tstat			

YES	FLM3	UDUST	38.68269	48.32133	0.80053				
YES	FLM12	STEEL	8092.35352	571.40967	14.16209				

	8131.03613								
MEASURED	ONCENTRATIC	FOR	SIZE:	COARS					
	12974.0+-	1297.4							
	Eligible	Space	Collinearity	Display					
==========									
ELIGIBLE	SPACE	DIM.	=	2	FOR	MAX.	UNC.	=	********
1	/	Singular	Value						

43.05077	********								

NUMBER	ESTIMABLE	SOURCES	=	2	FOR	MIN.	PROJ.	=	0.95
	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.	SOURCE	PROJ.

1	FLM3	1	FLM12						

ESTIMABLE	LINEAR	COMBINATIONS	OF	INESTIMABLE	SOURCES				
COEFF.	SOURCE	COEFF.	SOURCE	COEFF.	SOURCE	COEFF.	SOURCE	SCE	Std
---									
==========									
SPECIES	NCENTRATIONS:								
	CALCULATED	RESIDUAL							
	---	---							
SPECIES	FIT	MEASURED	CALCULATED	MEASURED	UNCERTAINTY				

TMAC	TMAU	*********+-********	*********+-********	0.63+-	0.08	-3.4			
TIC	TIU	*	55.59200+-	5.5592	57.39563+-	5.20165	1.03+-	0.14	0.2
VC	VU	*	23.59200+-	2.3592	15.35544+-	2.52909	0.65+-	0.13	-2.4
CRC	CRU	*	231.59100+-23.15910	531.36444+-********	2.29+-	1.55	0.8		
MNC	MNU	*	984.12000+-98.41200	*********+-********	2.24+-	0.32	4.9		
FEC	FEU	*	*********+-********	*********+-********	0.63+-	0.09	-3.2		
NIC	NIU	*	237.00999+-23.70100	177.04724+-17.70203	0.75+-	0.11	-2		
CUC	CUU	236.85201+-23.68520	71.01062+-	7.58701	0.30+-	0.04	-6.7		
ZNC	ZNU	*	350.12399+-35.01240	304.20587+-30.34735	0.87+-	0.12	-1		
BRC	BRU	*	1.62400+-	0.1624	0.00054+-25.28860	0.00+-15.57	-0.1		
PBC	PBU	43.39500+-	4.3395	192.21837+-17.70231	4.43+-	0.6	8.2		