COMPARATIVE EVALUATION OF AMBIENT FINE PARTICULATE MATTER ($PM_{2.5}$) DATA OBTAINED FROM URBAN AND RURAL MONITORING SITES ALONG THE UPPER OHIO RIVER VALLEY

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ABSTRACT

Advanced Technology Systems, Inc. (***ATS***), with Desert Research Institute (DRI) and Ohio University as subcontractors, was contracted by the NETL in September 1998 to manage the *Upper Ohio River Valley Project* (UORVP), which included the establishment and operation of four ambient air monitoring sites located in the Upper Ohio River Valley (UORV). Two urban and two rural monitoring sites were included in the UORVP. The four sites selected for the UOVRP were collocated at existing local or state air quality monitoring stations. The goal of the UORVP was to characterize the nature and composition of $PM_{2.5}$ and its precursor gases. In the process, the objectives of the UORVP were to examine the ambient air concentrations of $PM_{2.5}$ as compared with the promulgated $PM_{2.5}$ standards, the geographical, seasonal and temporal variations of ambient air concentrations of $PM_{2.5}$, the primary chemical constituents of $PM_{2.5}$, and the correlations between ambient air concentrations of $PM_{2.5}$ and its precursor gases, other gaseous pollutants and meteorological parameters. A variety of meteorological and pollutant measurement devices, including several different $PM_{2.5}$ samplers that provided either real-time or integrated concentration data, were deployed at the monitoring sites. The frequency of integrated sampling varied throughout the UORVP study period and was as follows:

- "Intensive" sampling periods were defined as periods in which samples were collected on a relatively frequent basis (ranged from 6-hour integrated samples collected round-the-clock to one 24-hour integrated sample collected every third day).
- "Background" sampling periods were defined as periods in which 24-hour integrated samples were collected every third or sixth day.

Sampling activities for the UORVP were initiated in February 1999 and concluded in February 2003. This Final Technical Progress Report summarizes the data analyses and interpretations conducted during the period from October 1998 through December 2004. This report was organized in accordance with the Guidelines for Organization of Technical Reports (September 2003).

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1.0 INTRODUCTION

1.1 Background and Summary of the Scope of Work

In July 1997, the U.S. Environmental Protection Agency (U.S. EPA) promulgated updates to the National Ambient Air Quality Standards for particulate matter (please refer to the following reference link: http://www.epa.gov/ttn/amtic/files/cfr/recent/pmnaaqs.pdf). The updates included (i) revisions to the existing daily ambient air standard for PM_{10} and (ii) establishing new daily and annual ambient air standards for $PM_{2.5}$ (herein after referred as fine particulate matter). Investigative studies conducted prior to July 1997 suggested that the U.S. EPA would eventually classify many areas of the U.S. as non-attainment areas with regards to the new $PM_{2.5}$ standards. The U.S. EPA mandates that state and local environmental regulatory agencies, in cooperation with industries located within non-attainment areas, develop state implementation plans (SIPs) for these areas. The SIPs include procedures and practices that will ultimately result with the non-attainment area demonstrating attainment with the pertinent ambient air standard. Historically, the SIPs often mandate reducing air emissions of the criteria pollutant and/or its precursor gases from stationary, mobile and area sources. In response to the new $PM_{2.5}$ ambient air standards, the U.S. Department of Energy's National Energy Technology Laboratory (NETL), in cooperation with key stakeholders including the U.S. EPA, local and state environmental regulatory agencies, industry and academia, elected to fund ambient air monitoring research programs located throughout the U.S. to investigate (i) the nature and composition of $PM_{2.5}$ and its precursor gases (e.g., sulfur dioxide [SO_2], nitrogen oxides [NO_X]) and (ii) the relationship between emissions from coal-fired electric utilities and ambient air quality. One of the research programs is the *Upper Ohio River Valley Project* (UOVRP), which included the establishment and operation of ambient air monitoring sites located in the Upper Ohio River Valley (UORV). The UORV was chosen for extensive fine particulate research since it is representative of areas in the eastern half of the continental United States that are not well characterized in terms of the ambient air concentrations and chemical composition of $PM_{2.5}$ but have a high density of coal-fired electric utility, heavy industry (e.g., coke and steel making), light industry and transportation emission sources. The UORV is also in the center of the ozone transport region, which provides a platform to study interstate pollution transport issues.

The location of the two urban and two rural ambient air monitoring sites included in the UORVP along with neighboring coal-fired electric utility plants are presented in Figure 1. The four sites selected for the UOVRP were collocated at existing local or state air quality monitoring stations. The sites were as follows:

SITE NAME	LOCATION	SITE TYPE	COOPERATING REGULATORY AGENCY
Athens (AT)	Athens, OH	Rural	Ohio EPA (OH EPA)
Holbrook (HB)	Holbrook, PA	Rural	Pennsylvania Department of Environmental Protection (PA DEP)
Lawrenceville (LW)	Pittsburgh, PA	Urban	Allegheny County (PA) Health Department (ACHD)
Morgantown (MO)	Morgantown, WV	Urban	West Virginia Department of Environmental Protection (WV DEP)

Details regarding the location of these four sites as well as a summary of the ambient air parameters measured at each site are presented in Section 3 of this report. Sampling activities for the UORVP were initiated in February 1999 and concluded in February 2003.

1.2 Project Goal and Objectives

The goal of the UORVP was to characterize the nature and composition of $PM_{2.5}$ and its precursor gases. In the process, the objectives of the UORVP were to address the following at sites located in the UORV:

- What are the ambient air concentrations of $PM_{2.5}$?
- How do the ambient air concentrations of $PM_{2.5}$ compare with the promulgated $PM_{2.5}$ standards?
- Are there geographical, seasonal or temporal variations of ambient air concentrations of $PM_{2.5}$?
- Are there significant differences in ambient air concentrations of $PM_{2.5}$ at sites that deploy different types of $PM_{2.5}$ samplers?
- What are the primary chemical constituents of $PM_{2.5}$?
- Are there any correlations between ambient air concentrations of $PM_{2.5}$ and its precursor gases?
- Are there any correlations between ambient air concentrations of $PM_{2.5}$ and other gaseous pollutants (e.g., ozone)?
- Are there any correlations between ambient air concentrations of $PM_{2.5}$ and meteorological parameters?

Advanced Technology Systems, Inc. (***ATS***) was contracted by the NETL in September 1998 to manage the UORVP. This Final Technical Report summarizes the data analyses and interpretations conducted during the period from October 1998 through December 2004. The

organizational format for this report is as follows (per the Guidelines for Organization of Technical Reports [September 2003]):

1. Introduction
2. Executive Summary
3. Experimental
4. Results and Discussion
5. Conclusions

1.3 Project Organization

A list of the individuals with major responsibilities who participated in this project includes the following:

- NETL Program Manager for the UORVP
- ***ATS*** Program Manager for the UORVP
- ***ATS*** Coordinator for Sampling and Analytical Laboratory Activities
- Subcontract Analytical Laboratory Representatives
- Subcontract Site Operators
- Cooperating Regulatory Agency Representatives

An organizational chart showing the relationships and the lines of communication among these individuals is presented in Figure 2. ***ATS*** contracted Desert Research Institute (DRI) to (i) provide many of the $PM_{2.5}$ and precursor gas samplers not already deployed at the sites by the cooperating regulatory agency or ***ATS*** and (ii) conduct the required analyses of the samples generated by DRI's samplers. Details regarding DRI's organizational structure for the UORVP were previously presented in the document prepared by DRI entitled "Quality Integrated Work Plan (QIWP) for the Upper Ohio River Valley Project" dated April 27, 1999.

2.0 EXECUTIVE SUMMARY

Advanced Technology Systems, Inc. (***ATS***), with Desert Research Institute (DRI) and Ohio University as subcontractors, was contracted by the NETL in September 1998 to manage the *Upper Ohio River Valley Project* (UORVP), which included the establishment and operation of four ambient air monitoring sites located in the Upper Ohio River Valley (UORV). Two urban and two rural monitoring sites were included in the UORVP. The four sites selected for the UOVRP were collocated at existing local or state air quality monitoring stations. The goal of the UORVP was to characterize the nature and composition of $PM_{2.5}$ and its precursor gases. In the process, the objectives of the UORVP were to examine the ambient air concentrations of $PM_{2.5}$ as compared with the promulgated $PM_{2.5}$ standards, the geographical, seasonal and temporal variations of ambient air concentrations of $PM_{2.5}$, the primary chemical constituents of $PM_{2.5}$, and the correlations between ambient air concentrations of $PM_{2.5}$ and its precursor gases, other gaseous pollutants and meteorological parameters. A variety of meteorological and pollutant measurement devices, including several different $PM_{2.5}$ samplers that provided either real-time or integrated concentration data, were deployed at the monitoring sites. The frequency of integrated sampling varied throughout the UORVP study period and was as follows:

- "Intensive" sampling periods were defined as periods in which samples were collected on a relatively frequent basis (ranged from 6-hour integrated samples collected round-the-clock to one 24-hour integrated sample collected every third day).
- "Background" sampling periods were defined as periods in which 24-hour integrated samples were collected every third or sixth day.

Sampling activities for the UORVP were initiated in February 1999 and concluded in February 2003. This Final Technical Report, which was organized in accordance with the Guidelines for Organization of Technical Reports (September 2003), summarizes the data analyses and interpretations conducted during the period from October 1998 through December 2004. From a global viewpoint, the findings can be summarized as follows:

Samples Collected During the Background Sampling Periods

- There are positive correlations of $PM_{2.5}$ mass concentrations among the four UORVP sites. The value of the correlation coefficient suggests that both regional and local sources contribute to $PM_{2.5}$ at these sites.
- The $PM_{2.5}$ mass concentrations are statistically higher at the urban sites as compared with the rural site (MO > LW > HB > AT). Please also note that the eastern-most sites had the highest $PM_{2.5}$ mass concentrations, thus suggesting that regional transport of air masses may also be contributing to $PM_{2.5}$.
- The overall average $PM_{2.5}$ mass concentrations measured at the HB, LW and MO sites are very nearly equal to the promulgated annual standard of 15 $\mu g/M^3$ but far less than the

24-hour standard of 65 $\mu g/M^3$. The $PM_{2.5}$ mass concentrations are higher during the ozone season as compared with the non-ozone season at all four UORVP sites.

- There are reasonably good (or better) correlations between $PM_{2.5}$ and PM_{10} at the four UORVP sites excluding the AT site during the non-ozone season (an explanation for this is currently unknown), thus suggesting the presence of common sources of $PM_{2.5}$ and PM_{10} at these sites. There are no simple linear correlations between either $PM_{2.5}$ or PM_{10} and ozone or sulfur dioxide at any of the four UORVP sites, regardless of season
- At the LW site, the $PM_{2.5}$ mass concentrations generated by the TEOM (a real-time analyzer) were statistically lower than those generated either by the DRI or FRM integrated sampling equipment, even though the trending was identical. Other researchers have also reported the same conclusion.

Samples Collected During the Intensive Sampling Periods

- In general, $PM_{2.5}$ particles were primarily composed of the following elements and ions (listed in descending order of abundance): sulfate ion, organic carbon, ammonium ion, elemental carbon and nitrate ion.
- Particulate sulfate content was greater in the summer as compared with the winter at the LW site, which is likely due to the presence of photochemically active oxidizing compounds (e.g., ozone, hydrogen peroxide) during the summer. Particulate sulfate concentration was strongly correlated with $PM_{2.5}$ concentration at the AT, HB and LW sites, regardless of season.
- There was a reasonably good correlation between summer nitric acid gas concentrations and $PM_{2.5}$ concentration at the HB and LW sites. However, there were no simple linear correlations between $PM_{2.5}$ and particulate organic carbon or ozone.
- Similar diurnal patterns of $PM_{2.5}$ and PM_{10} mass concentrations at the LW sites were observed (four scenarios). Increases in $PM_{2.5}$ and PM_{10} mass concentrations during the morning hours (0600 – 1200) were likely due to inputs from automotive sources and decreases in the atmospheric mixing height. Eventual decreases in $PM_{2.5}$ and PM_{10} mass concentrations during the afternoon or evening hours were likely due to increases in the atmospheric heights.

Implications

- The data obtained as part of the UORVP suggests that many regions within the UORV may be designated as non-attainment with respect to the annual $PM_{2.5}$ standard. If this is realized, then the State Implementation Plans will likely mandate reducing air emissions of $PM_{2.5}$ and/or its precursor gases from a large number of stationary, mobile and area sources that are located within a large geographical area. It should be noted that the UORV states (OH, PA and WV) submitted to the U.S. EPA in February 2004 a list of areas (counties) recommended to be designated to be in non-attainment with the $PM_{2.5}$ standards. The U.S. EPA responded to the state recommendations in April 2004. The U.S. EPA expects that the designations will be finalized by December 31, 2004.

3.0 EXPERIMENTAL

3.1 Ambient Air Monitoring Site Locations

Details regarding the locations of the four sites included in the UORVP are presented below:

SITE	LATITUDE AND LONGITUDE	ELEVATION (ASL)	SITE DESCRIPTION
AT	N39^o 48.693’ W81^o 86.852’	299 m	Site was collocated with an Ohio- EPA speciation site in Gifford State Park. The smallest of Ohio's State Forests, the 320 acre Gifford State Forest is located in northern Athens County, 17 miles northeast of Athens. Sampling equipment was located at ground level within a fenced area situated on a grassy field
HB	N39^o 48.969’ W80^o 17.077’	445 m	Site located on privately-owned land near Holbrook, PA; Terrain best described as rolling grassy hills; Land usage includes cow pasture; Sampling equipment was located at ground level within a fenced area situated on a grassy knoll
LW	N40^o 27.934’ W79^o 57.646’	267 m	Site located at the Allegheny County (PA) Health Department complex; The complex is situated within a joint residual and retail business district of Pittsburgh, PA; Sampling equipment located on the roof of Building No. 7 (~ 25 feet above ground)
MO	N39^o 39.003’ W79^o 55.245’	463 m	Site located at the Morgantown, WV Municipal Airport; Sampling equipment located at ground level in a grassy field within the complex

The LW site is the most northern and second most eastern of the four UORVP sites while the AT site is the most southern and western of the four UORVP sites. Since the prevailing wind direction in the Pittsburgh, PA area is westerly, it is expected that the LW and MO sites would generally be impacted the most by air emissions sources located in the UORV and the AT and HB sites would generally be impacted the least by air emissions sources located in the UORV (please see Section 4.2.1). Digital images of the four sites are presented in Appendix A.

3.2 Ambient Air Parameters and Sampling / Analytical Methodologies

The following ambient air parameters were quantified at one or more of the following UORVP sites:

- Mass concentrations of $PM_{2.5}$ and PM_{10}
- Chemical composition of $PM_{2.5}$ and PM_{10} – includes organic and elemental carbon, water soluble ions and selected elements (primarily metals)
- Particle size analysis of $PM_{2.5}$
- Concentrations of photo-chemically produced reactive gases – nitric acid (HNO_3)
- Concentrations of naturally occurring reactive gases – ammonia (NH_3)
- Concentrations of gaseous criteria pollutants – ozone (O_3), nitrogen oxides (NO_x), sulfur dioxide (SO_2) and carbon monoxide (CO)
- Meteorological parameters – wind speed and direction, temperature, relative humidity, solar radiation and precipitation depth

A summary of the ambient air parameters and the associated measurement techniques deployed at each of the four UORVP sites is presented in Table 1. Several different measurement techniques were utilized to measure integrated (over time) $PM_{2.5}$ and PM_{10} ambient air concentrations. The instrumentation for the integrated measurement technique essentially included an inlet particle size separator (impactor or cyclone), an optional denuder for removing selected gases (e.g., HNO_3), a filter pack loaded with multiple filters, a vacuum pump and a device for measuring sample gas volume. One measurement technique (TEOM) was utilized to measure real-time (continuous) $PM_{2.5}$ and PM_{10} ambient air concentrations. The instrumentation for the real-time measurement technique essentially includes an inlet particle size separator (impactor or cyclone), an oscillating microbalance, a vacuum pump and a device for measuring sample gas volume. Details regarding the DRI samplers and their analytical laboratory procedures were previously presented in the DRI QIWP. All other samplers and measurement devices were operated in accordance with the manufacturer's instructions and each operating group's quality assurance project plan. For the purposes of the UORVP, all $PM_{2.5}$ samplers were initially assumed to be equivalent (this was investigated as part of this study – please see Section 4.2.4).

3.3 Sampling Schedule

The analyzers that provided real-time data were designed to operate on a continuous basis throughout the UORVP study period. The sampling and analysis logs for the analyzers that provided integrated data are presented in Tables 2 through 6. The frequency of integrated sampling varied throughout the UORVP study period and was as follows:

- "Intensive" sampling periods were defined as periods in which samples were collected on a relatively frequent basis (ranged from 6-hour integrated samples collected round-the-clock to one 24-hour integrated sample collected every third day).
- "Background" sampling periods were defined as periods in which 24-hour integrated samples were collected every third or sixth day.

For each sampling period, all appropriate samples were analyzed for $PM_{2.5}$ or PM_{10} mass concentration. For each sampling period, a subset of selected samples was analyzed for targeted elements, ions or compounds (the other samples were archived – these samples may be retrieved and analyzed in the future if required). The following was deduced based on a qualitative analysis of the logs presented in Tables 2 through 6:

- There are very few PM_{10} samples with chemical speciation data.
- There are very few $PM_{2.5}$ samples collected during the background sampling periods at the HB, LW and MO sites with chemical speciation data.

As such, discussions regarding the chemical composition of the collected samples (Section 4 of this report) will be limited to $PM_{2.5}$ samples collected during the intensive sampling periods. The procedures utilized for determining the number of **"valid" samples for this report** are described in Section 4.1.

4.0 RESULTS AND DISCUSSION

4.1 Current Data Status for the UORVP Sites

Summaries of the current data statuses for the AT, HB, LW and MO sites are presented in Tables 7 through 10, respectively. All available data have been obtained by ***ATS***. Groups external to ***ATS*** provided validated data – the validation procedures can be obtained by ***ATS*** upon request. Data collected by ***ATS*** alone (the TEOM data for HB and LW and the SO_2 and meteorological data for LW) has undergone Level I validation to date. ***ATS*** submits that all validated data will require additional "filtering" in order to develop a final data set that will be utilized for the data analyses and interpretation. Such filtering steps may include the following:

<u>For Data Obtained Using Continuous Analyzers</u>

- Eliminate voided and missing data (these values are often assigned the value of –99)
- Reassign values that are less than the accepted detection limit / threshold value of the continuous analyzer
- Flag or eliminate other suspicious data as judged by ***ATS***

<u>For Data Obtained Using Integrated Samplers</u>

- Eliminate voided and missing data (these values are often assigned the value of –99)
- Eliminate duplicate data entries that present different values (i.e., two data entries with the same identification but differing analytical values)
- "Blank correct" the results for <u>minor contamination</u> if not already performed by the group that submitted the data to ***ATS*** (DRI submitted blank-corrected data while Chester LabNet did not) – ***ATS*** voided data for which the contamination was not considered minor
- For the data provided by DRI, eliminate samples (paired observations only) at the HB and LW sites that satisfied the following criteria:
  PM_{10} mass concentration < $PM_{2.5}$ mass concentration; and
  The associated error bars did not overlap (defined as Quality Control Test No. 1)
- For the data provided by DRI, eliminate samples that satisfied the following criteria:
  $PM_{2.5}$ or PM_{10} mass concentrations < Sum of the individual chemical concentrations for $PM_{2.5}$ or PM_{10}; and
  The associated error bars did not overlap (defined as Quality Control Test No. 2)
- For the data provided by DRI, eliminate samples that satisfied the following criteria:
  Total chlorine concentration < Water-soluble chloride concentration; and
  The associated error bars did not overlap (defined as Quality Control Test No 3)
- For the data provided by DRI, eliminate samples that satisfied the following criteria:
  Total potassium concentration < Water-soluble potassium concentration; and
  The associated error bars did not overlap (defined as Quality Control Test No. 4)

- For the data provided by DRI and Chester LabNet, eliminate samples that satisfied the following criteria:
  Charge Balance Ratio < 0.80 or Charge Balance Ratio > 1.20
  where Charge Balance Ratio (equivalents basis) =
  Sum of the water-soluble cations / Sum of the water-soluble anions
  (defined as Quality Control Test No. 5)
- Void other suspicious data as judged by ***ATS***

It should be noted that DRI provided an extensive data summary. Per DRI's standard operating procedures (SOPs), data entries were flagged (using a variety of descriptors) as appropriate if (i) non-standard procedures were utilized in the field or in the laboratory or (ii) peculiar observations of the samples were noted. DRI voided some samples as appropriate (occurred primarily due to field equipment failures) and elected to report the remainder of the data either with or without data flags. DRI's SOPs reserve the right for the end user of the data to accept or reject flagged data entries. ***ATS*** adopted a fairly conservative approach for filtering DRI's data prior to conducting the analyses presented in this report (i.e., ***ATS*** excluded many, but not all, of the flagged data entries – depending on the nature of the flag).

By comparison, Chester LabNet provided an abbreviated data summary. It should be noted that in conducting the chemical speciation analyses of $PM_{2.5}$ samples, both DRI and Chester LabNet reported very low values (often below analytical detection limits) for species other than total $PM_{2.5}$ catch and sulfate content of the $PM_{2.5}$ catch. DRI elected to report "non-detect" values as the analytical detection limit. However, Chester LabNet elected to report "non-detect" values as zero, which artificially skews the distribution of that species lower than actual. As such, analyses of Chester LabNet's chemical speciation data were limited to those species that were present in quantities sufficiently above their analytical detection limit (i.e., total $PM_{2.5}$ catch and sulfate content of the $PM_{2.5}$ catch).

The data analyses presented in the following sections summarize the efforts from the integrated (over time) filter and real-time (continuous) analyzer sampling conducted at the four UORVP sites (the data used in these analyses are presented in Appendix B). Please also note that in an attempt to present both a comprehensive and concise report, ***ATS*** elected to utilize the $PM_{2.5}$ or PM_{10} data generated by the pertinent cooperating regulatory agency at the four UORVP sites to supplement (but not replace) any of these data already generated by ***ATS***. ***ATS*** also utilized other ambient air data generated by the pertinent cooperating regulatory agency that were not already generated by ***ATS*** (e.g., ozone data).

4.2 Data Collected During the Background Sampling Periods

ATS elected to utilize a statistical approach in an attempt to assimilate the voluminous quantity of ambient air data collected during the background sampling periods. For simplicity, ***ATS***

assumed that the populations of $PM_{2.5}$ and PM_{10} mass concentrations at the UORVP sites have a normal distribution with a known mean and variance (i.e., a plot of the distribution function would show the familiar bell curve). Histograms of the $PM_{2.5}$ and PM_{10} mass concentrations measured using the integrated sampling equipment at the AT, HB, LW and MO sites during the background sampling periods are presented in Figures 3 through 6, respectively. The histograms suggest that the $PM_{2.5}$ and PM_{10} mass concentrations are distributed in reasonably normal manner (as opposed to other population density functions such as gamma, exponential and chi-square distributions). In practice, the statistical parameters presented in the following sections were calculated using a modified normal distribution know as the t distribution, which accounts for the unknown population variances and finite sample sizes. Although the t distribution is strictly applicable to populations with normal density functions, the t distribution is also applicable for other non-normal density functions that possess bell-shaped distributions (reference: Probability and Statistics for Engineers and Scientists, 2nd Edition, Walpole and Myers, 1978, Chapter 5).

4.2.1 $PM_{2.5}$ Mass Concentrations – Site Comparisons – Integrated Sampling Equipment

ATS examined the 24-hour average $PM_{2.5}$ mass concentrations for the four UORVP sites (samples were collected every sixth day).

(i) Data sets were generated that sorted the mass concentrations by the common sample date (not examining seasonal variations in $PM_{2.5}$ mass concentrations here). The correlation coefficient (r) for each pairing was calculated. Please recall that the correlation coefficient is a measure of the linear relationship between two variables. The results are as follows:

$PM_{2.5}$ Pairing	r value	Conclusion
LW / HB (77)	0.68	Reasonably good positive correlation between LW and HB
LW/ MO (72)	0.72	Reasonably good positive correlation between LW and MO
HB / MO (51)	0.71	Reasonably good positive correlation between HB and MO
AT / HB (51)	0.56	Slight positive correlation between AT and HB
AT / LW (74)	0.60	Slight positive correlation between AT and LW
AT / MO (63)	0.52	Slight positive correlation between AT and MO

A scatter plot for each pairing also confirms the positive correlations. Figure 7 is a representative plot of filter masses for Lawrenceville versus Holbrook. The results suggest that both regional and local sources contribute to $PM_{2.5}$ at these sites (r values > ~ 0.9 would suggest that regional sources dominate $PM_{2.5}$ contributions while r values < ~ 0.5 would suggest that local sources dominate $PM_{2.5}$ contributions). The value in parenthesis in the first column of the table lists the number of available pairings.

(ii) Data sets were generated that calculated the differences for each pairing. A statistical hypothesis test was run to determine if the average difference for each pairing was significantly different from zero at the 95 percent confidence level. The results are as follows:

$PM_{2.5}$ Pairing	Conclusion
LW / HB	The average difference is significantly different from zero (LW > HB)
LW/ MO	The average difference is significantly different from zero (LW< MO)
HB / MO	The average difference is significantly different from zero (HB < MO)
AT / HB	The average difference is significantly different from zero (AT < HB)
AT / LW	The average difference is significantly different from zero (AT < LW)
AT / MO	The average difference is significantly different from zero (AT < MO)

The data collected during the background sampling periods show that $PM_{2.5}$ mass concentrations are statistically higher at the urban sites as compared with the rural site (MO > LW > HB > AT). Please also note that the eastern-most sites had the highest $PM_{2.5}$ mass concentrations, thus suggesting that regional transport of air masses may also be contributing to $PM_{2.5.}$ An air shed modeling study could be used to support this suggestion.

(iii) Data sets were generated that compared the $PM_{2.5}$ mass concentrations measured at the four UORVP sites with the following promulgated $PM_{2.5}$ mass concentration standards:

<u>24-hour standard</u> = 65 $\mu g/M^3$ measured as the 98th percentile of the 24-hour $PM_{2.5}$ mass concentrations in a year (averaged over three years)

<u>Annual standard</u> = 15 $\mu g/M^3$ measured as the three year average of the annual arithmetic mean

The results are as follows:

Site	Overall Average $PM_{2.5}$ Conc.	50th Percentile $PM_{2.5}$ Conc.	98th Percentile $PM_{2.5}$ Conc.
AT	8.7 μg/M^3	6.9 μg/M^3	25.5 μg/M^3
HB	12.9 μg/M^3	10.2 μg/M^3	35.1 μg/M^3
LW	14.5 μg/M^3	12.6 μg/M^3	32.7 μg/M^3
MO	16.2 μg/M^3	15.4 μg/M^3	34.9 μg/M^3

The results show that the overall average $PM_{2.5}$ mass concentrations measured at the HB, LW and MO sites are very nearly equal to the promulgated annual standard of 15 μg/M^3 but far less than the 24-hour standard of 65 μg/M^3. These results are also in agreement with the results presented in the prior subsection ($PM_{2.5}$ mass concentrations MO > LW > HB > AT).

(iv) Data sets were generated that segregated the $PM_{2.5}$ mass concentrations measured at the four UORVP sites by season of the year. For this study, ***ATS*** elected to utilize the following UORV "seasons":

Ozone season — Defined as the period from April through October
Non-ozone season — Defined as the period from November through March
The results are as follows:

Site	Ozone Season – 50th Percentile $PM_{2.5}$ Conc.	Non-Ozone Season – 50th Percentile $PM_{2.5}$ Conc.
AT	8.3 μg/M^3 (39)	5.6 μg/M^3 (39)
HB	13.0 μg/M^3 (46)	8.5 μg/M^3 (38)
LW	13.8 μg/M^3 (62)	11.8 μg/M^3 (49)
MO	16.5 μg/M^3 (42)	11.8 μg/M^3 (35)

The results show that $PM_{2.5}$ mass concentrations are higher during the ozone season as compared with the non-ozone season at all four UORVP sites. The value in parenthesis lists the number of available samples.

4.2.2 PM_{10} Mass Concentrations – Site Comparisons – Integrated Sampling Equipment

ATS examined the 24-hour average PM_{10} mass concentrations for the four UORVP sites (samples were collected every sixth day).

(i) Data sets were generated that sorted the mass concentrations by the common sample date (not examining seasonal variations in PM_{10} mass concentrations here). The correlation coefficient (r) for each pairing was calculated. The results are as follows:

PM_{10} Pairing	r value	Conclusion
LW / HB (85)	0.86	Good positive correlation between LW and HB
LW/MO (102)	0.71	Reasonably good positive correlation between LW & MO
HB / MO (96)	0.72	Reasonably good positive correlation between HB and MO
AT / HB (90)	0.83	Good positive correlation between AT and HB
AT / LW (95)	0.67	Slight positive correlation between AT and LW
AT / MO (107)	0.56	Slight positive correlation between AT and MO

A scatter plot for each pairing also confirms the positive correlations. Figure 8 is a representative plot of filter masses for Lawrenceville and Holbrook. The results suggest that both regional and local sources contribute to PM_{10} at these sites (r values > ~ 0.9 would suggest that regional sources dominate PM_{10} contributions while r values < ~ 0.5 would suggest that local sources dominate PM_{10} contributions). The value in parenthesis in the first column of the table lists the number of available pairings.

(ii) Data sets were generated that calculated the differences for each pairing. A statistical hypothesis test was run to determine if the average difference for each pairing was significantly different from zero at the 95 percent confidence level. The results are as follows:

PM_{10} Pairing	Conclusion
LW / HB	The average difference is significantly different from zero (LW > HB)
LW/ MO	Insufficient data to conclude that the average difference is significantly different from zero (LW ≅ MO)
HB / MO	The average difference is significantly different from zero (HB < MO)
AT / HB	The average difference is significantly different from zero (AT < HB)
AT / LW	The average difference is significantly different from zero (AT < LW)
AT / MO	The average difference is significantly different from zero (AT < MO)

The data collected during the background sampling periods show that PM_{10} mass concentrations are statistically higher at the urban sites as compared with the rural site (MO ≅ LW > HB > AT). Please also note that the eastern-most sites had the highest PM_{10} mass concentrations, thus suggesting that regional transport of air masses may also be contributing to PM_{10}. An air shed modeling study could be used to support this suggestion.

(iii) Data sets were generated that compared the PM_{10} mass concentrations measured at the four UORVP sites with the following promulgated PM_{10} mass concentration standards:

<u>24-hour standard</u> = 150 $\mu g/M^3$ measured as the 99th percentile of the 24-hour PM_{10} mass concentrations in a year (averaged over three years)

<u>Annual standard</u> = 50 $\mu g/M^3$ measured as an annual arithmetic mean

The results are as follows:

Site	Overall Average PM_{10} Conc.	50th Percentile PM_{10} Conc.	99th Percentile PM_{10} Conc.
AT	18.6 $\mu g/M^3$	16.0 $\mu g/M^3$	41.7 $\mu g/M^3$
HB	17.1 $\mu g/M^3$	14.2 $\mu g/M^3$	49.7 $\mu g/M^3$
LW	22.8 $\mu g/M^3$	20.2 $\mu g/M^3$	62.0 $\mu g/M^3$
MO	22.7 $\mu g/M^3$	21.0 $\mu g/M^3$	56.0 $\mu g/M^3$

The results show that the overall average PM_{10} mass concentrations measured at the four UORVP sites are far less than the promulgated annual standard of 50 $\mu g/M^3$ and the 24-hour standard of 150 $\mu g/M^3$. These results are similar with the results presented in the prior subsection (PM_{10} mass concentrations MO ≅ LW > HB ≅ AT).

(iv) Data sets were generated that segregated the PM_{10} mass concentrations measured at the four UORVP sites by season of the year. For this study, ***ATS*** elected to utilize the following UORV "seasons":

Ozone season — Defined as the period from April through October
Non-ozone season — Defined as the period from November through March
The results are as follows:

Site	Ozone Season – 50th Percentile PM_{10} Conc.	Non-Ozone Season – 50th Percentile PM_{10} Conc.
AT	22.0 $\mu g/M^3$ (64)	12.0 $\mu g/M^3$ (47)
HB	18.0 $\mu g/M^3$ (58)	10.4 $\mu g/M^3$ (41)
LW	21.5 $\mu g/M^3$ (58)	18.3 $\mu g/M^3$ (46)
MO	24.0 $\mu g/M^3$ (67)	15.0 $\mu g/M^3$ (49)

The results show that PM_{10} mass concentrations are higher during the ozone season as compared with the non-ozone season at all four UORVP sites. The value in parenthesis lists the number of available samples.

4.2.3 Correlations of $PM_{2.5}$ and PM_{10} Mass Concentrations with Ozone and Sulfur Dioxide Concentrations

Data sets were generated that sorted the 24-hour average $PM_{2.5}$ and PM_{10} mass concentrations, 24-hour average ozone concentrations and 24-hour average sulfur dioxide concentrations by the common sample date for the four UORVP sites. The data sets were then segregated by the UORV season. The correlation coefficient (r) for each pairing of interest was calculated. The results are as follows:

Ozone Season (April through October)

Site	r value $PM_{2.5}$ / PM_{10}	r value $PM_{2.5}$ / O_3	r value PM_{10} / O_3	r value $PM_{2.5}$ / SO_2	r value PM_{10} / SO_2
AT	0.69	N/A	N/A	N/A	N/A
HB	0.94	0.65	0.65	0.47	0.26
LW	0.88	0.23	0.37	N/A	N/A
MO	0.73	0.37	0.45	0.11	0.09

Non-Ozone Season (November through March)

Site	r value $PM_{2.5}$ / PM_{10}	r value $PM_{2.5}$ / O_3	r value PM_{10} / O_3	r value $PM_{2.5}$ / SO_2	r value PM_{10} / SO_2
AT	0.44	N/A	N/A	N/A	N/A
HB	0.97	0.18	0.18	0.35	0.43
LW	0.94	-0.32	-0.17	N/A	N/A
MO	0.66	N/A	N/A	0.16	0.01

The results show reasonably good (or better) correlations between $PM_{2.5}$ and PM_{10} at the four UORVP sites excluding the AT site during the non-ozone season (an explanation for this is currently unknown), thus suggesting the presence of common sources of $PM_{2.5}$ and PM_{10} at these sites. The results also suggest that there is no simple linear correlation between either $PM_{2.5}$ or PM_{10} and ozone or sulfur dioxide at any of the four UORVP sites regardless of season.

4.2.4 Comparison of $PM_{2.5}$ Mass Concentrations Measured Using Integrated and Real-Time Sampling Equipment

The data presented below summarizes efforts from both continuous particulate measurements as well as those from discrete filter sampling. As much as was possible, comparisons were drawn between the sampling methodologies in addition to noting observed similarities or differences

between the rural and urban sites. Also of interest, were the correlations of the mass data with simultaneously acquired meteorological and ambient gas monitoring data

Table 11 lists the 7048 discrete filter samples that were acquired to during the sampling period. These are categorized by sampling device and inlet size. Also given in Table 11 are lists of the precursor gases and meteorological parameters that were measured along with the corresponding time periods in which these measurements were carried out.

Table 12 lists the number of filter samples that have been weighed and categorized by monitoring site, by inlet size ($PM_{2.5}$ or PM_{10}) and by sampling device. These results were reported by the Desert Research Institute, who performed analyses on samples from the Lawrenceville, Holbrook and Morgantown sites, and by Chester Lab Net, who carried out the analyses on samples acquired at the Athens site.

Table 13 lists the total number of 1314 samples on which chemical analysis was performed. These are also listed by monitoring site, by inlet size ($PM_{2.5}$, PM_{10} or Total Suspended Particulate) and by sampling device. These results were reported by the Desert Research Institute, who performed analyses on samples from the Lawrenceville, Holbrook and Morgantown sites, and by Chester Lab Net, who carried out the analyses on samples acquired at the Athens site. These results reflect QA/QC evaluation performed by the noted laboratories.

Table 14 is a tabulation of continuously collected data from June of 1999 through November of 2001. Included are all TEOM continuous gas monitor and meteorological data.

An examination of monthly average TEOM mass concentration values shows that, as expected, the PM_{10} values from the Lawrenceville site were considerably higher than the corresponding $PM_{2.5}$ values. Also, Lawrenceville $PM_{2.5}$ levels were slightly higher than the Holbrook (HB) $PM_{2.5}$ values. The only exception is noted with November 2000 data. Since the former is an

urban site and the latter a rural one, we conclude that the differences were a result of local urban activity contributions.

Seasonal differences were also exhibited by the TEOM data. Mass concentrations showed a maximum value in the summer and a minimum value in winter, with a gradual transition occurring between these major seasons. This trend was also observed with ozone levels and temperature measurements.

The discussion below presents data that shows that most of the ambient fine particulate in this part of the country is contributed from regional transport and that local effects play a minor role in the observed levels. The data also demonstrates that there is a correlation between wind direction and high levels of $PM_{2.5}$.

Plotted in Figure 9 are $PM_{2.5}$ half-hour averages of continuous measurements obtained using the TEOM balances for July 2000. For clarity, the individual points are not shown; only the connecting lines are presented in this figure. Data from the Lawrenceville site are shown in red, and data from the Holbrook site are presented in blue.

Immediately obvious is the fact that the data from the two sites show the same trends over this typical one-month time period. Since one site is urban (Lawrenceville) and the other rural (Holbrook), and the two sites are approximately 65 miles apart, the inference can be made that the minor variations in the measurements taken at any given time between the two sites can be attributed to local sources and that the overall similarity in the trending, results from the more pervasive regional background $PM_{2.5}$ levels. An interesting side note on the impact of local effects is the observation that the one measurement, higher than 100 $\mu g/M^3$, occurred at approximately 10:30 PM on July 4th and only at the Lawrenceville site. We strongly suspect that this was due to by-products released from a fireworks display at a local (City of Pittsburgh) Independence Day celebration.

Data shown as a time series in Figure 9 are used to compare the rates of concentration change between the two sites in Figure 10. Each point on the graph consists of an x-coordinate, which is the 24-hour difference in mass concentration for measurements taken at Lawrenceville at a given time and a y-coordinate, which is the 24-hour difference in mass concentration for measurements taken at Holbrook at the same time. This scatter plot compares the rate of change in concentration between the two sites. If, for example, concentration differences are close in value for the two sites at each point in time, the plot in Figure 10 will show the points lying close to the 45° line, $y = x$. Thus, the interpretation of the data shown in Figure 9 that the concentrations of $PM_{2.5}$ measured at Lawrenceville and at Holbrook show similar trending is further justified since the linear regression line in Figure 10 clearly shows a positive slope.

To quantify and graphically display the data similar to that shown in Figures 9 and 10, data were compiled for different months to reflect changing seasons. Figures 11 through 13 provide distributions of mass measurements (Threshold Concentration) versus a corresponding "Measurement Percentile" for the two major sites for each of the four seasons of the year over a two year period. Half-hour average mass concentration data were taken from both $PM_{2.5}$ and PM_{10} TEOM measurements. Data for each three-month season, approximately 4300 points, were sorted and plotted based on 1 $\mu g/M^3$ intervals from 0 $\mu g/M^3$ to 100 $\mu g/M^3$.

Figure 11 shows $PM_{2.5}$ TEOM data gathered at the Lawrenceville site and categorized by season into eight distribution curves from June 1999 through May 2001. Although the shape of the entire curve must be considered in describing these data distributions, the "Threshold Concentration" value at the 50th "Measurement Percentile" value can be used for quick comparisons. For example, the "Threshold Concentration" value at the 50th "Measurement Percentile" for the "summer 1999" curve was approximately 19 $\mu g/M^3$. Therefore, 19 $\mu g/M^3$ was the median value for this data set. This was the largest median value of the eight distribution curves. The corresponding 50th "Measurement Percentiles" for the "Winter 2000" was approximately 10 $\mu g/M^3$ and was the lowest value associated with any of the eight curves. In general, the Lawrenceville $PM_{2.5}$ median values were highest in summer and lowest in winter, with intermediate values observed in the spring and fall.

Figure 12 shows Lawrenceville PM_{10} data plotted in the same manner as in Figure 11. The corresponding 50th "Measurement Percentiles" for the "Summer 1999" and "Winter 2000" were approximately 26 $\mu g/M^3$ and 17 $\mu g/M^3$, respectively. That these values were higher than the corresponding values in Figure 11 is not surprising, since a PM_{10} value measured at any given time and place is expected to be equal to or greater than the value obtained from a collocated $PM_{2.5}$ measurement.

Figure 13 shows Holbrook $PM_{2.5}$ data plotted in the same manner as in Figure 12. The corresponding 50th "Measurement Percentiles" for the "Summer 1999" and "Winter 2000" were approximately 18 $\mu g/M^3$ and 8 $\mu g/M^3$, respectively. These values were very similar to those observed in Figure 11 for Lawrenceville. This again suggests that, as did the raw data presented in Figure 9, regional factors have more of an impact on mass concentration of the fine particulate, observed at both the urban and rural sites, than the corresponding local effects at either site.

Figure 14 shows a comparison between Lawrenceville and Holbrook $PM_{2.5}$ TEOM data plotted in the same manner as in Figures 11 through 13 over a one-year period from June 1999 to May

2000. The corresponding 50th "Measurement Percentiles" for Lawrenceville and Holbrook "Summer 1999" curves were approximately 19 $\mu g/M^3$ and 18 $\mu g/M^3$, respectively. The corresponding 50th "Measurement Percentiles" for Lawrenceville and Holbrook "Winter 2000" curves were approximately 10 $\mu g/M^3$ and 8 $\mu g/M^3$, respectively. Although these are the same values given in the discussion on Figures 11 and 13, Figure 14 demonstrates clearly that measurements made at the Lawrenceville site were slightly higher than those observed at the Holbrook site. This suggests that even though regional effects are responsible for the overall similar trending between the two sites, local urban activity is contributing to the slightly higher Lawrenceville values.

Figures 15 through 19 are yearly TEOM data distribution plots constructed in the same manner as the seasonal distribution plots given in Figures 11 through 14. Figures 15 through 17 present data from the Lawrenceville $PM_{2.5}$, the Holbrook $PM_{2.5}$ and the Lawrenceville PM_{10} TEOMs, respectively. These data must be interpreted with caution since data collection was initiated in June of 1999 resulting in this year being represented by only a six month period of measurements while both 2000 and 2001 plots encompass complete twelve month sets. Nevertheless, combined plots in Figures 18 and 19 demonstrate clear trends. Figure 18, which shows a comparison of $PM_{2.5}$ data at Lawrenceville and Holbrook, demonstrates that $PM_{2.5}$ concentrations are consistently higher at the urban Lawrenceville site than at the rural Holbrook site over this two and one half year period. Figure 19, which gives a comparison of $PM_{2.5}$ and PM_{10} data at Lawrenceville, demonstrates that over this period of time PM_{10} concentrations are consistently higher than the $PM_{2.5}$ concentrations at a given location.

A comparison was also drawn on the performance of the TEOMs relative to the discreet filter-based samplers. The latter included FRM as well as DRI-SFSs. Data from the 24-hour integrated filter sampling was plotted against values obtained by integrating corresponding 24-hour intervals on the TEOM traces. Figures 20 and 21 depict such traces for $PM_{2.5}$ data obtained for Lawrenceville and Holbrook. Evident from these traces was the good agreement between the discrete filter data and the TEOM measurements within experimental error. However, the FRM-obtained data is consistently lower than the averages from the TEOM/DRI-SFS measurements except for an anomalous June 5th occurrence at Holbrook, when the FRM value was observed to be higher than the other two. This was likely due to a sampling malfunction with the impactor allowing some PM_{10} through to the filter. There was also no statistically significant difference in the average levels determined by each of these sampling techniques except for the Holbrook June 5th data.

Another approach to comparing TEOM and SFS measurements is presented in Figure 22. Here, 6-hour SFS $PM_{2.5}$ mass concentration samples acquired during the Summer 1999 Intensive Sampling Program at Lawrenceville were plotted against the corresponding 6-hour TEOM averages. The 45^0 angle red line represents a theoretical fit in which the SFS values and the

TEOM averages are shown to be equivalent. The black line was determined by linear regression. It has a slope (m) equal to 0.9044 and an offset (b) equal to + 0.3714. The R^2 constant is 0.8971. The SFS measurements and the TEOM averages compare well since the slope of the regression line is close to that of 45^0 angle line (1.0000) and the R^2 constant of 0.8971 indicates a reasonably good line fit.

In summary, ***ATS*** examined the 24-hour average $PM_{2.5}$ mass concentrations that were measured using integrated and real-time sampling equipment.

(i) For each UORVP site, data sets were generated that sorted the 24-hour average $PM_{2.5}$ mass concentrations by the common sample date (not examining seasonal variations in $PM_{2.5}$ mass concentrations here). The correlation coefficient (r) for each pairing of interest was calculated. The results are as follows (please see Table 1 for the equipment legend):

Site	$PM_{2.5}$ Pairing	r value	Conclusion
AT	SASS / OH EPA (FRM) (61)	0.76	Good positive correlation between these two integrated samplers
HB	DRI / FRM (69)	0.96	Very good positive correlation between these two integrated samplers
LW	DRI / FRM (57)	0.90	Very good positive correlation between these two integrated samplers
LW	DRI / TEOM (53)	0.89	Very good positive correlation between this integrated sampler and real-time sampler
LW	FRM / TEOM (36)	0.88	Very good positive correlation between this integrated sampler and real-time sampler
MO	DRI / WV DEP (FRM) (74)	0.80	Good positive correlation between these two integrated samplers

SASS - Met-One speciation sampler
OH EPA / WV DEP - Federal Reference Method Samplers (FRM)

A scatter plot for each pairing also confirms the positive correlation. The value in parenthesis in the second column lists the number of available pairings. Pictorially, this is shown in Figures 20 & 21 for Lawrenceville and Holbrook. The 24-hour TEOM and filter sample averages are superimposed on the TEOM races for both sites.

(ii) For each UORVP site, data sets were generated that calculated the differences for each pairing of interest. A statistical hypothesis test was run to determine if the average difference for each pairing was significantly different from zero at the 95 percent confidence level. The results are as follows:

Site	$PM_{2.5}$ Pairing	Conclusion
AT	SASS / OH EPA (61)	The average difference is significantly different from zero (SASS < OH EPA)
HB	DRI / FRM (69)	The average difference is significantly different from zero (DRI > FRM)
LW	DRI / FRM (57)	Insufficient data to conclude that the average difference is significantly different from zero
LW	DRI / TEOM (53)	The average difference is significantly different from zero (DRI > TEOM)
LW	FRM / TEOM (36)	The average difference is significantly different from zero (FRM > TEOM)
MO	DRI / WV DEP (74)	The average difference is significantly different from zero (DRI > WV DEP)

The results presented above suggest the following:

- In comparing the DRI with the FRM, the results show different conclusions for identical tests performed at two separate sites. The reasons for the statistically significant average difference at the HB site are currently unknown.

- At the LW site, the $PM_{2.5}$ mass concentrations generated by the TEOM were statistically lower than those generated either by the DRI or FRM integrated sampling equipment. Other researchers have also reported the same conclusion – please see the following reference links:

  http://www.awma.org/journal/ShowAbstract.asp?Year=1997&PaperID=384

  http://bronze.nescaum.org/committees/monitoring/nov03meeting/Dirk-TEOMconvJulian.ppt

  http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=9180064&dopt=Abstract

  http://www.awma.org/journal/ShowAbstract.asp?Year=2002&PaperID=985

4.3 Data Collected During the Intensive Sampling Periods

ATS elected to utilize a statistical approach in an attempt to assimilate the voluminous quantity of ambient air data collected during the intensive sampling periods. As previously stated, ***ATS*** assumed that the populations of $PM_{2.5}$ and PM_{10} mass concentrations at the UORVP sites have a normal distribution.

Figures 25 through 27 give a breakdown of the distribution of major chemical species on samples taken at the Lawrenceville and Holbrook sites during the 1999 Winter and the 1999 Summer Intensive Sampling Programs. The percent distributions of the species were based on the total mass as captured on the filters.

A typical **pie chart** contains the following components:

1) **Geological** = 1.89*Al + 2.14*Si + 1.4*Ca + 1.43*Fe (elements from XRF)
2) **Organics** = 1.4*Organic Carbon (TOR)
3) **Elemental Carbon** (TOR)
4) **Nitrate** = Nitrate (IC)
5) **Sulfate** = Sulfate (IC)
6) **Ammonium** = ammonium (AC)
7) **Trace elements** = Sum of XRF species - (Al + Si + Ca + Fe + S)
8) **Unidentified** = Total mass - sum of items (1-7)

The road salt component [**Road Salt** = 1.65*Cl (XRF)] was not included. Generally this parameter depends upon location and season.

Figure 25 shows a comparison of chemical composition between Lawrenceville and Holbrook for samples obtained during the Winter 1999 Intensive Sampling Program, while Figure 26 presents a comparison between Lawrenceville and Holbrook for samples obtained during the Summer 1999 Intensive Sampling Program. Several clear distinctions in the chemical make-up of the samples can be made. First, in winter the nitrate component is larger in particulate matter ($PM_{2.5}$) captured at Lawrenceville (18%) than that collected at Holbrook (7%). In summer, nitrate is barely detectable at either site (0-1%). Second, ammonium ion appears fairly constant between sites and between seasons, ranging between 12% and 14% of total sample mass. Third, sulfate represents a much larger percentage of the sample composition at Holbrook (44% in summer, 33% in winter) than at Lawrenceville (34% in summer, 26% in winter), and appears as a larger fraction in the summer than in the winter.

Figure 27 compares chemical compositions for $PM_{2.5}$ and PM_{10} for samples collected at Lawrenceville during the 1999 Winter Intensive. Fine particulate matter ($PM_{2.5}$) is generally expected to form through nucleation processes following chemical reactions, while coarser particulate matter (PM_{10}) is more likely to be formed through abrasive processes. This idea is consistent with the observation that the PM_{10} fraction has a much larger fraction of geological material (16%) than the $PM_{2.5}$ fraction (3%). Conversely, the $PM_{2.5}$ fraction has the larger percentages of volatile components, including nitrate, sulfate, ammonium and total carbon, than the PM_{10} fraction.

Figures 28 through 39 reveal information on the stoichiometry of the major cations and anions present in the fine particulate matter and their relationship to the total mass concentration.

Figure 28 is a plot of the ammonium mass concentration vs. sulfate mass concentration, with the corresponding linear regression line, for 36 (6-hour) SFS samples collected during the 1999 Winter Intensive Sampling Program at the Lawrenceville site. The molar ratio of ammonium ion (NH_4^+) to sulfate ion (SO_4^{2-}), calculated from the slope of the regression line, was determined to be 2.29. The theoretical stoichiometric value for ammonium bisulfate (NH_4HSO_4) is 1.00 and for ammonium sulfate ($(NH_4)_2SO_4$) is 2.00. A value greater than 2.00 suggests the presence of other anions since a mixture of NH_4HSO_4 and $(NH_4)_2SO_4$ must give a value between 1.00 and 2.00. Consistent with this unexpectedly higher ratio is the presence of nitrate ion (NO_3^-) since it represents 18% (Figure 25) of the total mass. This additional amount of anionic material probably satisfies charge balance requirements demanded by the excess ammonium ion.

Figure 29 is a plot of sulfate mass concentration vs. $PM_{2.5}$ mass concentration, and Figure 30 is a plot of ammonium mass concentration vs. $PM_{2.5}$ mass concentration for 36 SFS samples collected during the 1999 Winter Intensive Sampling Program at Lawrenceville. Slopes of the corresponding linear regression lines provide an overall estimate of the ammonium and sulfate fractions of the total mass. The approximate percentage of the total sample mass that the sulfate ion (or the ammonium ion) represents is determined by multiplying the value of the slope by 100. Thus, sulfate ion and ammonium ion are calculated to be 28% and 14%, respectively, of the total sample mass, which compare well with the values given in Figure 25 of 26% and 14%, respectively.

Figure 31 is a plot of ammonium mass concentration vs. sulfate mass concentration, with the corresponding linear regression line, for 9 (24-hour) SFS samples collected during the 1999 Winter Intensive Sampling Program at the Holbrook site. Again, the molar ratio of ammonium ion to sulfate ion was calculated from the slope of the regression line and determined to be 1.91. This is close to the theoretical value for ammonium sulfate.

Figure 32 is a plot of sulfate mass concentration vs. $PM_{2.5}$ mass concentration, and Figure 33 is a plot of ammonium mass concentration vs. $PM_{2.5}$ mass concentration for 9 SFS samples collected during the 1999 Winter Intensive Sampling Program at Holbrook. The linear regression lines for both plots fail to intercept the origin resulting in a negative value for the y-intercept. We propose that this non-zero intercept may reflect losses of ammonium and sulfate ions from the samples. This apparent loss of sample mass occurred at Holbrook and not at Lawrenceville during the Winter Intensive, probably because the 6-hour Lawrenceville samples were recovered and refrigerated sooner than the corresponding 24-hour Holbrook samples, after the completion of the sampling.

Figure 34 is a plot of the ammonium mass concentration vs. sulfate mass concentration, with the corresponding linear regression line, for 37 (6-hour) SFS samples collected during the 1999 Summer Intensive Sampling Program at the Lawrenceville site. The molar ratio of ammonium ion (NH_4^+) to sulfate ion (SO_4^{2-}), calculated from the slope of the regression line, was determined to be 1.67. This suggests a sizable presence of ammonium bisulfate (NH_4HSO_4) in addition to ammonium sulfate ($(NH_4)_2SO_4$). A value between 1.00 and 2.00 would be anticipated from a mixture of NH_4HSO_4 and $(NH_4)_2SO_4$ without the presence of other anions. This is consistent with the low nitrate ion (NO_3^-) concentration of 1% (Figure 26) for samples collected during the warm summer season.

Figure 35 is a plot of sulfate mass concentration vs. $PM_{2.5}$ mass concentration, and Figure 36 is a plot of ammonium mass concentration vs. $PM_{2.5}$ mass concentration for 37 SFS samples collected during the 1999 Summer Intensive Sampling Program at Lawrenceville. Again, the linear regression lines for both plots fail to intercept the origin resulting in a negative value for the y-intercept. Since this suggests that some amount of ammonium and sulfate ions was lost from each sample and this effect was not seen at the Lawrenceville site during the Winter Intensive, we propose that the loss of volatile material occurs at a much higher rate during high summer temperatures than at the relatively cooler winter temperatures.

Figure 37 is a plot of ammonium mass concentration vs. sulfate mass concentration, with the corresponding linear regression line, for 10 (24-hour) SFS samples collected during the 1999 Summer Intensive Sampling Program at the Holbrook site. Again, the molar ratio of ammonium ion to sulfate ion was calculated from the slope of the regression line. It was determined to be 1.57, which is close to the theoretical value for a 50%/50% mixture of ammonium sulfate and ammonium bisulfate. This result is also consistent with the absence of nitrate in the samples (Figure 26).

Figure 38 is a plot of sulfate mass concentration vs. $PM_{2.5}$ mass concentration, and Figure 39 is a plot of ammonium mass concentration vs. $PM_{2.5}$ mass concentration for 10 SFS samples collected during the 1999 Summer Intensive Sampling Program at Holbrook. Again, the linear regression lines for both plots fail to intercept the origin resulting in a negative value for the y-intercept, suggesting that some amount of ammonium and sulfate ions was lost from each sample. We submit that this effect is probably the result of a significant loss of volatile material from the samplers due to the high summer temperatures.

Wind trajectory calculations were performed in order to relate wind direction to possible $PM_{2.5}$ sources. Figure 40 shows the results from a typical wind trajectory model calculation provided at the NOAA Air Resources Laboratory's website. This example shows the results from a calculation to determine the path that a parcel of air traversed in a given 24-hour period when a destination (in this case Lawrenceville), a time and a final altitude are given.

Figure 41 is a plot in polar coordinates of mass concentration ($\mu g/M^3$) as 'r' determined by averaging 6-hour TEOM measurements, against wind direction as 'θ' derived from wind trajectories determined for the appropriate 6-hour period. Thus, the distance from the origin is a measure of particulate matter mass concentration and the angle, or simply geographic direction, indicates the direction of the wind at that time. These calculations were performed for July 1999 at the Lawrenceville site. Figure 41 shows that at times of high $PM_{2.5}$ concentration, the wind is usually out of the South-West direction. This suggests the possibility of major sources of $PM_{2.5}$ being in that direction.

Figure 42 is the same type of plot shown in Figure 41; however, it shows data from the Lawrenceville site for July 2000. Although it is apparent that most high mass concentration points correlate with the South-West direction, some also arise out of the North-West. Points indicating low mass concentrations appear in the North-East quadrant similar to those seen in Figure 41. However, a greater number appear in Figure 42. This is simply a consequence of the fact that overall $PM_{2.5}$ levels were higher in July of 1999 than in July of 2000. The plot in Figure 43 easily verifies this fact since the corresponding 50th "Measurement Percentiles" for July 1999 and July 2000 were approximately 21 $\mu g/M^3$ and 18 $\mu g/M^3$, respectively.

Figures 44 and 45 are plots of ozone concentrations against NO_X concentrations for measurements taken at the Lawrenceville site during the Summer of 2001 and the Winter of 2002, respectively. Both plots show that whenever one species is present at a high concentration the other tends to be observed at a lower concentration. We propose that this effect is probably a result of chemical reaction between the two moieties. Thus, whenever one species is in stoichiometric excess of the other, chemical reaction occurs at a significant rate until the concentration of the latter is driven down to a very low level. At this point, reaction effectively stops leaving a relatively large concentration of the initially higher concentration species and a very low concentration of the initially lower concentration species.

4.3.1 Chemical Composition of $PM_{2.5}$ Samples and Correlations with Nitric Acid and Ammonia Gas Concentrations

Data sets were generated that grouped the $PM_{2.5}$ samples collected during the intensive sampling periods by season of the year (fall, winter or summer). ***ATS*** examined the chemical speciation data on a site and seasonal basis to determine the primary elements or ions that comprise $PM_{2.5}$. The results are as follows:

6-Hour or 24-Hour Average $PM_{2.5}$ Samples – 50th Percentile Values

Parameter		LW Fall (38)	LW Winter (52)	LW Summer (133)		AT Summer (23)	HB Summer (25)
Mass Concentration ($\mu g/m^3$)		10.1	12.9	20.7		10.9	19.6
Organic Carbon / Mass (ratio)		0.29	0.16	0.24		N/A	0.19
Elemental Carbon / Mass (ratio)		0.11	0.08	0.09		N/A	0.05
Ammonium Ion (NH_4^+) / Mass (ratio)		0.15	0.16	0.16		N/A	0.14
Sulfate Ion (SO_4^{2-}) / Mass (ratio)		0.32	0.31	0.44		0.43	0.45
Nitrate Ion (NO_3^-) / Mass (ratio)		0.09	0.18	0.03		N/A	0.02
Total Sodium (Na) / Mass (ratio)		0.01	0.01	0.02		N/A	0.01
Total Potassium (K)/Mass (ratio)		0.01	0.00	0.00		N/A	0.00
Total Iron (Fe) / Mass (ratio)		0.01	0.01	0.01		N/A	0.00
Σ Chemical Speciation Ratios		0.98	0.90	0.98		N/A	0.86
NH_4^+ / SO_4^{2-} (equivalents ratio)		1.13	1.28	0.95		N/A	0.86
NH_4^+ / NO_3^- (equivalents ratio)		5.12	3.01	19.68		N/A	28.29

6-hour samples – LW

24-hour samples – AT & HB

The value in parenthesis lists the number of available samples. There was an insufficient number of samples (< 20) for the AT winter, HB Winter, MO summer and MO winter groupings. Correlations of $PM_{2.5}$ samples collected during the intensive sampling with selected chemical species are presented below:

6-Hour or 24-Hour Average $PM_{2.5}$ Samples – Selected Correlations

Parameter (Conc.)		LW Fall	LW Winter	LW Summer		AT Summer	HB Summer
Sulfate Ion		0.93 (38)	0.83 (52)	0.96 (133)		0.93 (23)	0.97 (25)
Organic Carbon		0.78 (38)	0.46 (52)	0.67 (133)		N/A	0.57 (25)
Nitric Acid Gas		N/A	0.25 (68)	0.63 (161)		N/A	0.68 (36)
Ammonia Gas		N/A	0.34 (54)	0.16 (130)		N/A	0.14 (31)

The value in parenthesis lists the number of available pairings. The results presented above suggest the following:

- In general, $PM_{2.5}$ is primarily composed of the following elements and ions (listed in descending order of abundance): sulfate ion, organic carbon, ammonium ion, elemental carbon and nitrate ion.
- Particulate sulfate content is greater in the summer as compared with the winter values at the LW site, which is likely due to the presence of photochemically active oxidizing compounds (e.g., ozone, hydrogen peroxide) during the summer. Particulate sulfate concentration is strongly correlated with $PM_{2.5}$ concentration at the AT, HB and LW sites regardless of season.
- Particulate ammonium contents are essentially the same at the LW site regardless of season. As such, changes in the ratio of particulate ammonium to particulate sulfate (equivalents basis) are dictated by changes in particulate sulfate content. For reference, ammonium sulfate $\{(NH_4)_2SO_4\}$ has an equivalence ratio equal to 1.0 while ammonium bisulfate $\{NH_4HSO_4\}$ has an equivalence ratio equal to 0.5. Assuming that the sulfate is associated with ammonium, the results suggest that the ammonium sulfate-type compound is acidified in the summer as compared with the winter at the LW site, which is likely due to the presence of photochemically-produced acids (e.g., nitric acid) during the summer. There is a reasonably good correlation between summer nitric acid gas concentrations and $PM_{2.5}$ concentration at the HB and LW sites.
- Particulate nitrate content is lower during the summer as compared with the winter at the LW site. This result is expected if the available particulate nitrate is associated with particulate ammonium. The equilibrium between particulate ammonium nitrate $\{NH_4NO_3\}$, nitric acid gas $\{HNO_3\}$ and ammonia gas $\{NH_3\}$ is strongly dependent on ambient temperature (the equilibrium is shifted toward the gaseous compounds at higher temperatures). The equivalents ratio of NH_4^+ / NO_3^- suggests an excess of particulate ammonium relative to particulate nitrate at both sites regardless of season.
- In general, there are no simple linear correlations between $PM_{2.5}$ and particulate organic carbon or ozone for the groupings presented above.

4.3.2 Diurnal Variations of LW $PM_{2.5}$ and PM_{10} Mass Concentrations – Integrated Sampling Equipment

For the LW site, ***ATS*** examined the 6-hour integrated $PM_{2.5}$ and PM_{10} mass concentrations to determine the presence of diurnal variations of these concentrations. For $PM_{2.5}$ and PM_{10}, ***ATS*** calculated the difference in the concentrations for each consecutive 6-hour sampling period (e.g., concentration for [0600 to 1200] time period minus the concentration for the [0000 to 0600] time period). Composite data sets were generated that sorted the differences by the common sampling comparison period and the season of the year (summer or winter). A statistical hypothesis test was run to determine if the average difference for each seasonal sampling comparison period is significantly different from zero at the 95 percent confidence level. The results are as follows:

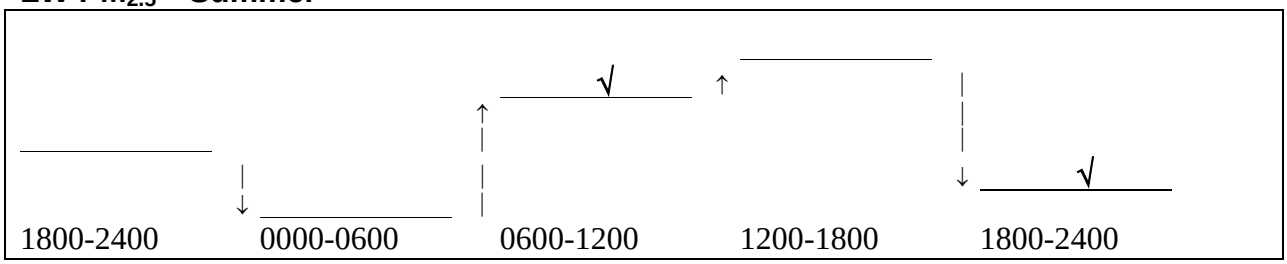
<u>Legend</u>

↑ Average difference in concentration for consecutive 6-hour sampling periods > 0

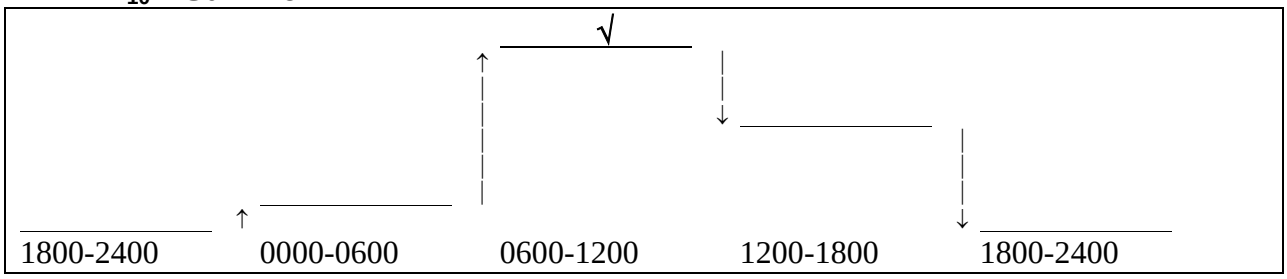
↓ Average difference in concentration for consecutive 6-hour sampling periods < 0
(size of ↑ and ↓ approximates the value of the average difference = 0.5 μg/M^3)

√ Average difference is significantly different from zero

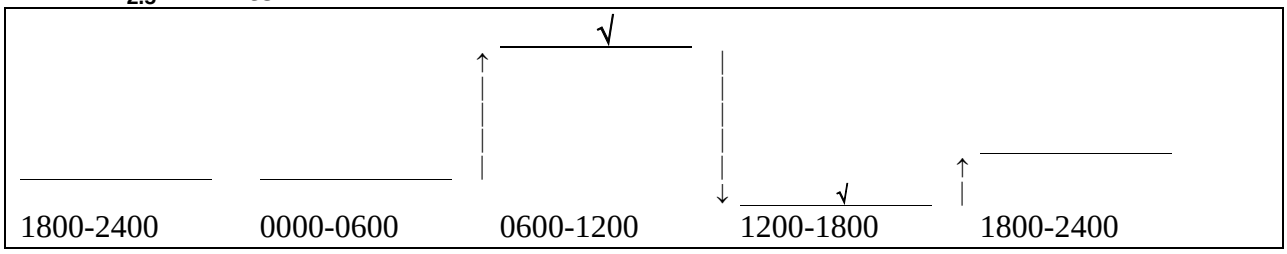
LW $PM_{2.5}$ – Summer



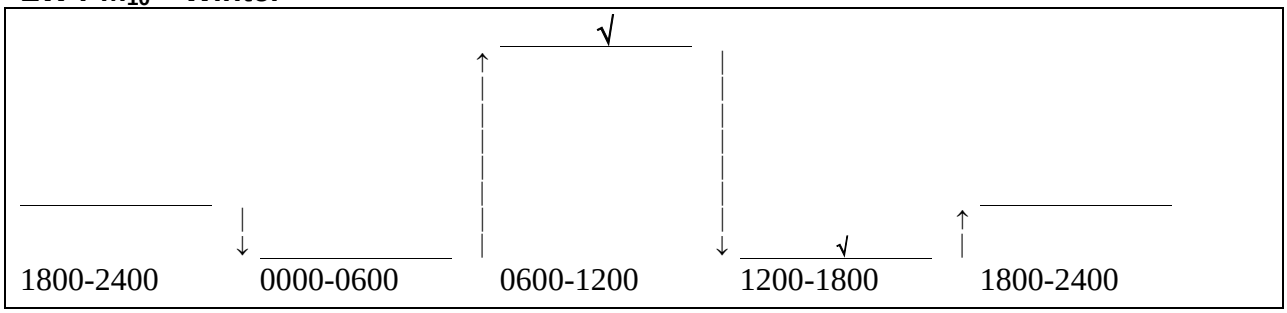
LW PM_{10} – Summer



LW $PM_{2.5}$ – Winter



LW PM_{10} – Winter



Similar patterns are presented for all four scenarios. Increases in $PM_{2.5}$ and PM_{10} mass concentrations during the morning hours (0600 – 1200) are likely due to inputs from automotive sources and decreases in the atmospheric mixing height. Eventual decreases in $PM_{2.5}$ and PM_{10} mass concentrations during the afternoon or evening hours are likely due to increases in the atmospheric heights. The increase in the summer $PM_{2.5}$ and mass concentration from the morning hours to the afternoon hours is likely due to the occurrence of atmospheric photochemical activity (recall that there is a reasonably good correlation between summer nitric acid gas concentrations and $PM_{2.5}$ concentration).

5.0 CONCLUSIONS

5.1 Summary of Findings

The following can be concluded from the findings presented in Section 4:

Samples Collected During the Background Sampling Periods

- There are positive correlations of $PM_{2.5}$ mass concentrations among the four UORVP sites. The value of the correlation coefficient suggests that both regional and local sources contribute to $PM_{2.5}$ at these sites.
- The $PM_{2.5}$ mass concentrations are statistically higher at the urban sites as compared with the rural site (MO > LW > HB > AT). Please also note that the eastern-most sites had the highest $PM_{2.5}$ mass concentrations, thus suggesting that regional transport of air masses may also be contributing to $PM_{2.5.}$
- The overall average $PM_{2.5}$ mass concentrations measured at the HB, LW and MO sites are very nearly equal to the promulgated annual standard of 15 $\mu g/M^3$ but far less than the 24-hour standard of 65 $\mu g/M^3$. The $PM_{2.5}$ mass concentrations are higher during the ozone season as compared with the non-ozone season at all four UORVP sites.
- There are positive correlations of PM_{10} mass concentrations among the four UORVP sites. The value of the correlation coefficient suggests that both regional and local sources contribute to PM_{10} at these sites.
- The PM_{10} mass concentrations are statistically higher at the urban sites as compared with the rural sites (MO ≅ LW > HB > AT). Please also note that the eastern-most sites had the highest PM_{10} mass concentrations, thus suggesting that regional transport of air masses may also be contributing to $PM_{10.}$
- The overall average PM_{10} mass concentrations measured at the four UORVP sites are far less than the promulgated annual standard of 50 $\mu g/M^3$ and the 24-hour standard of 150 $\mu g/M^3$. The PM_{10} mass concentrations are higher during the ozone season as compared with the non-ozone season at all four UORVP sites.
- There are reasonably good (or better) correlations between $PM_{2.5}$ and PM_{10} at the four UORVP sites excluding the AT site during the non-ozone season (an explanation for this is currently unknown), thus suggesting the presence of common sources of $PM_{2.5}$ and PM_{10} at these sites. There are no simple linear correlations between either $PM_{2.5}$ or PM_{10} and ozone or sulfur dioxide at any of the four UORVP sites regardless of season.
- At the LW site, the $PM_{2.5}$ mass concentrations generated by the TEOM were statistically lower than those generated either by the DRI or FRM integrated sampling equipment. Other researchers have also reported the same conclusion.

Samples Collected During the Intensive Sampling Periods

- In general, $PM_{2.5}$ is primarily composed of the following elements and ions (listed in descending order of abundance): sulfate ion, organic carbon, ammonium ion, elemental carbon and nitrate ion.
- Particulate sulfate content is greater in the summer as compared with the winter at the LW site, which is likely due to the presence of photochemically active oxidizing compounds (e.g., ozone, hydrogen peroxide) during the summer. Particulate sulfate concentration is strongly correlated with $PM_{2.5}$ concentration at the AT, HB and LW sites regardless of season.
- Particulate ammonium content is essentially the same at the LW site regardless of season. As such, changes in the ratio of particulate ammonium to particulate sulfate (equivalents basis) are dictated by changes in particulate sulfate content. For reference, ammonium sulfate {$(NH_4)_2SO_4$} has an equivalence ratio equal to 1.0 while ammonium bisulfate {NH_4HSO_4} has an equivalence ratio equal to 0.5. Assuming that the sulfate is associated with ammonium, the results suggest that the ammonium sulfate-type compound is acidified in the summer as compared with the winter at the LW site, which is likely due to the presence of photochemically-produced acids (e.g., nitric acid) during the summer. There is a reasonably good correlation between summer nitric acid gas concentrations and $PM_{2.5}$ concentration at the HB and LW sites.
- Particulate nitrate content is lower during the summer as compared with the winter at the LW site. This result is expected if the available particulate nitrate is associated with particulate ammonium. The equilibrium between particulate ammonium nitrate {NH_4NO_3}, nitric acid gas {HNO_3} and ammonia gas {NH_3} is strongly dependent on ambient temperature (the equilibrium is shifted toward the gaseous compounds at higher temperatures). The equivalents ratio of NH_4^+ / NO_3^- suggests an excess of particulate ammonium relative to particulate nitrate at both sites regardless of season.
- In general, there are no simple linear correlations between $PM_{2.5}$ and particulate organic carbon or ozone for the groupings presented above.
- Similar diurnal patterns of $PM_{2.5}$ and PM_{10} mass concentrations at the LW sites were observed (four scenarios). Increases in $PM_{2.5}$ and PM_{10} mass concentrations during the morning hours (0600 – 1200) are likely due to inputs from automotive sources and decreases in the atmospheric mixing height. Eventual decreases in $PM_{2.5}$ and PM_{10} mass concentrations during the afternoon or evening hours are likely due to increases in the atmospheric heights. The increase in the summer $PM_{2.5}$ and mass concentration from the morning hours to the afternoon hours is likely due to the occurrence of atmospheric photochemical activity (recall that there is a reasonably good correlation between summer nitric acid gas concentrations and $PM_{2.5}$ concentration).
- Most high PM2.5 episodes occurred when the predominating wind direction was from the South-West.

5.2 Implications

Historically, regions within the UORV that were initially designated to be in non-attainment with the PM_{10} ambient air standards were primarily localized industrial areas (e.g., Clairton, PA). As such, the SIPs for these areas focused on controlling air emissions from selected industrial facilities in an attempt to obtain attainment status with respect to the 24-hour PM_{10} standard (there were no regions within the UORV that were designated to be in non-attainment with respect to the annual PM_{10} standard). By comparison, the data obtained as part of the UORVP suggests that many regions within the UORV may be designated as non-attainment with respect to the annual $PM_{2.5}$ standard. If this is realized, then the SIPs will likely mandate reducing air emissions of $PM_{2.5}$ and/or its precursor gases from a large number of stationary, mobile and area sources that are located within a large geographical area. It should be noted that the UORV states (OH, PA and WV) submitted to the U.S. EPA in February 2004 a list of areas (counties) recommended to be designated to be in non-attainment with the $PM_{2.5}$ standards (please refer to the following reference links: http://www.epa.gov/pmdesignations/regions/region3.htm and http://www.epa.gov/pmdesignations/regions/region5.htm). The U.S. EPA responded to the state recommendations in April 2004. The U.S. EPA expects that the designations will be finalized by December 31, 2004.

6.0 ACKNOWLEDGEMENTS

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COMPARATIVE EVALUATION OF AMBIENT FINE PARTICULATE MATTER ($PM_{2.5}$) DATA OBTAINED FROM URBAN AND RURAL MONITORING SITES ALONG THE UPPER Ohio River VALLEY

FINAL TECHNICAL REPORT
OCTOBER 1, 1998 THROUGH DECEMBER 31, 2004

Submitted to:

U. S. Department of Energy
National Energy Technology Laboratory
Pittsburgh, PA 15236

DOE AWARD NUMBER: DE-AC26-98FT40456

APPENDIX A

Digital Images of the UORVP Air Monitoring Sites

COMPARATIVE EVALUATION OF AMBIENT FINE PARTICULATE MATTER ($PM_{2.5}$) DATA OBTAINED FROM URBAN AND RURAL MONITORING SITES ALONG THE UPPER OHIO RIVER VALLEY

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APPENDIX B

Data Used for the Statistical Analyses

(Please see the spreadsheet files saved on the enclosed compact disk)

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Figure 1

Location of the UORVP Air Monitoring Sites and Neighboring Coal-Fired Electric Utility Plants

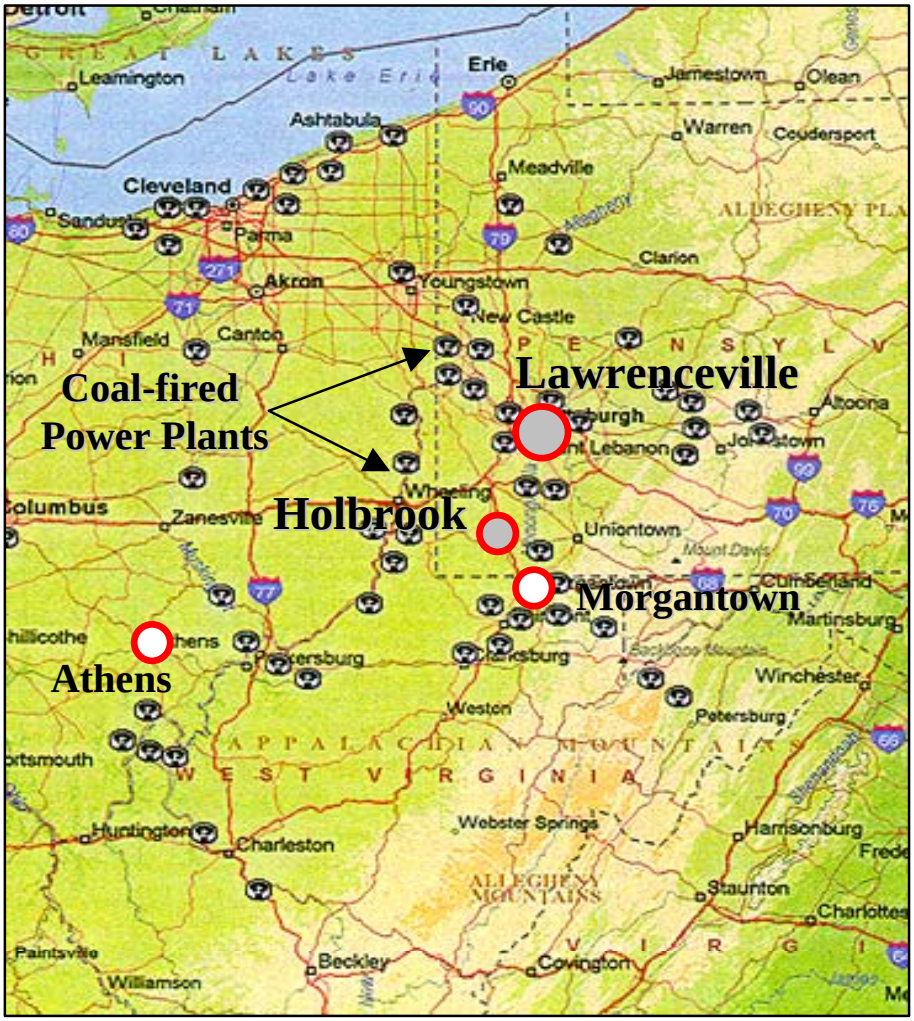

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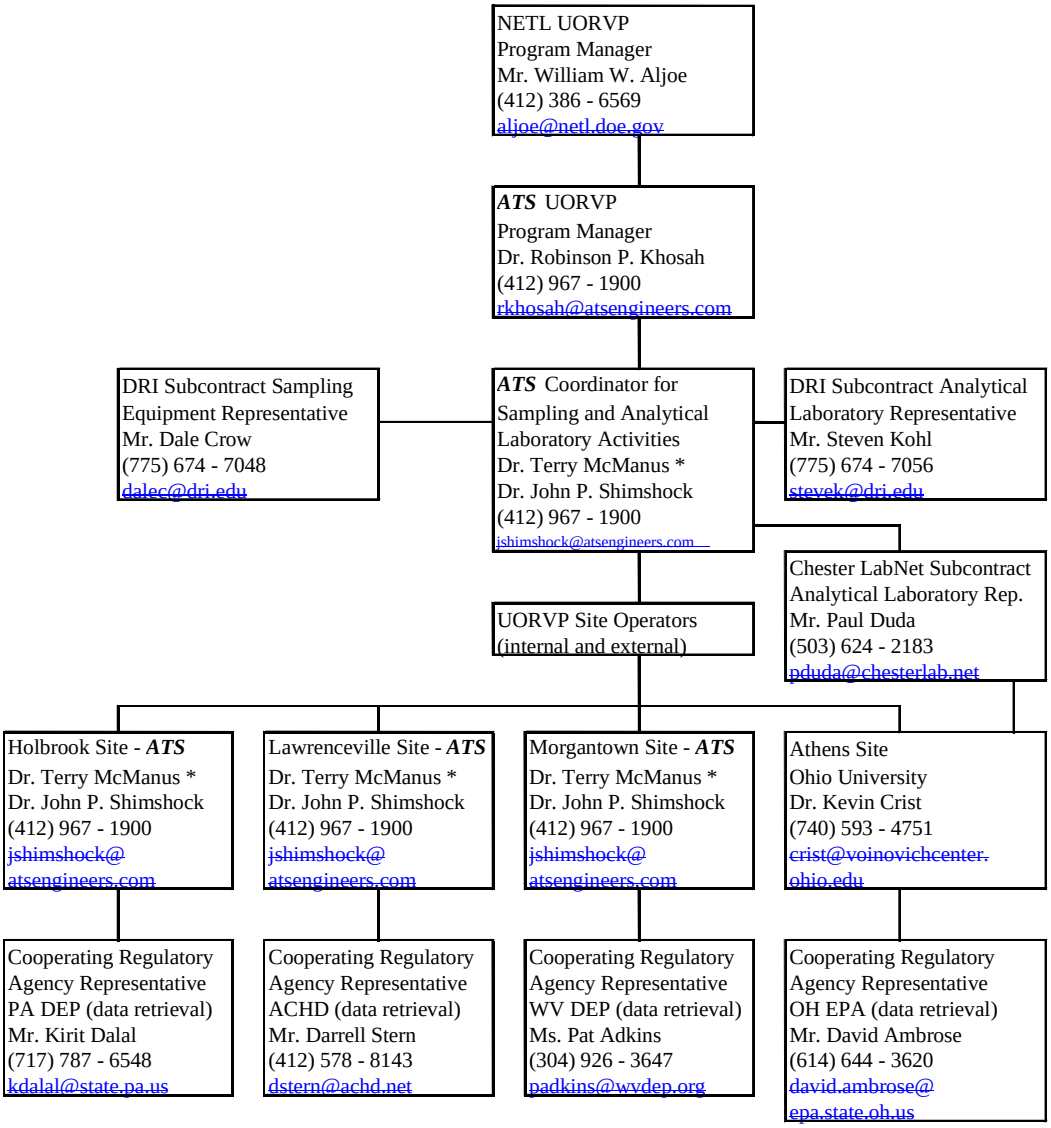
FIGURE 2

UORVP ORGANIZATION CHART



*: Currently with West Virginia University - Morgantown, WV

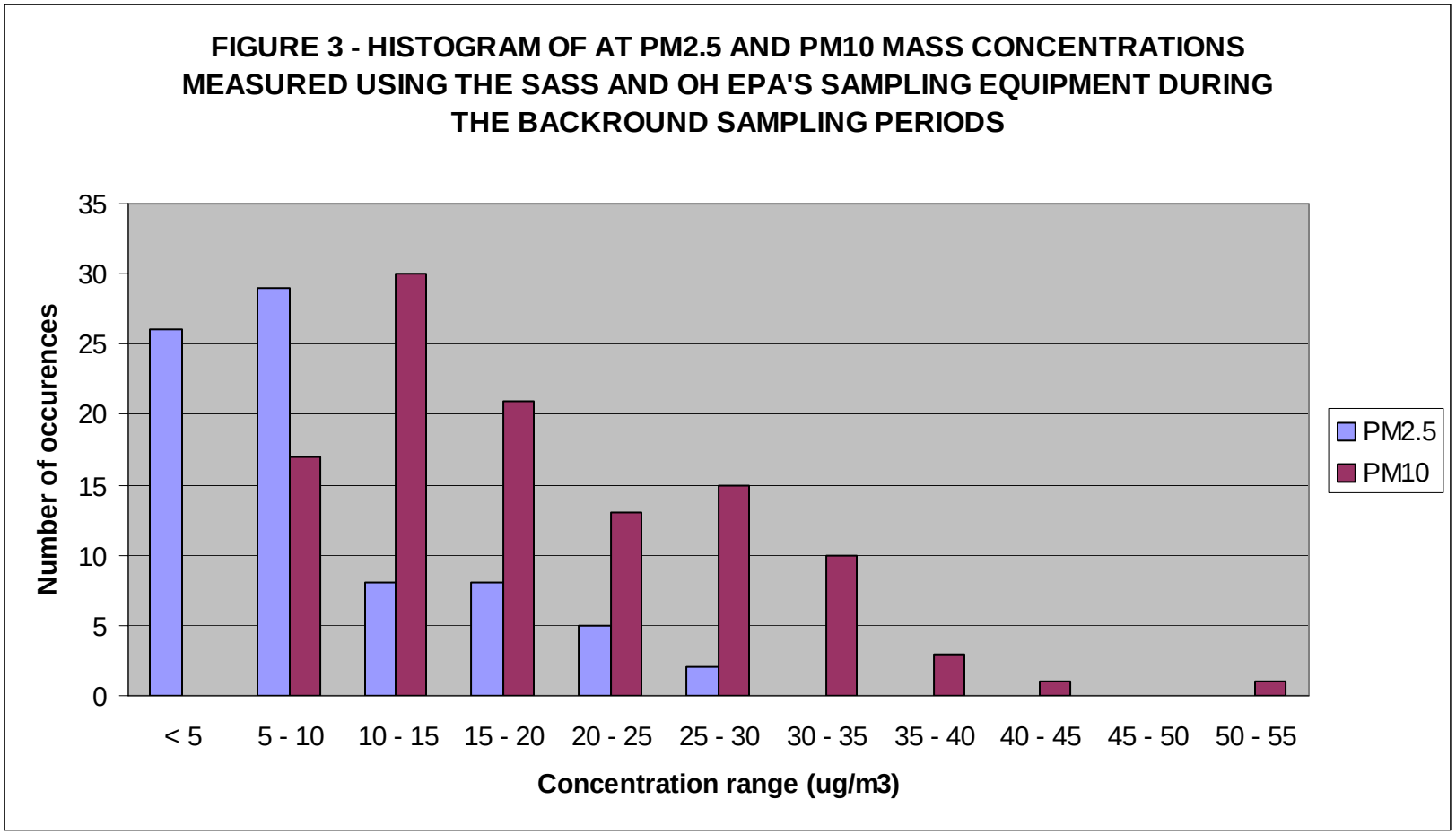


FIGURE 3 - HISTOGRAM OF AT PM2.5 AND PM10 MASS CONCENTRATIONS MEASURED USING THE SASS AND OH EPA'S SAMPLING EQUIPMENT DURING THE BACKROUND SAMPLING PERIODS
Number of occurences
35
30
25
20
15
10
5
0
< 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
Concentration range (ug/m3)
PM2.5
PM10

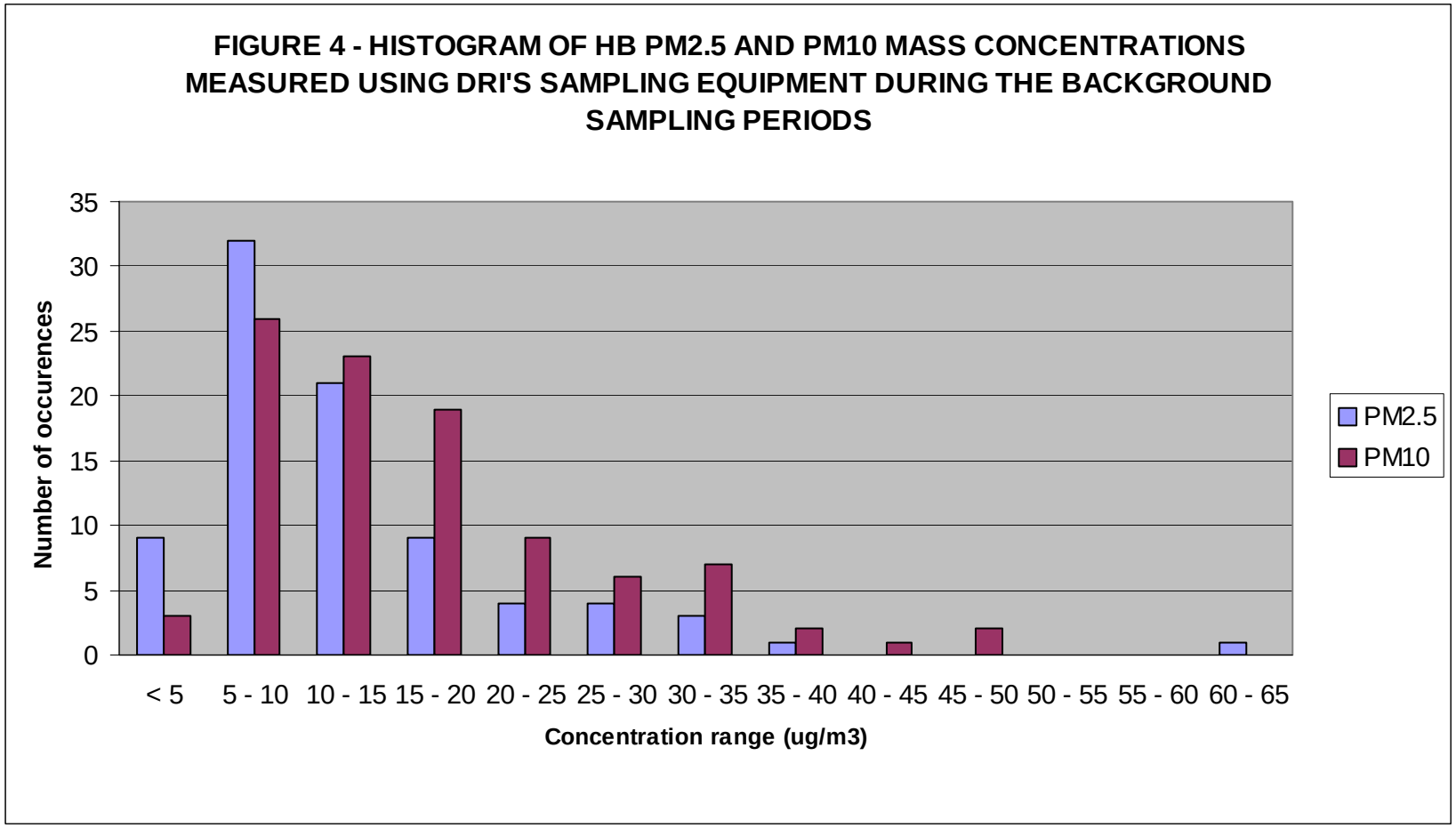


FIGURE 4 - HISTOGRAM OF HB PM2.5 AND PM10 MASS CONCENTRATIONS MEASURED USING DRI'S SAMPLING EQUIPMENT DURING THE BACKGROUND SAMPLING PERIODS
Number of occurences
35
30
25
20
15
10
5
0
< 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
Concentration range (ug/m3)
PM2.5
PM10

FIGURE 5 - HISTOGRAM OF LW PM2.5 AND PM10 MASS CONCENTRATIONS MEASURED USING DRI'S SAMPLING EQUIPMENT DURING THE BACKGROUND SAMPLING PERIODS

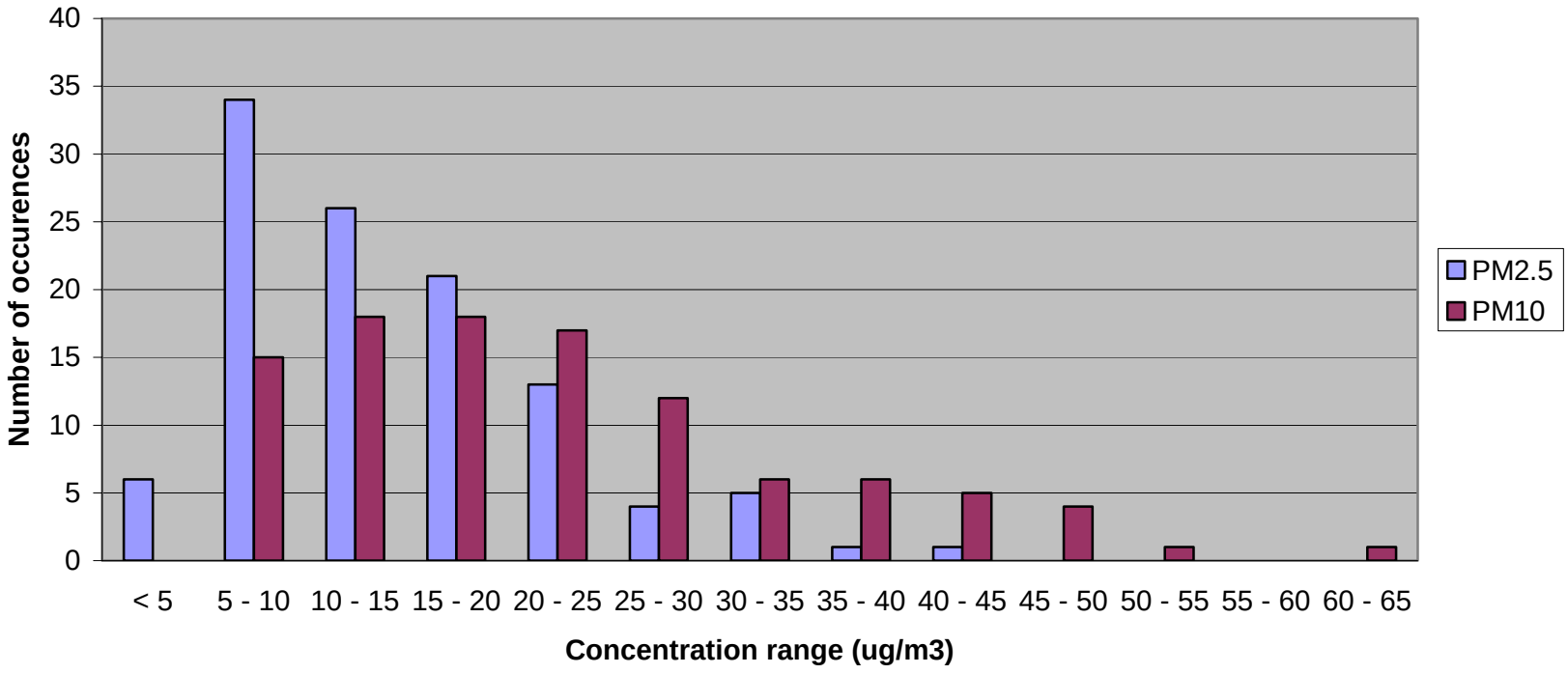


FIGURE 6 - HISTOGRAM OF MO PM2.5 AND PM10 MASS CONCENTRATIONS MEASURED USING DRI'S AND WV DEP'S SAMPLING EQUIPMENT DURING THE BACKGROUND SAMPLING PERIODS

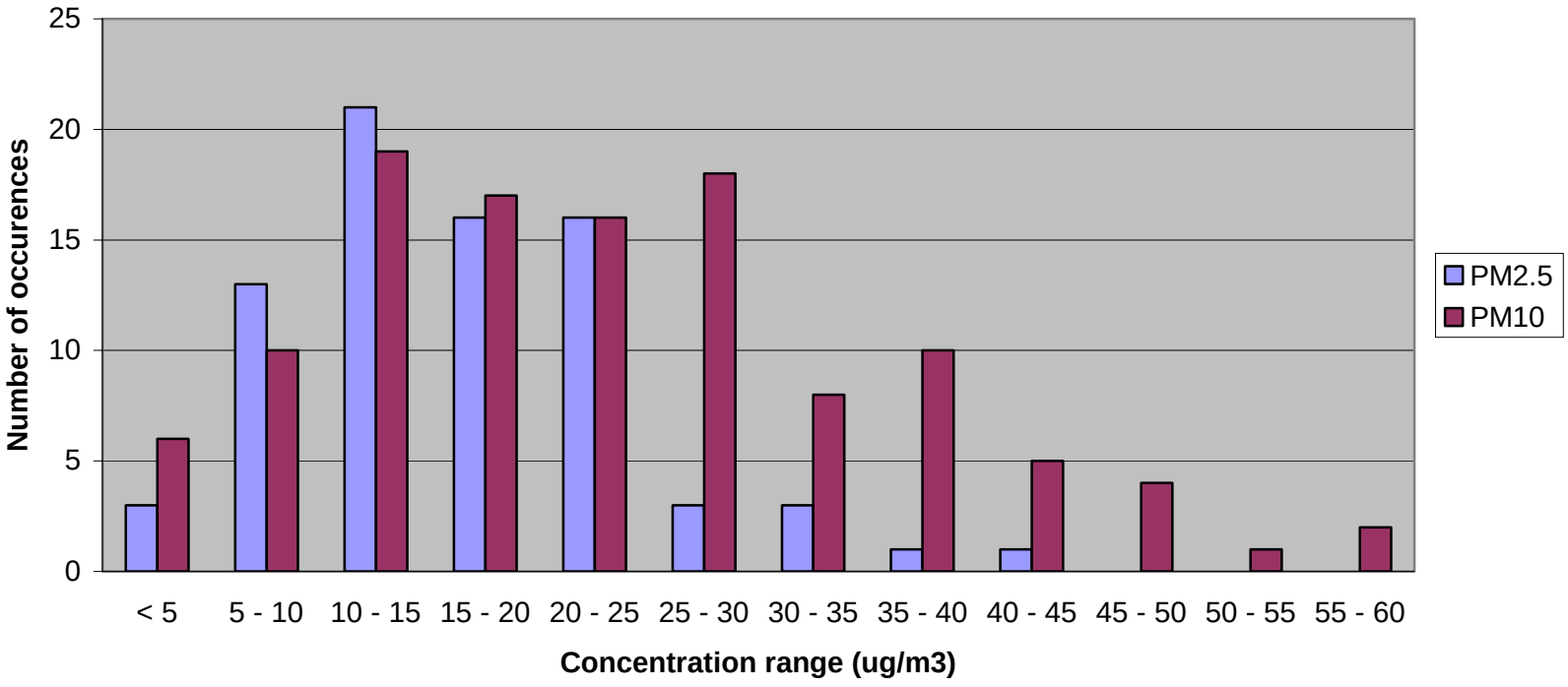


Figure 7
$PM_{2.5}$ Filter Sample Mass Data
(24-hour Integrated Samples)
1999 - 2001

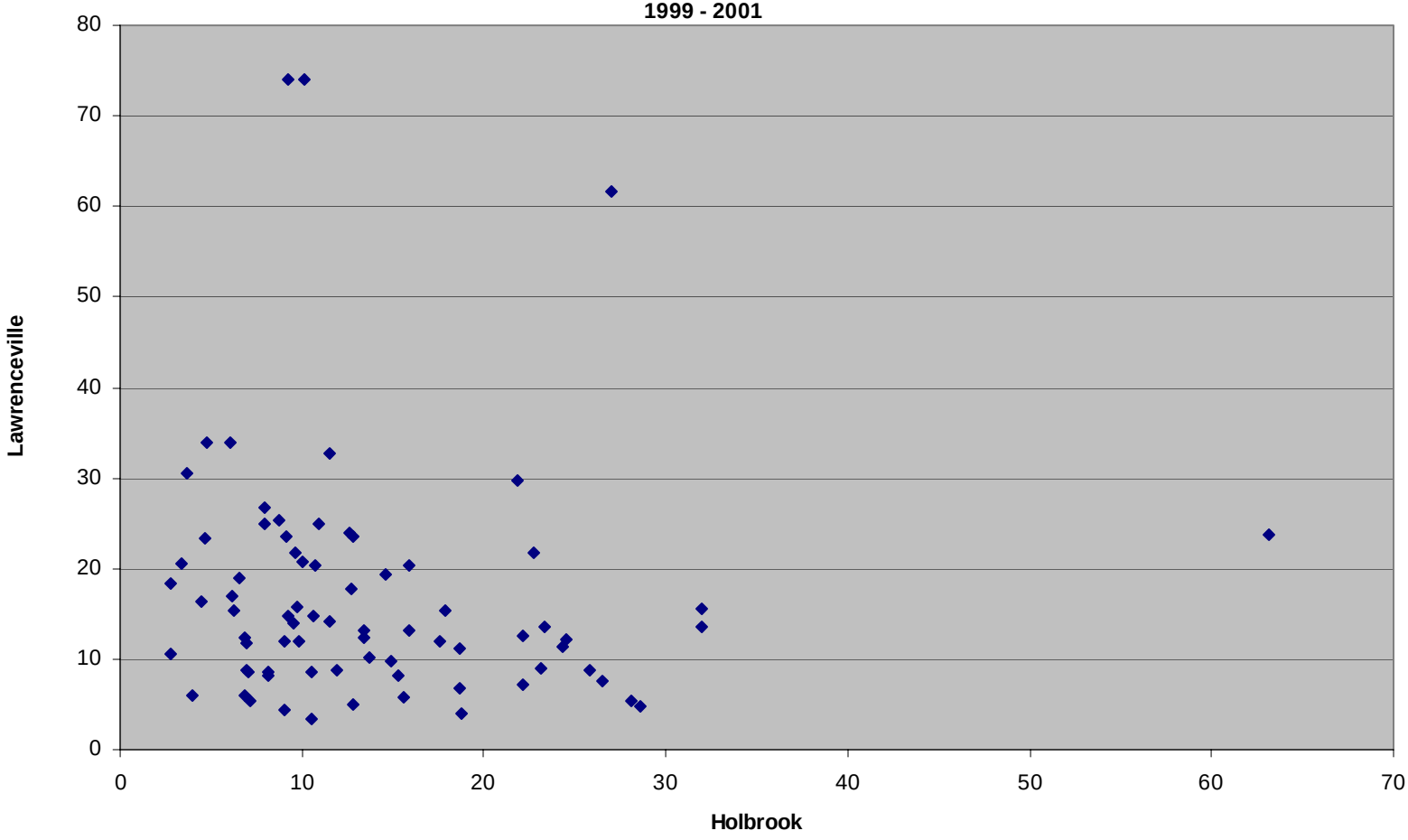


Figure 8
PM_{10} Filter Sample Mass Data
(24-Hour Integrated Samples)
1999-2001

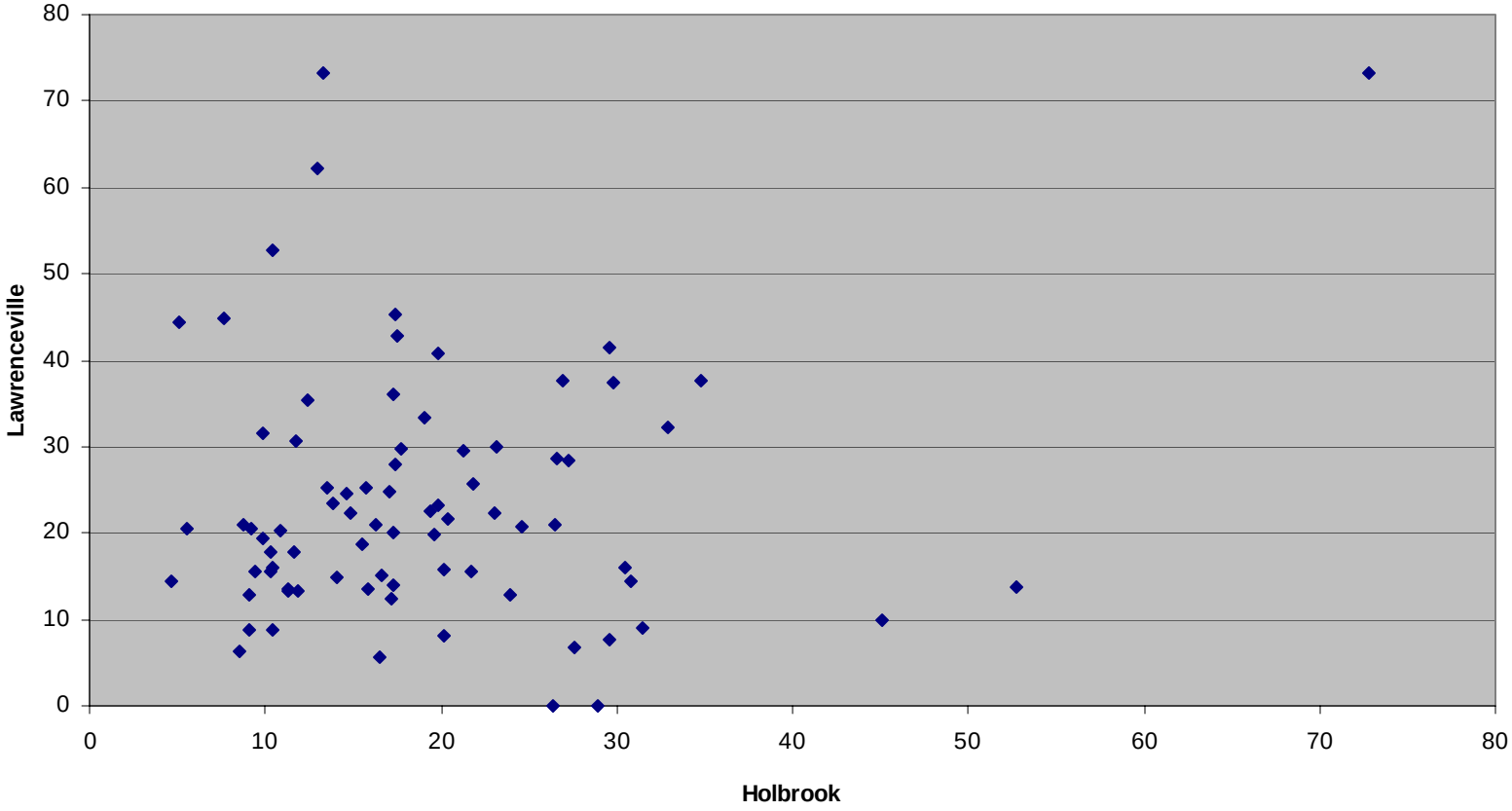


Figure 9

Lawrenceville & Holbrook $PM_{2.5}$ TEOMs

July 2000

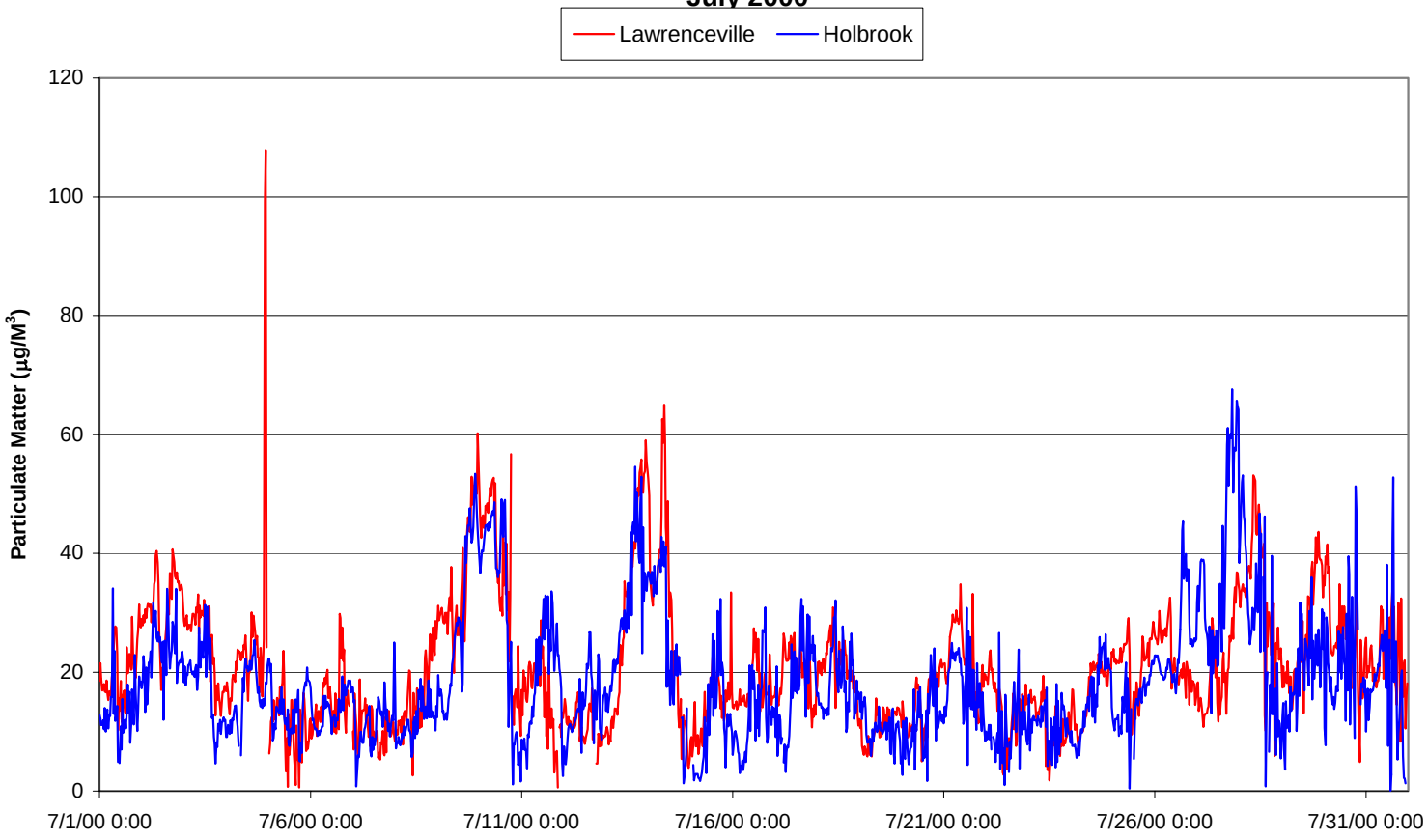


Figure 10

Lawrenceville & Holbrook $PM_{2.5}$ TEOMs

July 2000

24-hour Concentration Differences

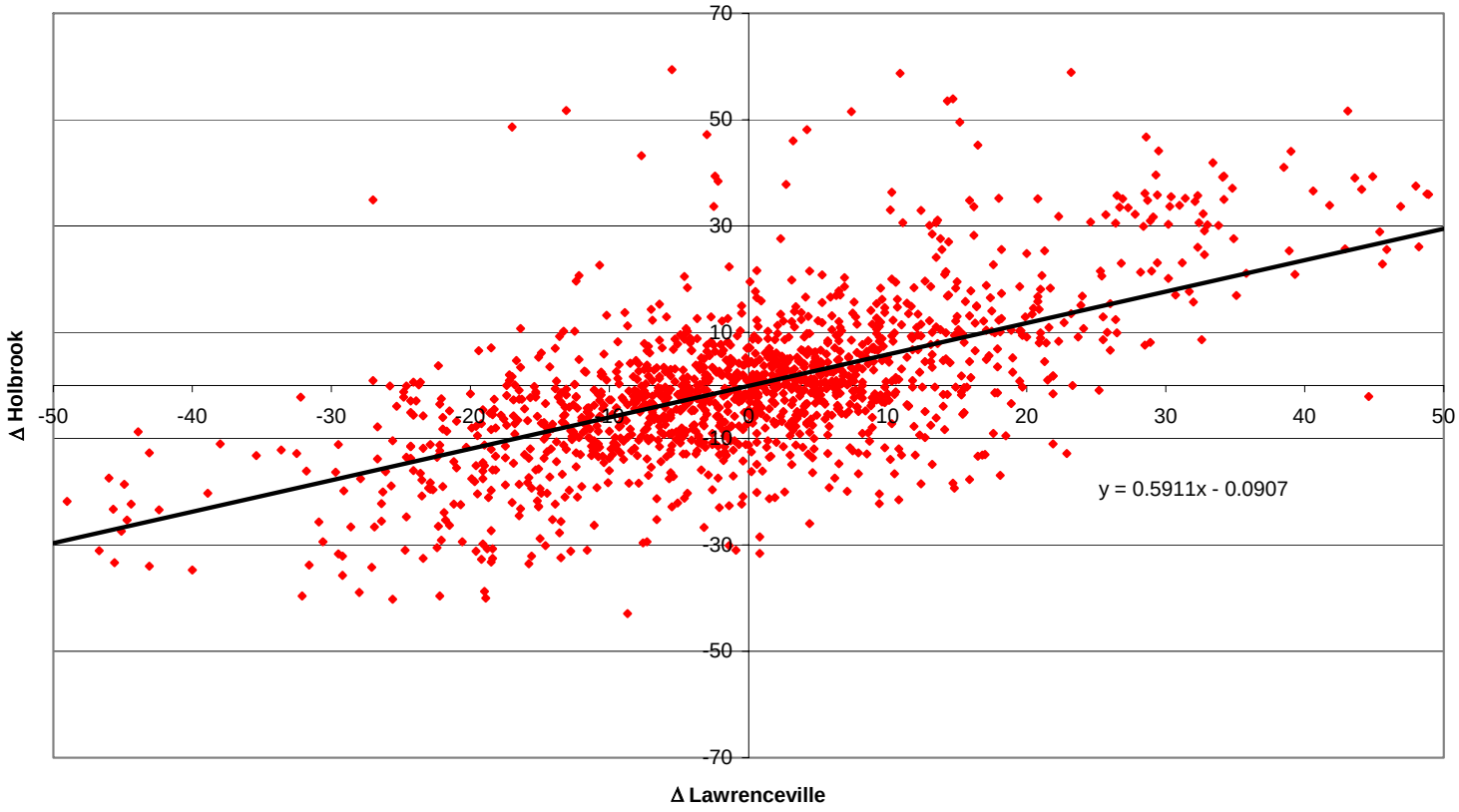


Figure 11

June 1999-May 2001

Lawrenceville ($PM_{2.5}$) TEOM Data Distribution

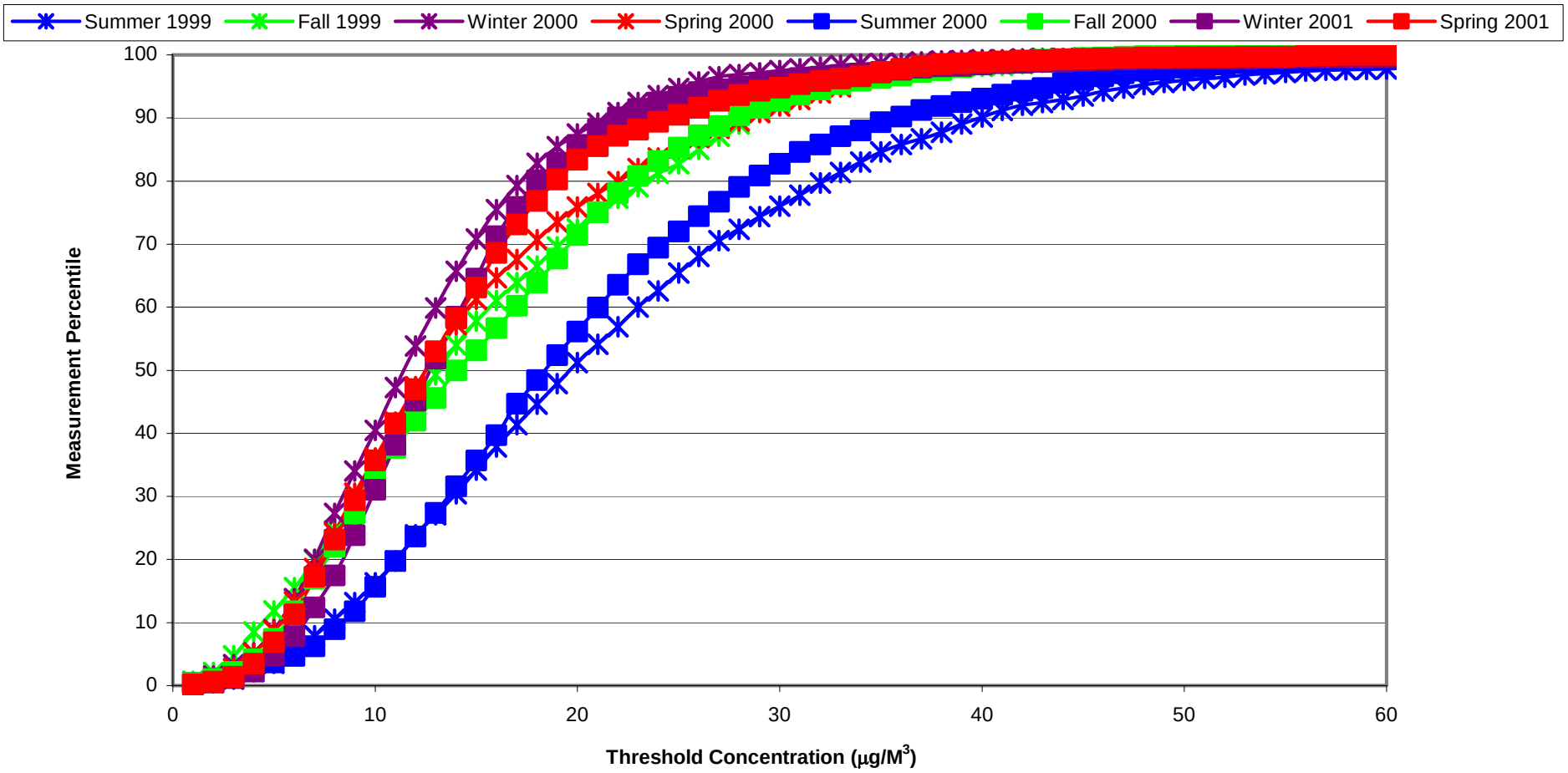


Figure 12

June 1999-May 2001
Lawrenceville (PM_{10}) TEOM Data Distribution

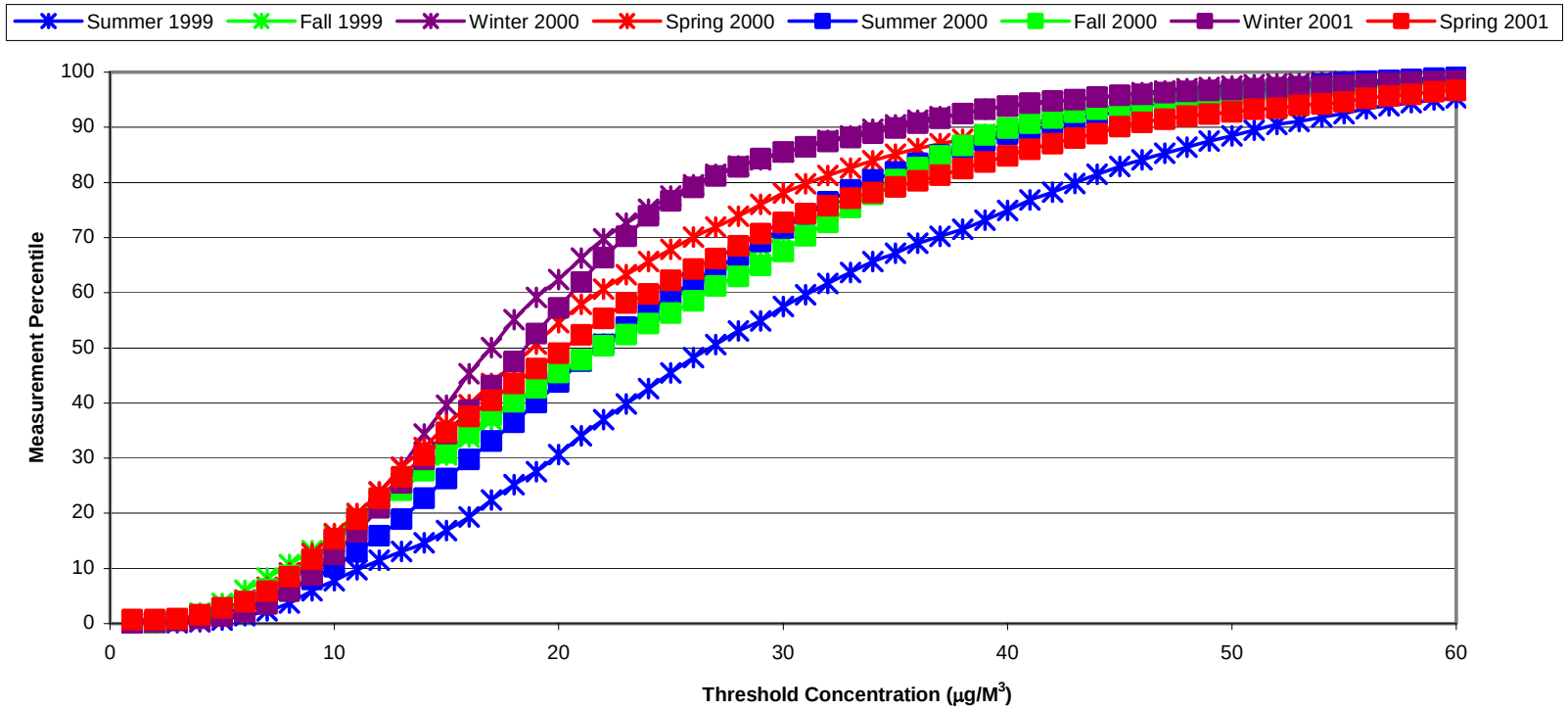


Figure 13

June 1999-May 2001

Holbrook ($PM_{2.5}$) TEOM Data Distribution

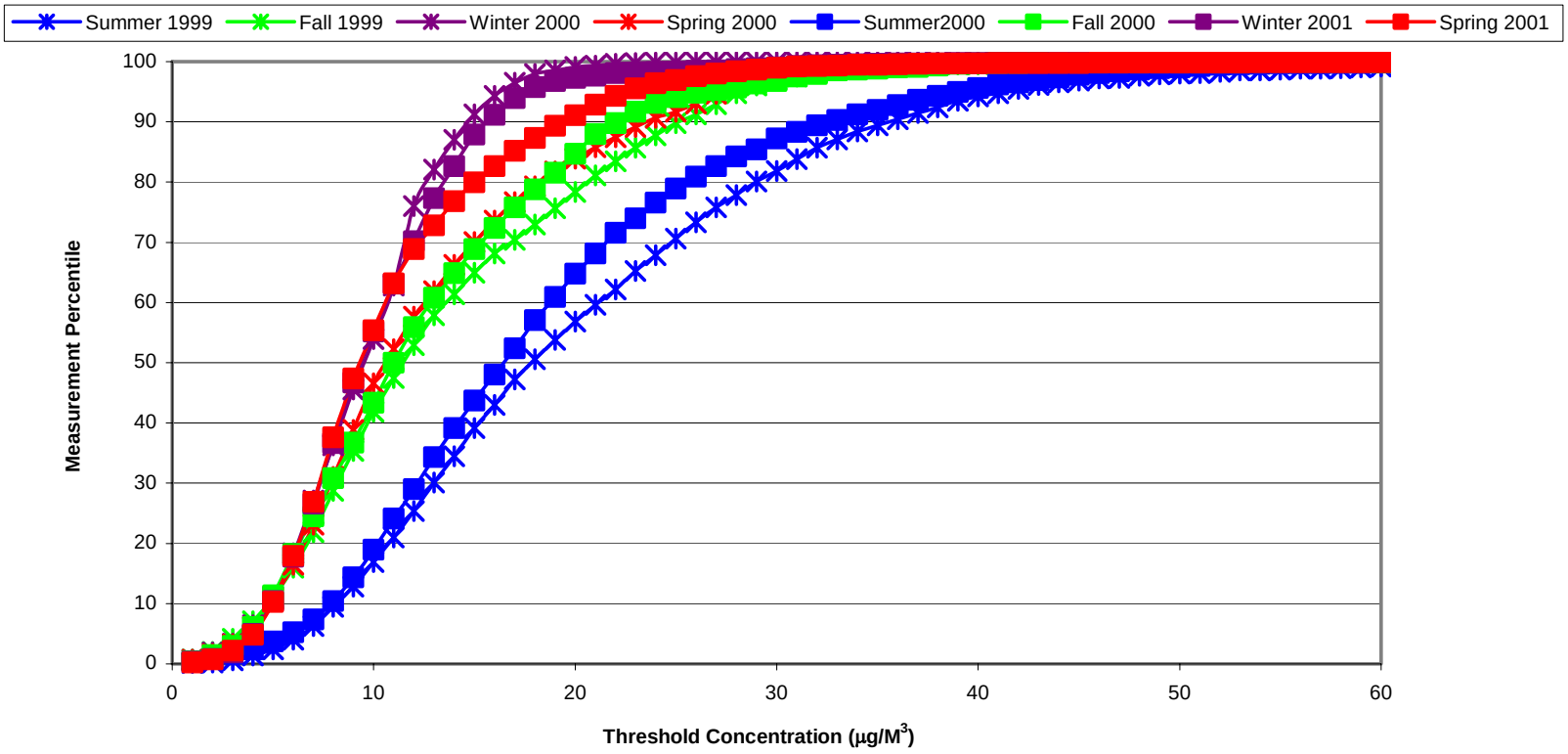


Figure 14

June 1999 – May 2000
Holbrook & Lawrenceville ($PM_{2.5}$) Data Distribution

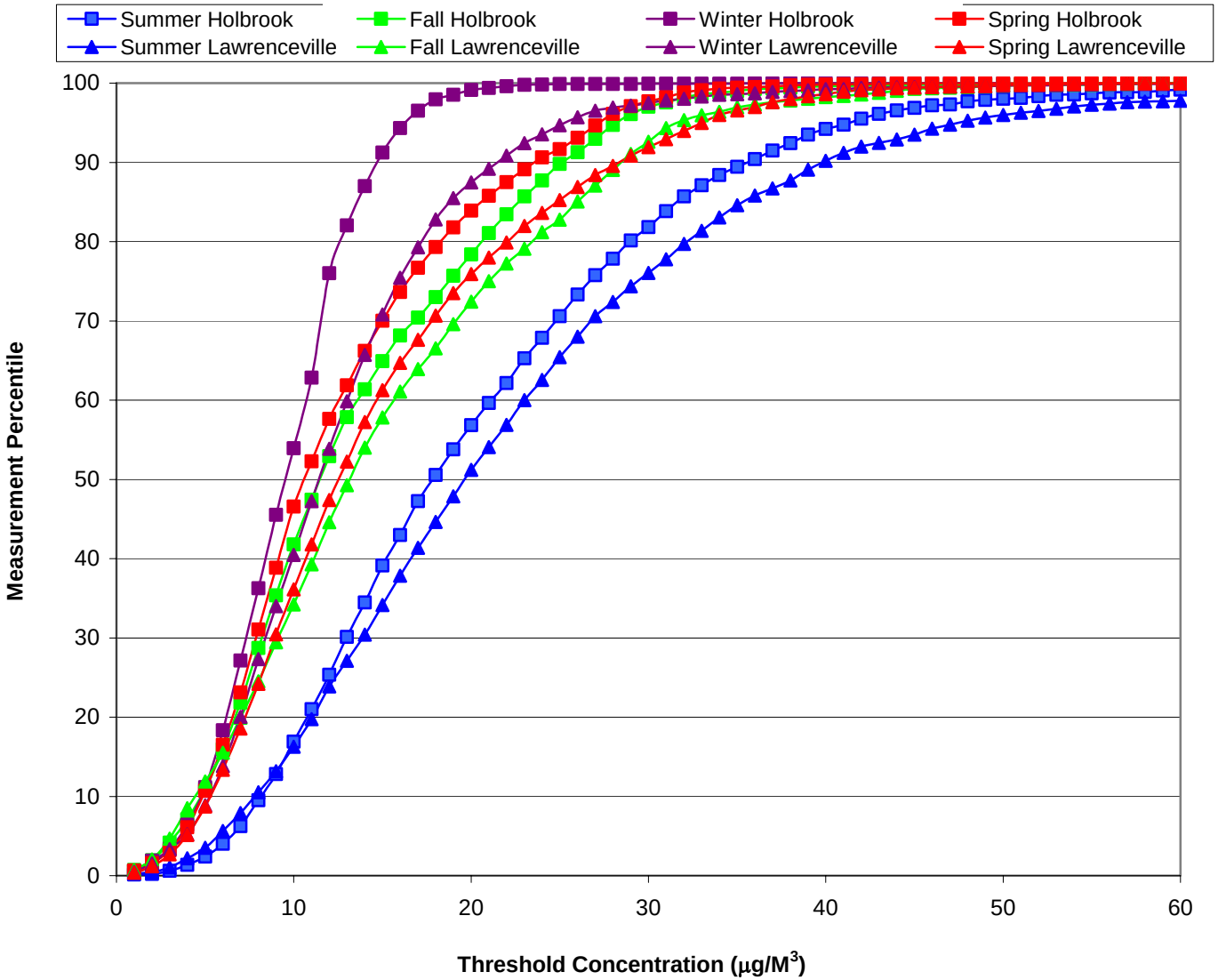


Figure 15

1999, 2000 & 2001 Lawrenceville
$PM_{2.5}$ TEOM Data Distribution

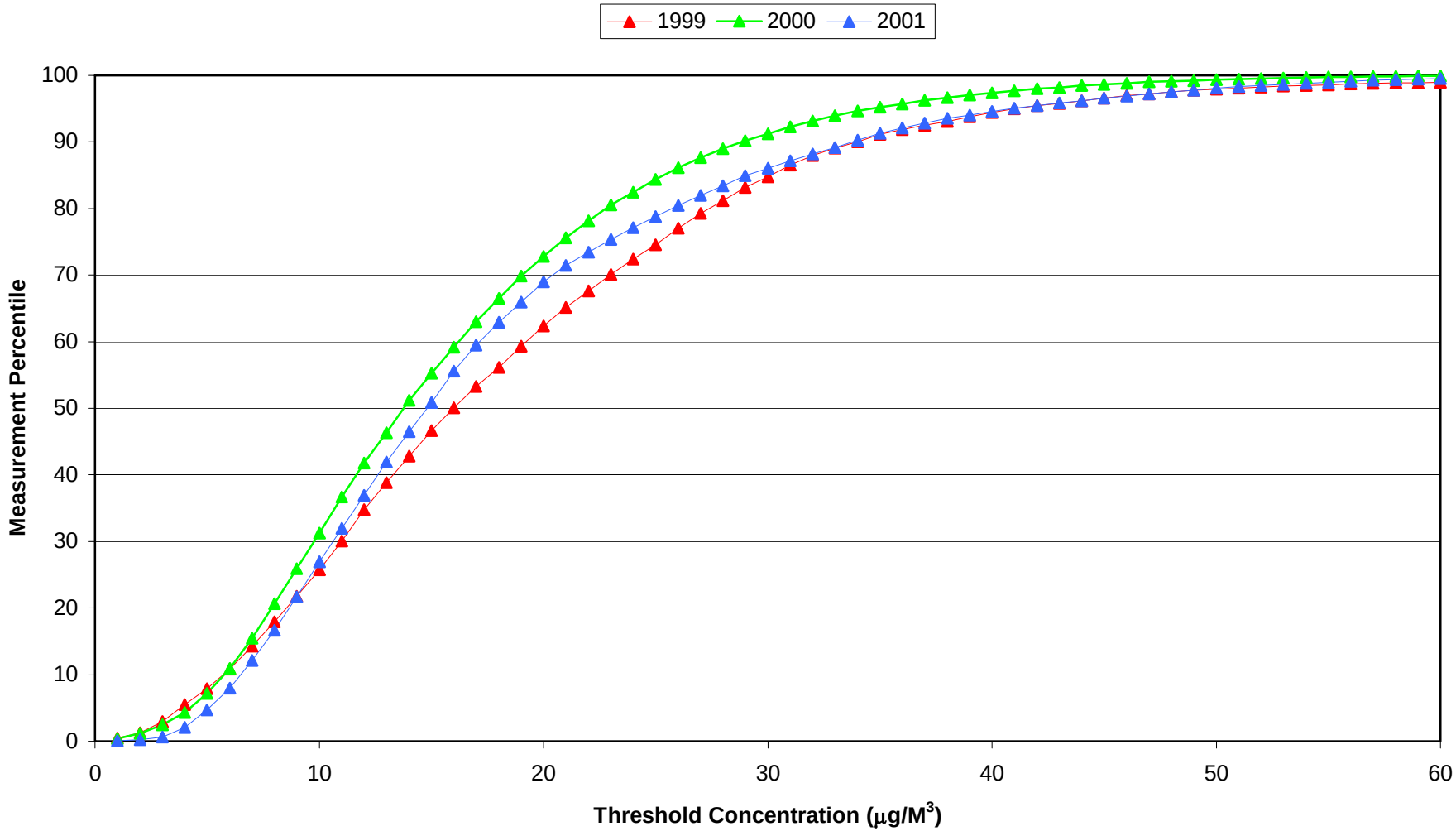


Figure 16

1999, 2000 & 2001 Holbrook

$PM_{2.5}$ TEOM Data Distribution

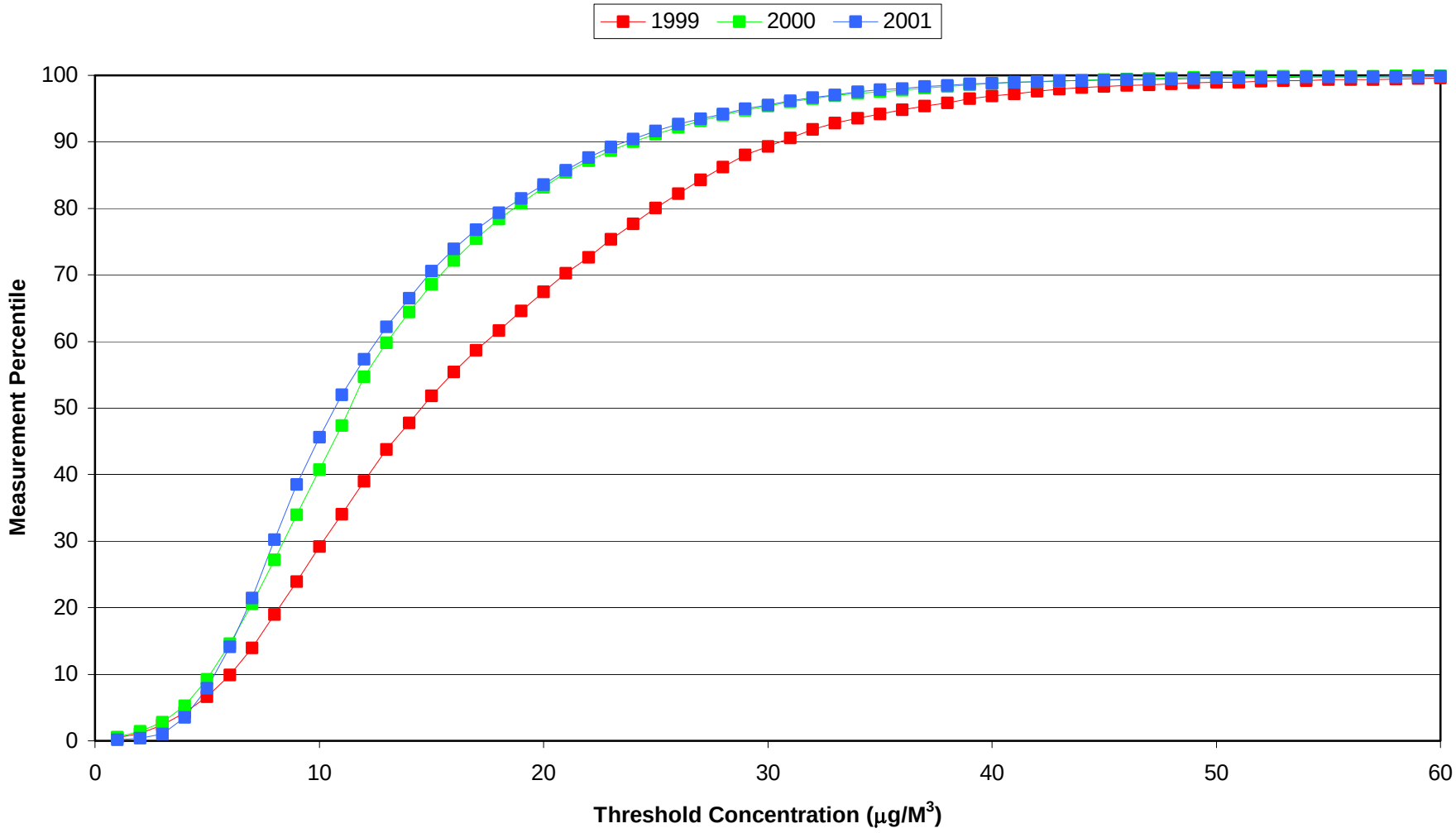


Figure 17

1999, 2000 & 2001 Lawrenceville
PM_{10} TEOM Data Distribution

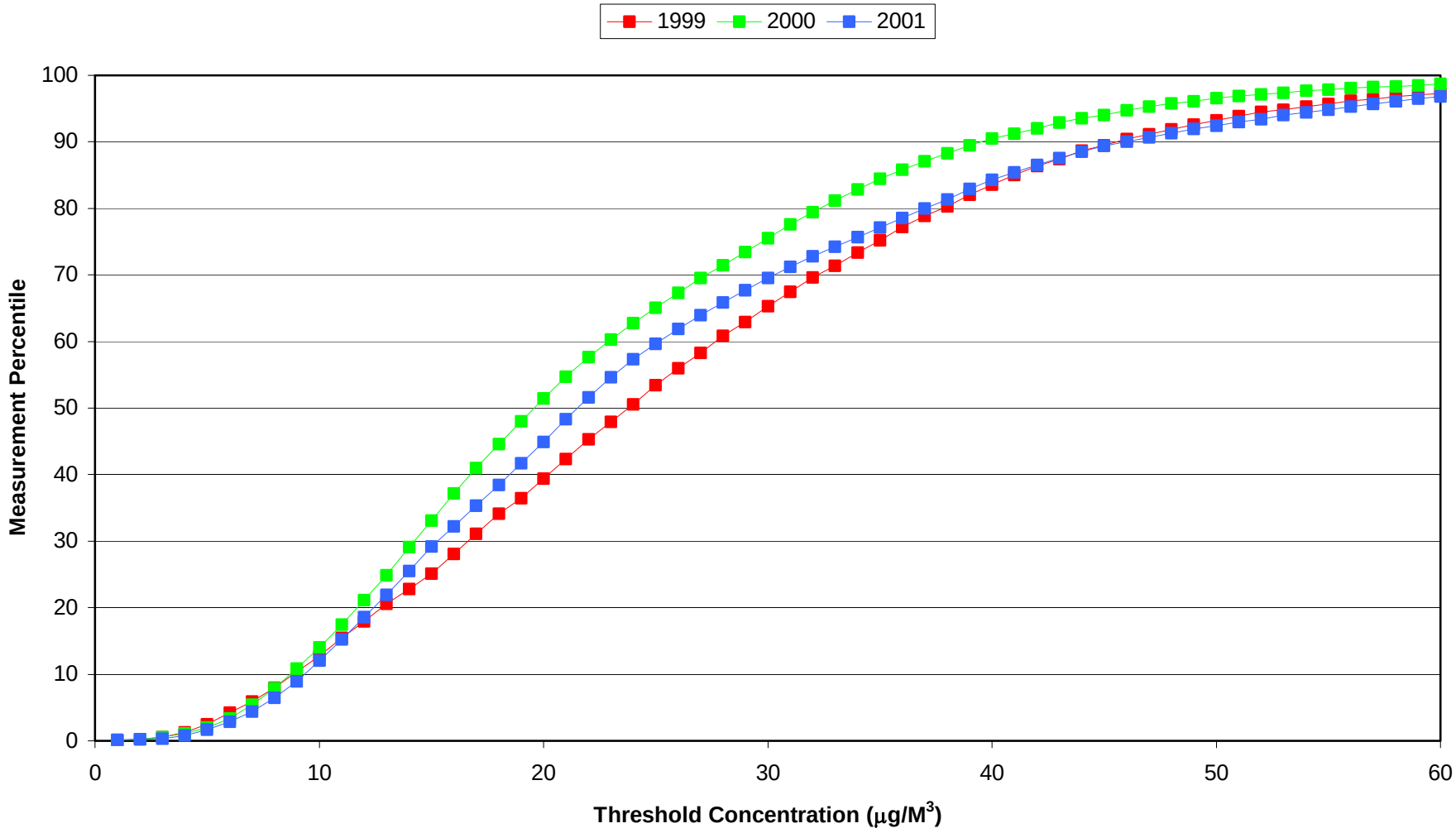


Figure 18

1999, 2000 & 2001 Lawrenceville & Holbrook
$PM_{2.5}$ TEOM Data Distribution

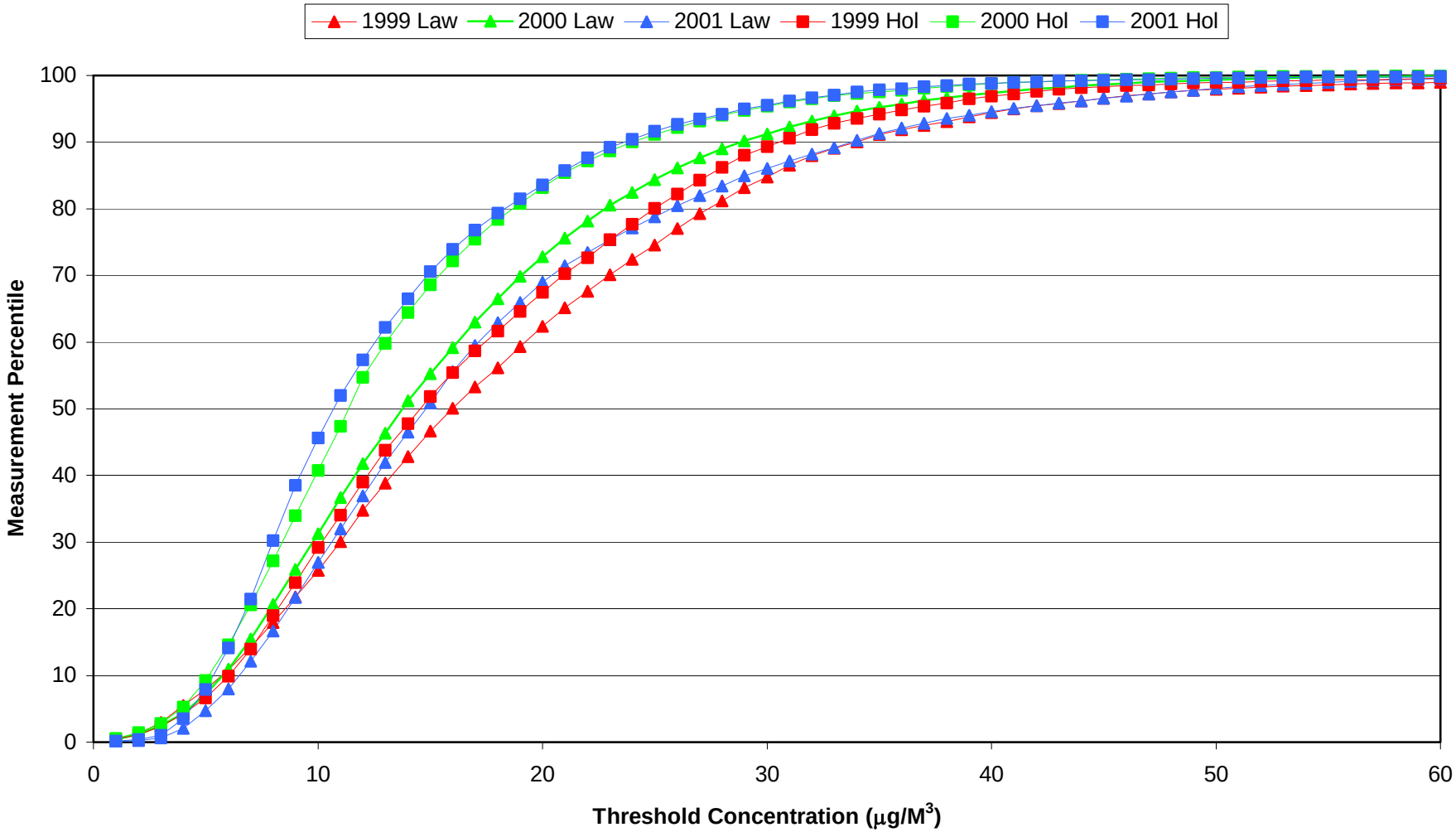


Figure 19
1999, 2000 & 2001 Lawrenceville
$PM_{2.5}$ & PM_{10} TEOM Data Distribution

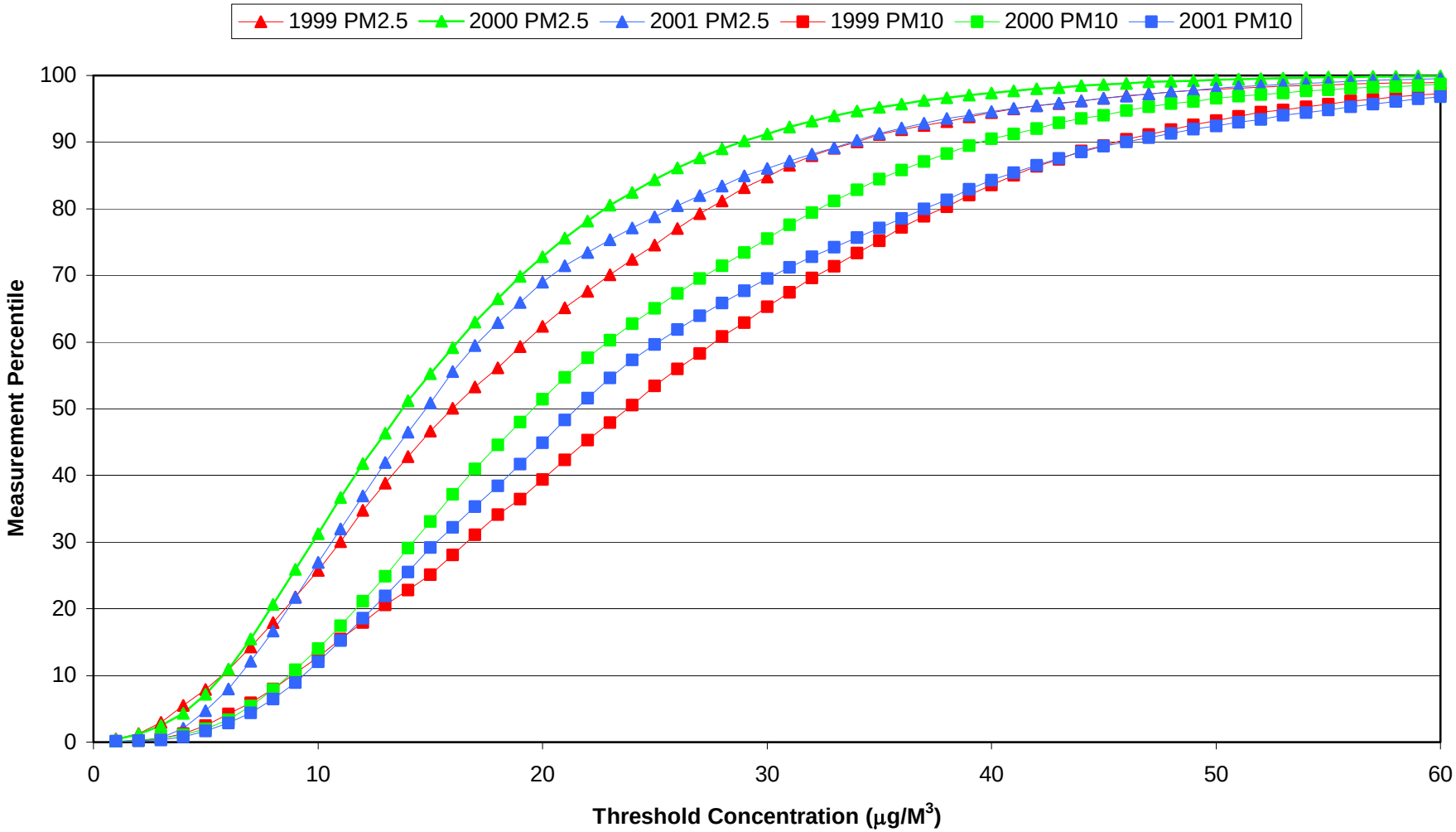


Figure 20

Lawrenceville-TEOM $PM_{2.5}$, SFS $PM_{2.5}$ & FRM $PM_{2.5}$

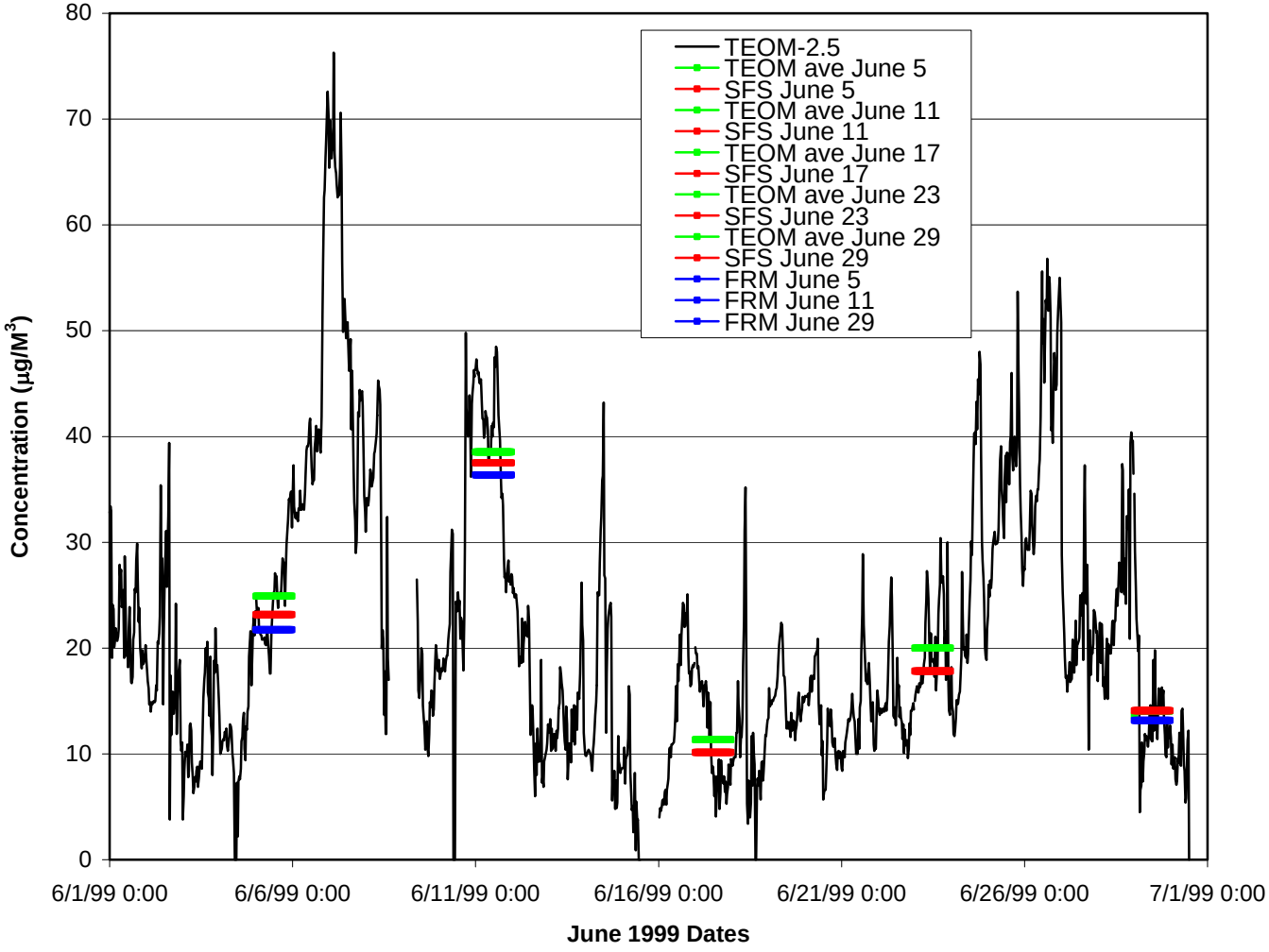


Figure 21

Holbrook-TEOM $PM_{2.5}$, SFS $PM_{2.5}$ & FRM $PM_{2.5}$

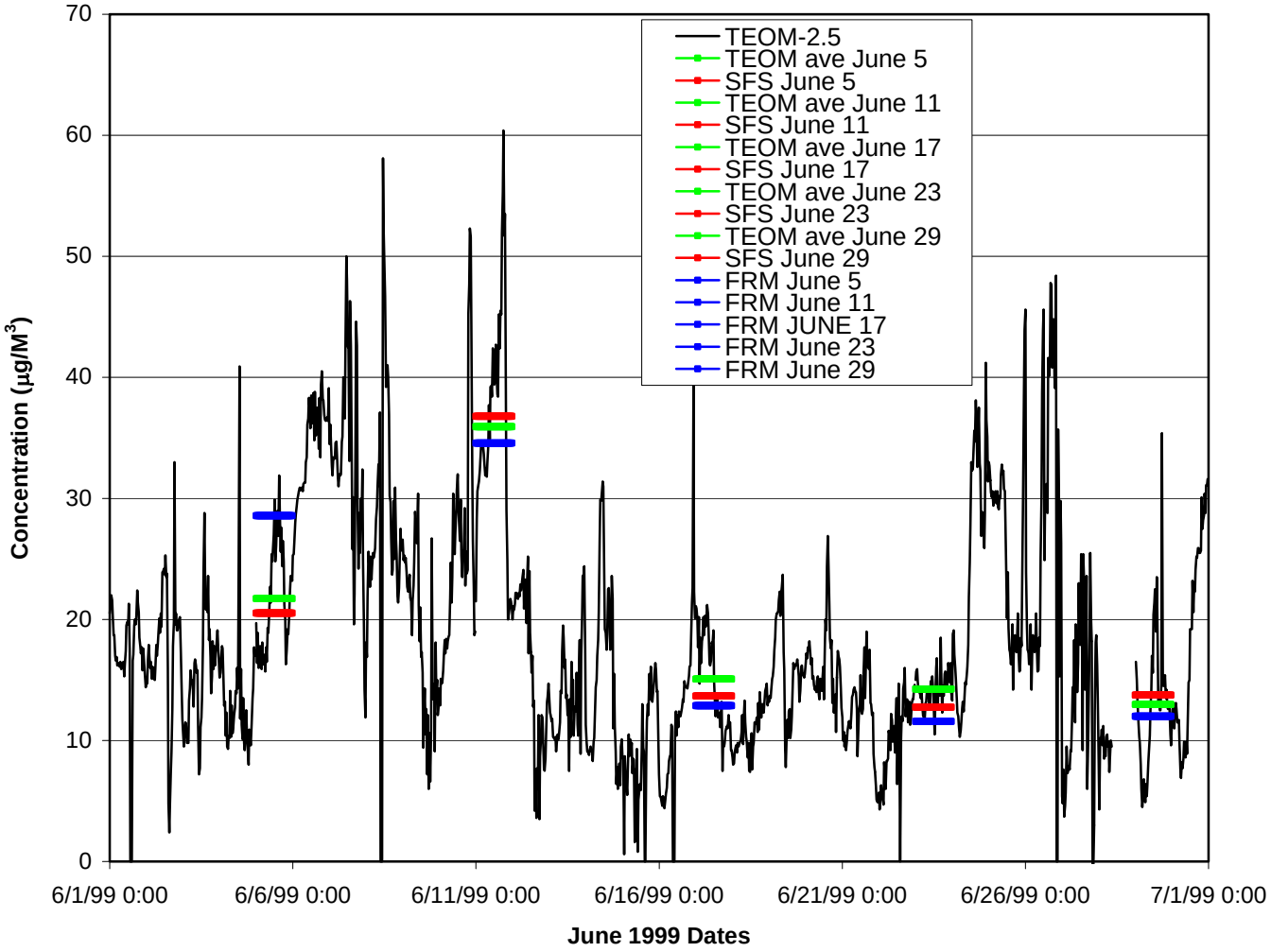


Figure 22

SFS vs. TEOM Averages ($PM_{2.5}$)

Lawrenceville 8/7/99-9/11/99

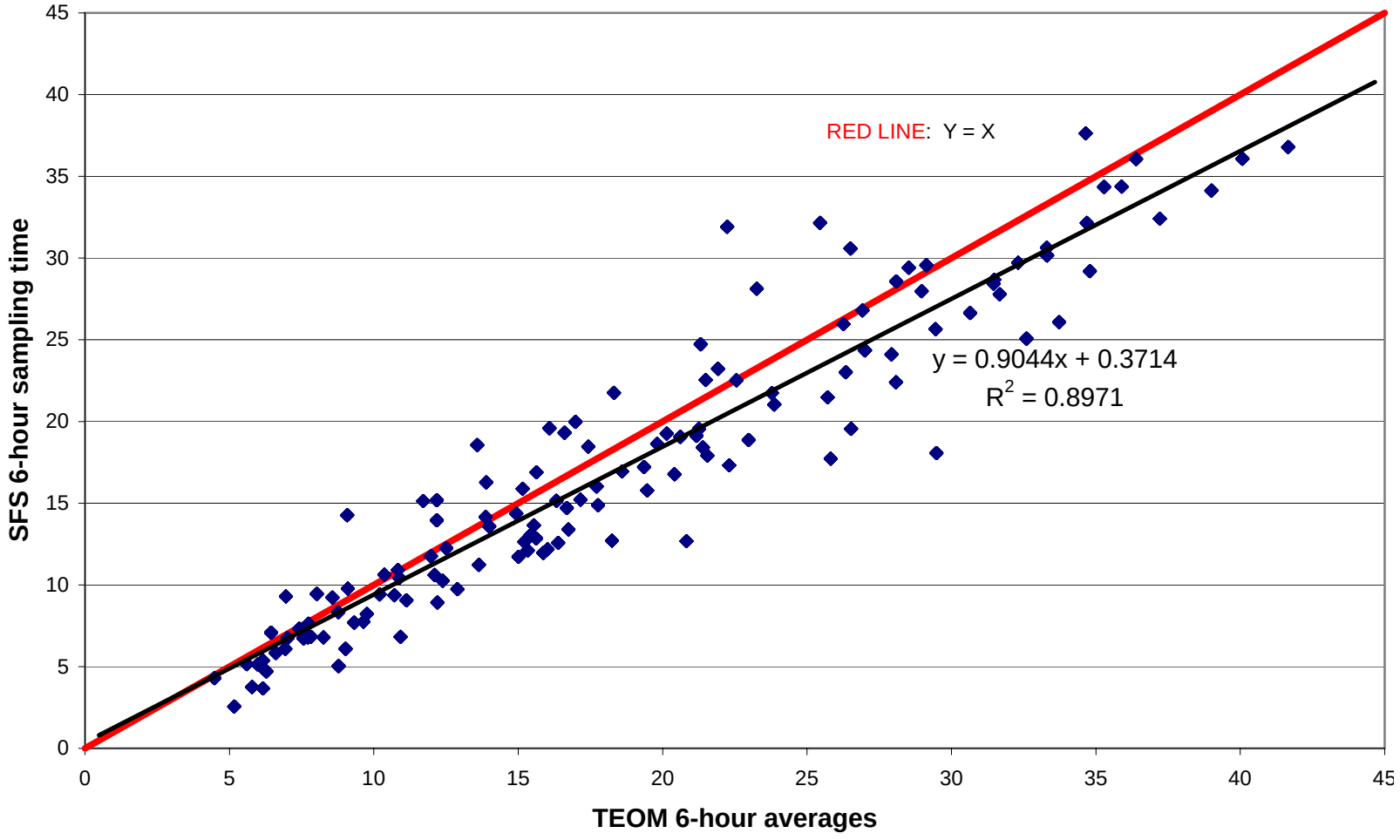
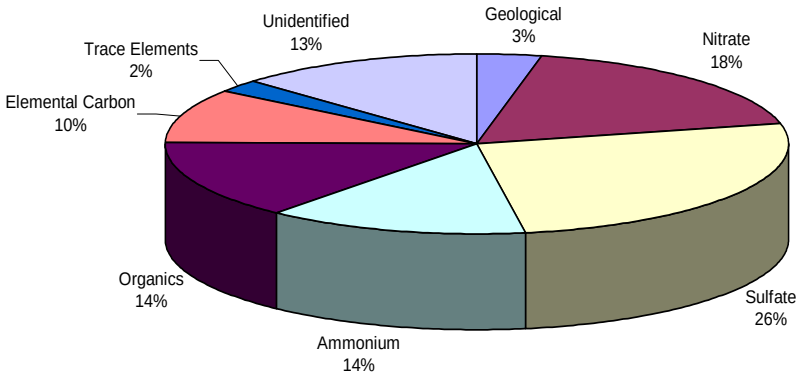


FIGURE 25
LAWRENCEVILLE/HOLBROOK
WINTER COMPARISON

Winter 1999
Lawrenceville
$PM_{2.5}$ Intensive Sampling Program
(36 6-Hour Samples)



Winter 1999
Holbrook
$PM_{2.5}$ Intensive Sampling Program
(9 24-Hour Samples)

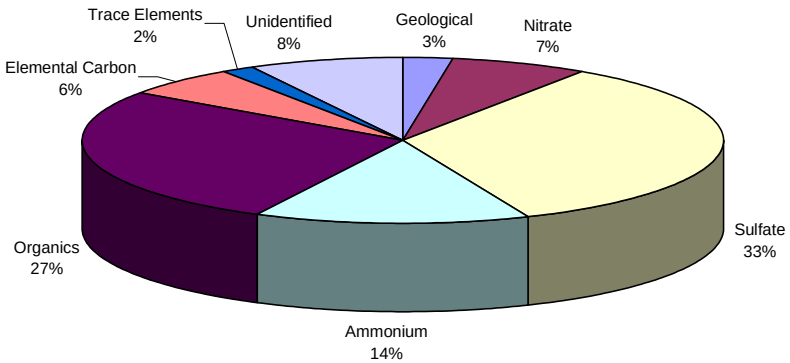
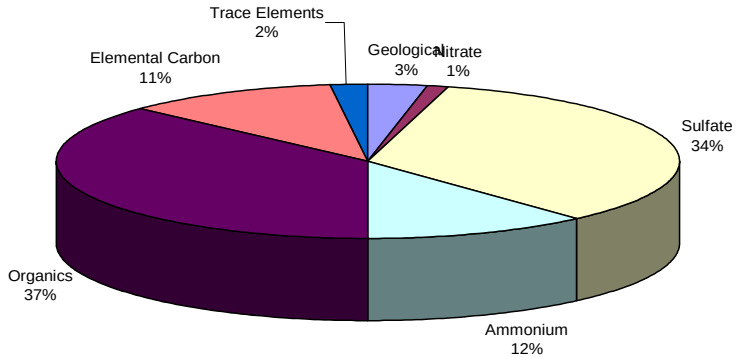


FIGURE 26
LAWRENCEVILLE/HOLBROOK
SUMMER COMPARISON

Summer 1999
Lawrenceville
$PM_{2.5}$ Intensive Sampling Program
(39 6-Hour Samples)



Summer 1999
Holbrook
$PM_{2.5}$ Intensive Sampling Program
(10 24-Hour Samples)

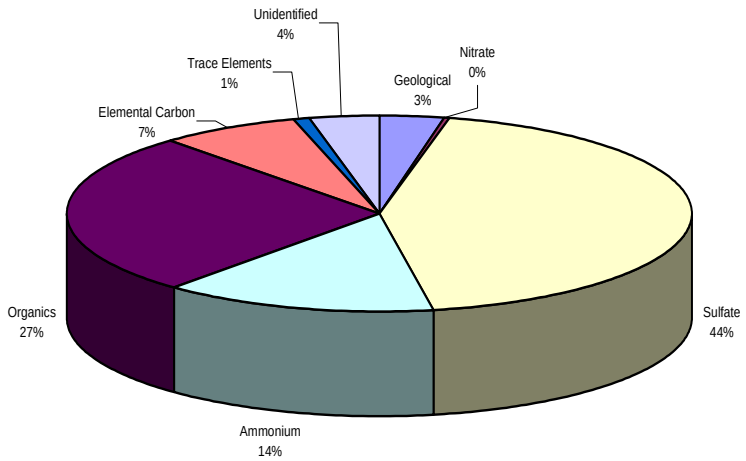
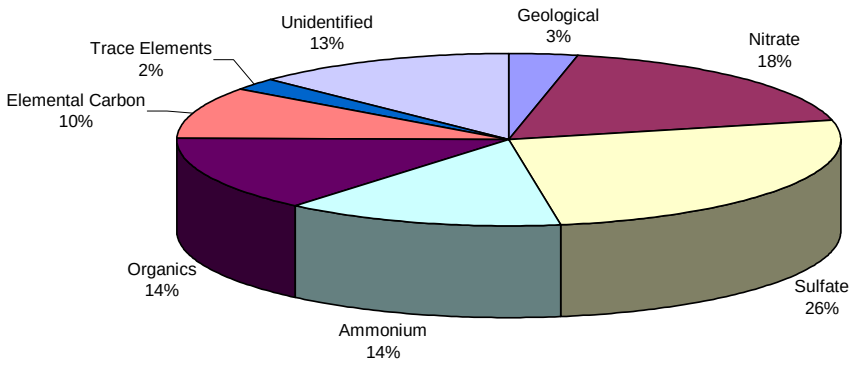


FIGURE 27
LAWRENCEVILLE
$PM_{2.5}/PM_{10}$ COMPARISON

Winter 1999
Lawrenceville
$PM_{2.5}$ Intensive Sampling Program
(36 6-Hour Samples)



Winter 1999
Lawrenceville
(PM_{10}) Intensive Sampling Program
(36 6-Hour Samples)

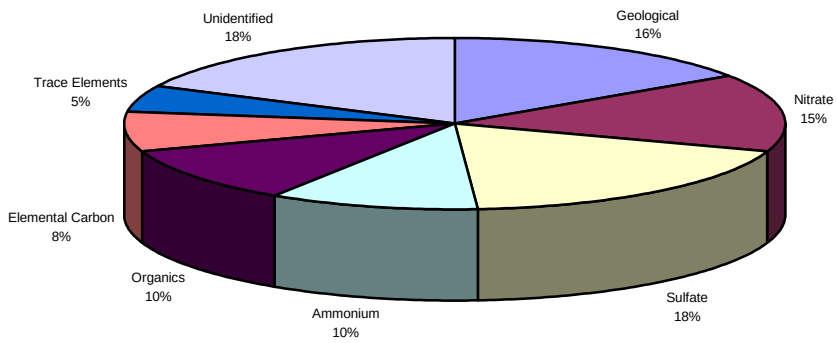


Figure 28

***ATS* Winter 1999 Intensive Sampling Program**

Lawrenceville - SFS Data

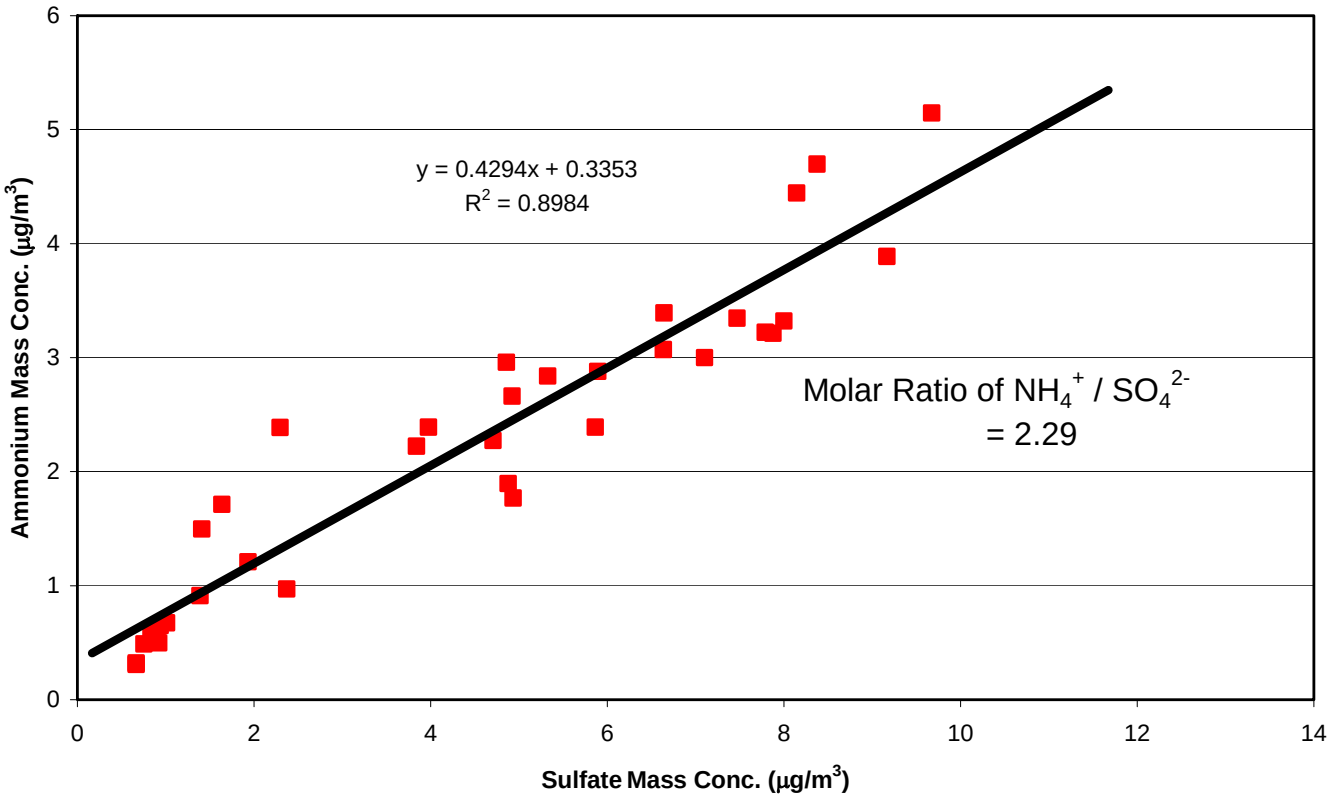


Figure 29
***ATS* Winter 1999 Intensive Sampling Program**
Lawrenceville - SFS Data

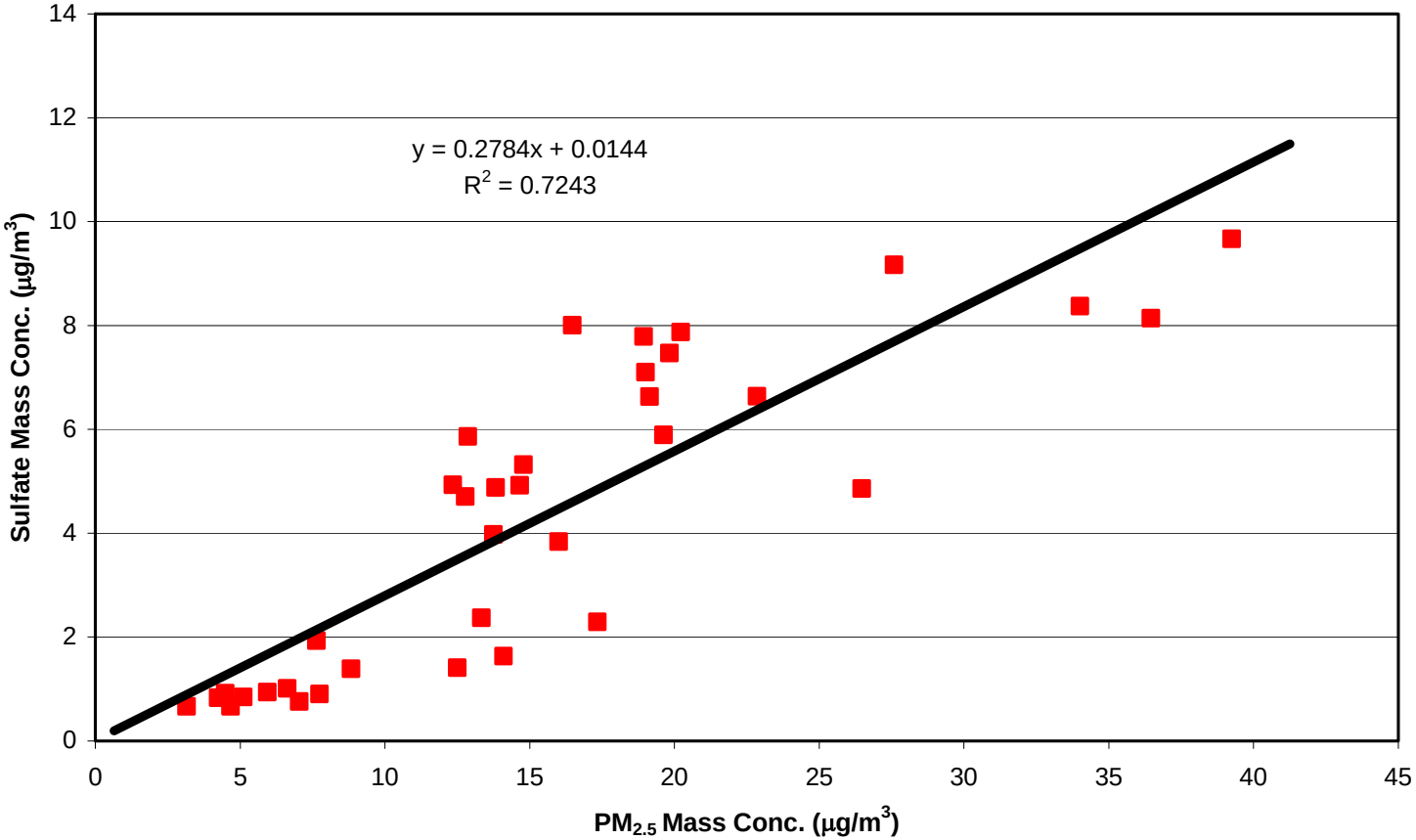


Figure 30

***ATS* Winter 1999 Intensive Sampling Program**

Lawrenceville - SFS Data

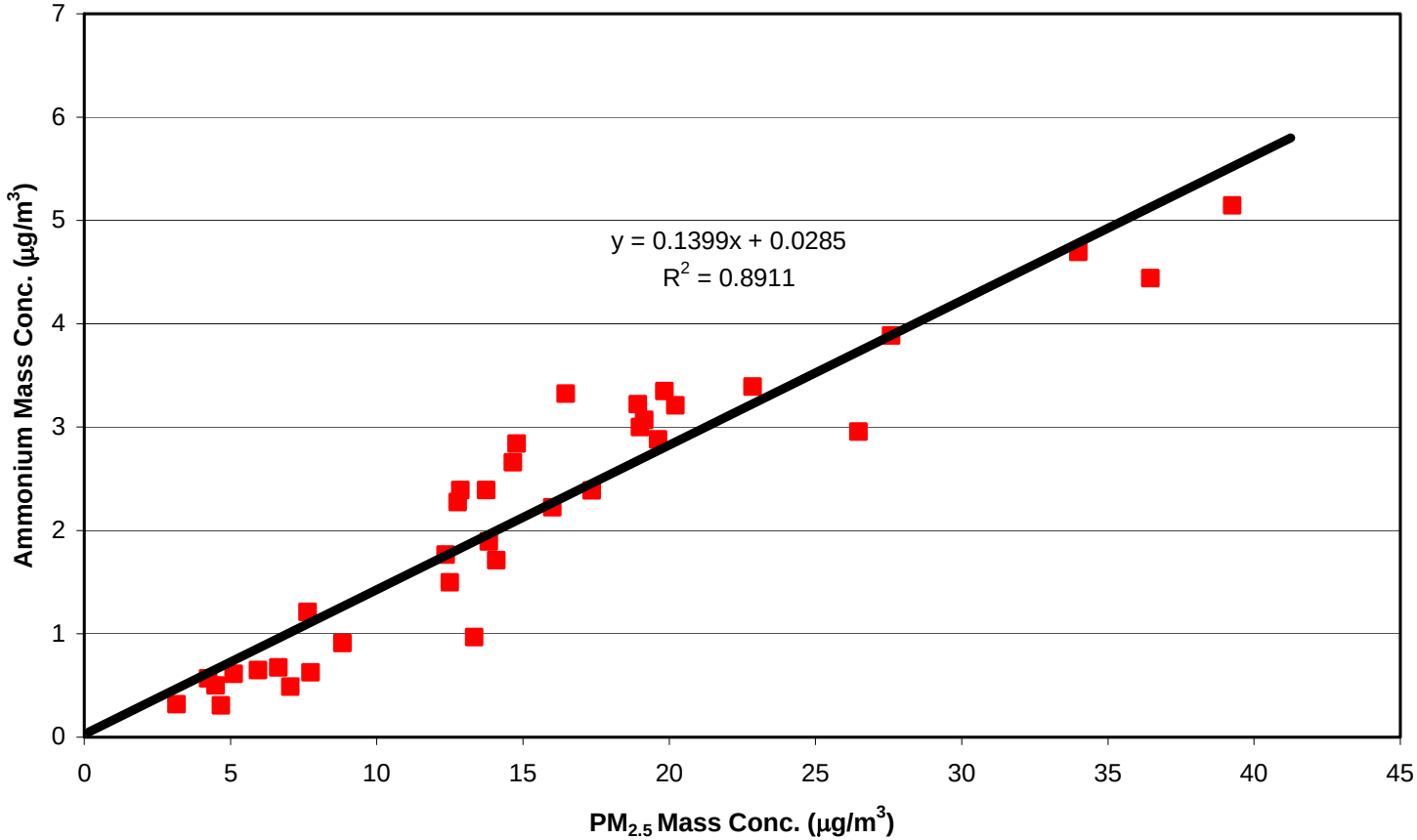


Figure 31

***ATS* Winter 1999 Intensive Sampling Program**

Holbrook - SFS Data

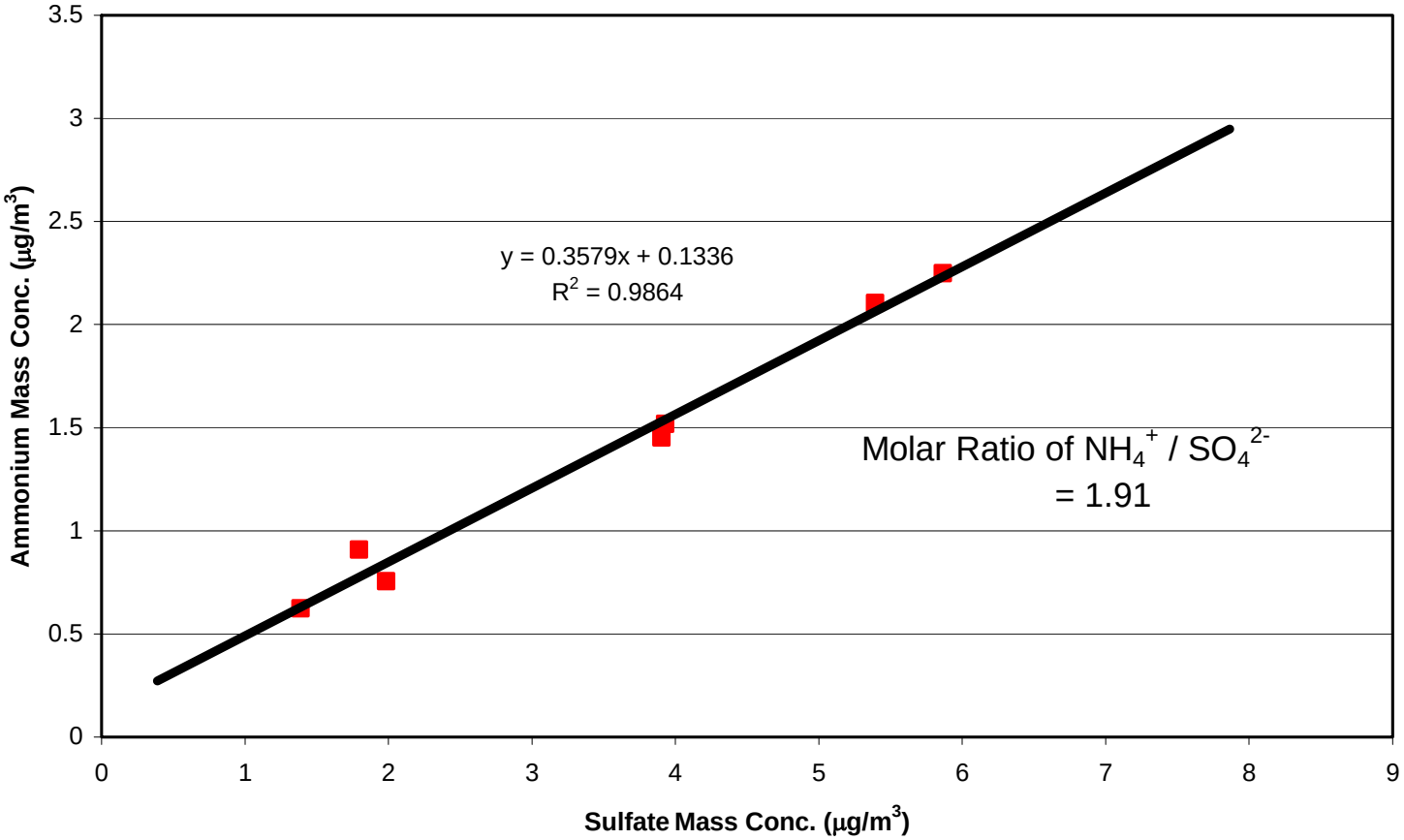


Figure 32

***ATS* Winter 1999 Intensive Sampling Program**

Holbrook - SFS Data

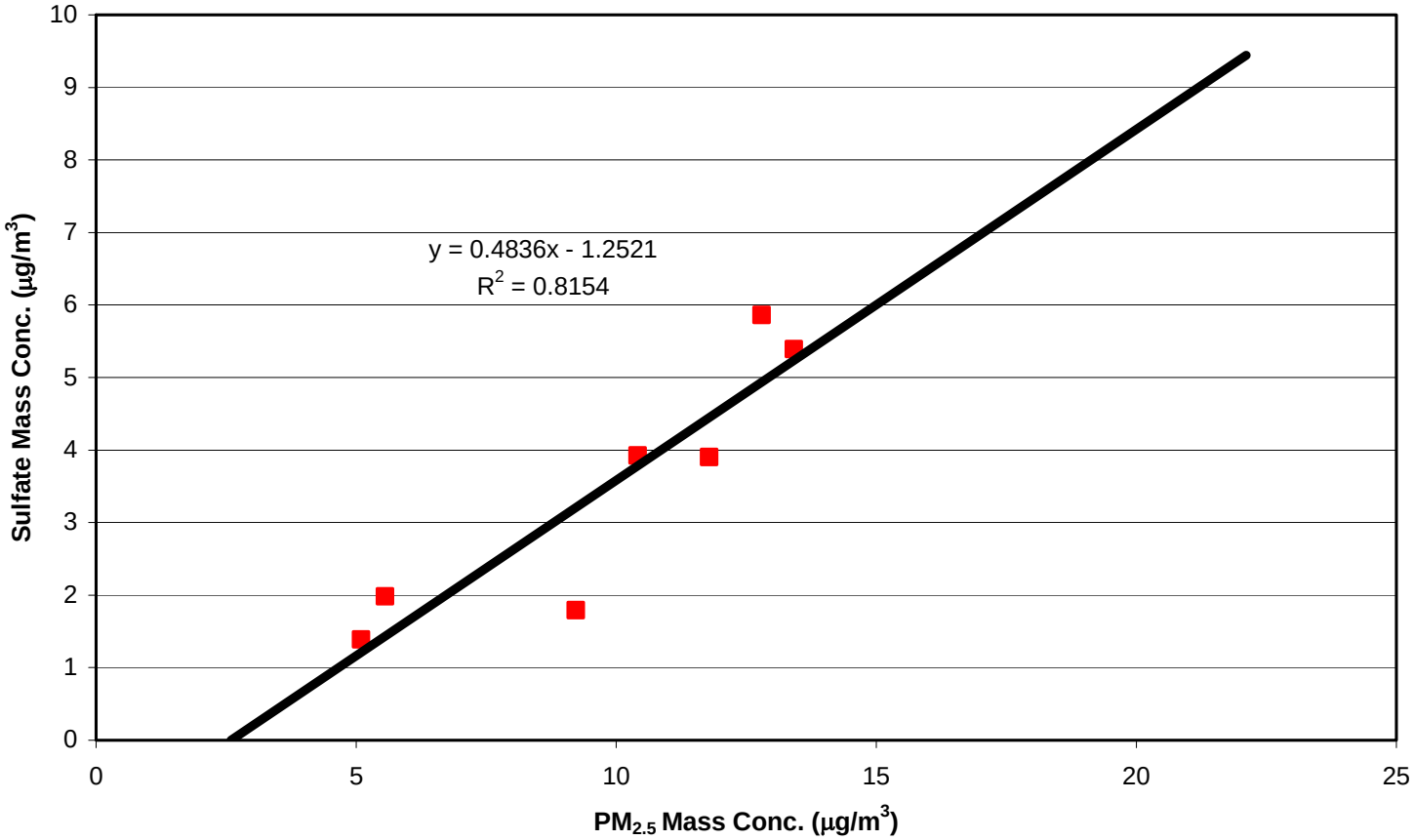


Figure 33

***ATS* Winter 1999 Intensive Sampling Program**

Holbrook - SFS Data

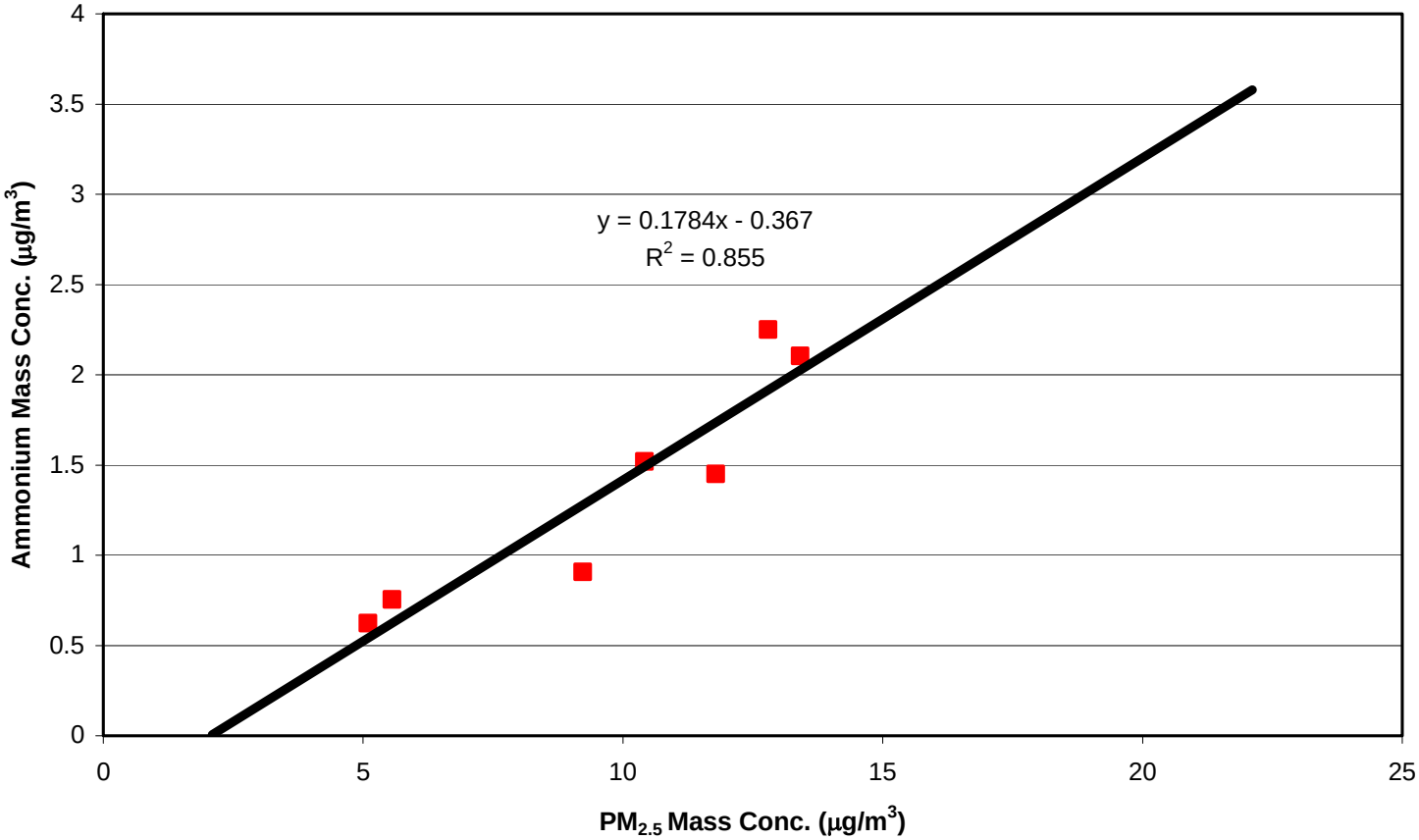


Figure 34

ATS Summer 1999 Intensive Sampling Program

Lawrenceville – SFS Data

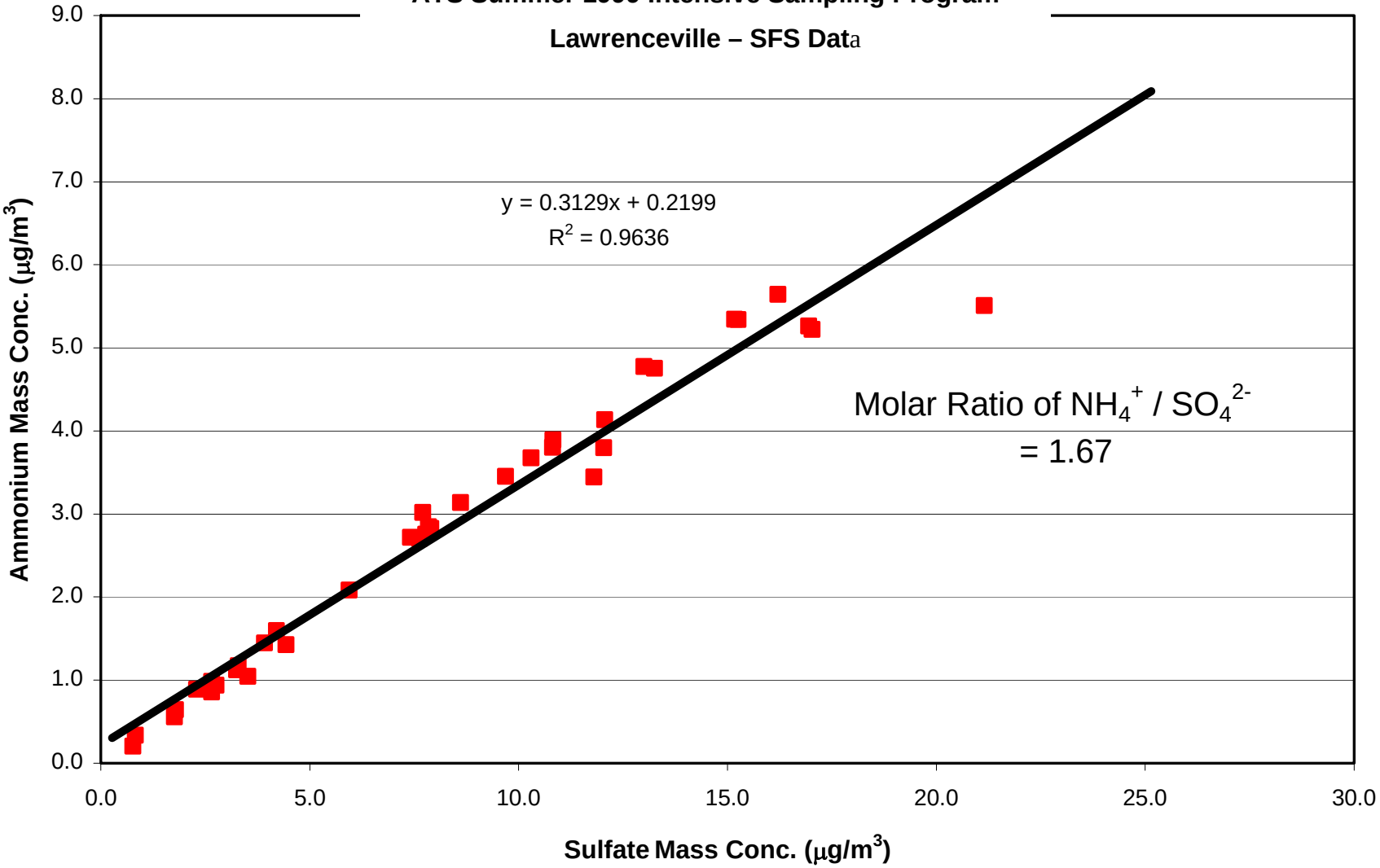
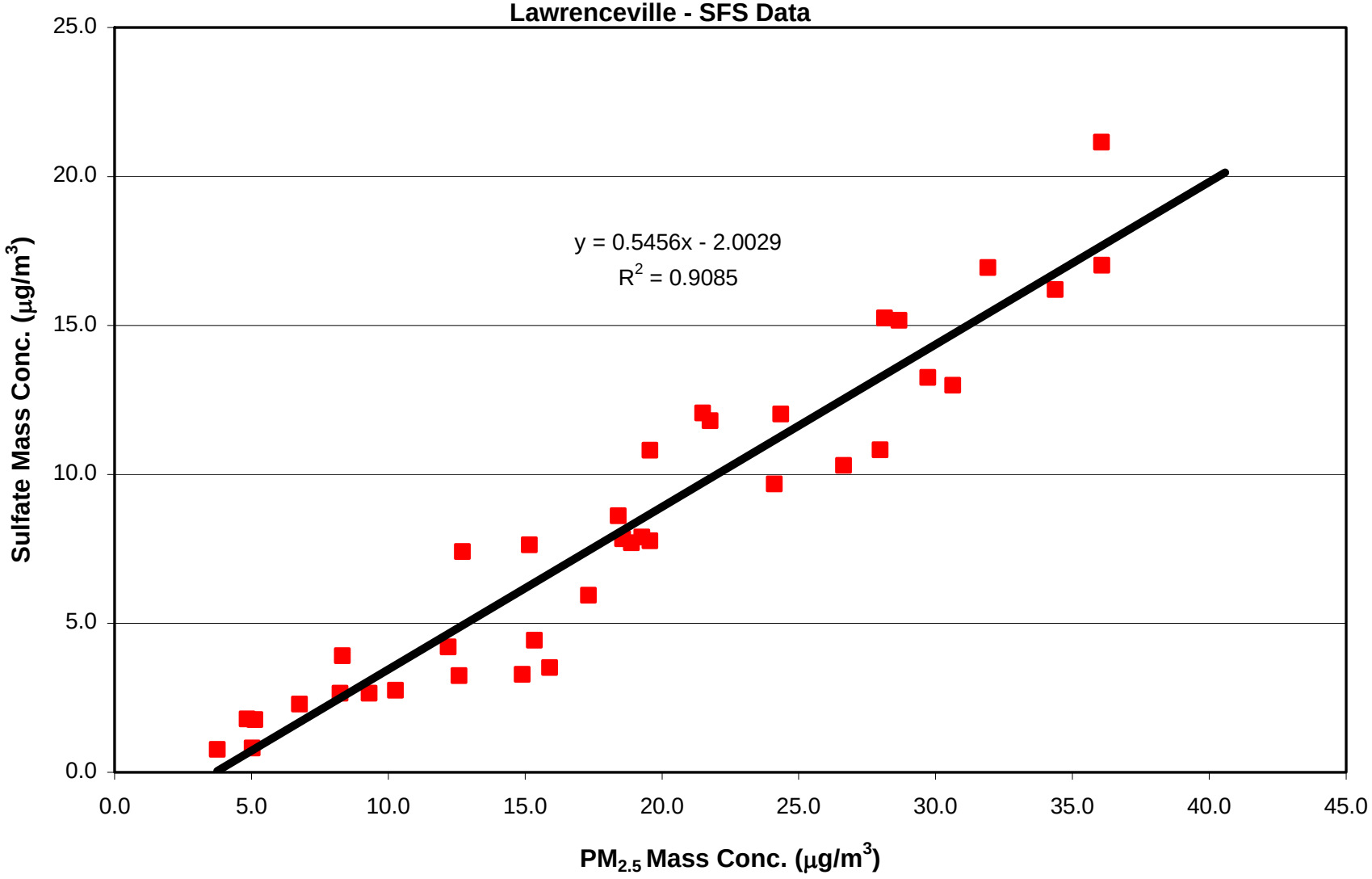


Figure 35

***ATS* Summer 1999 Intensive Sampling Program**

Lawrenceville - SFS Data



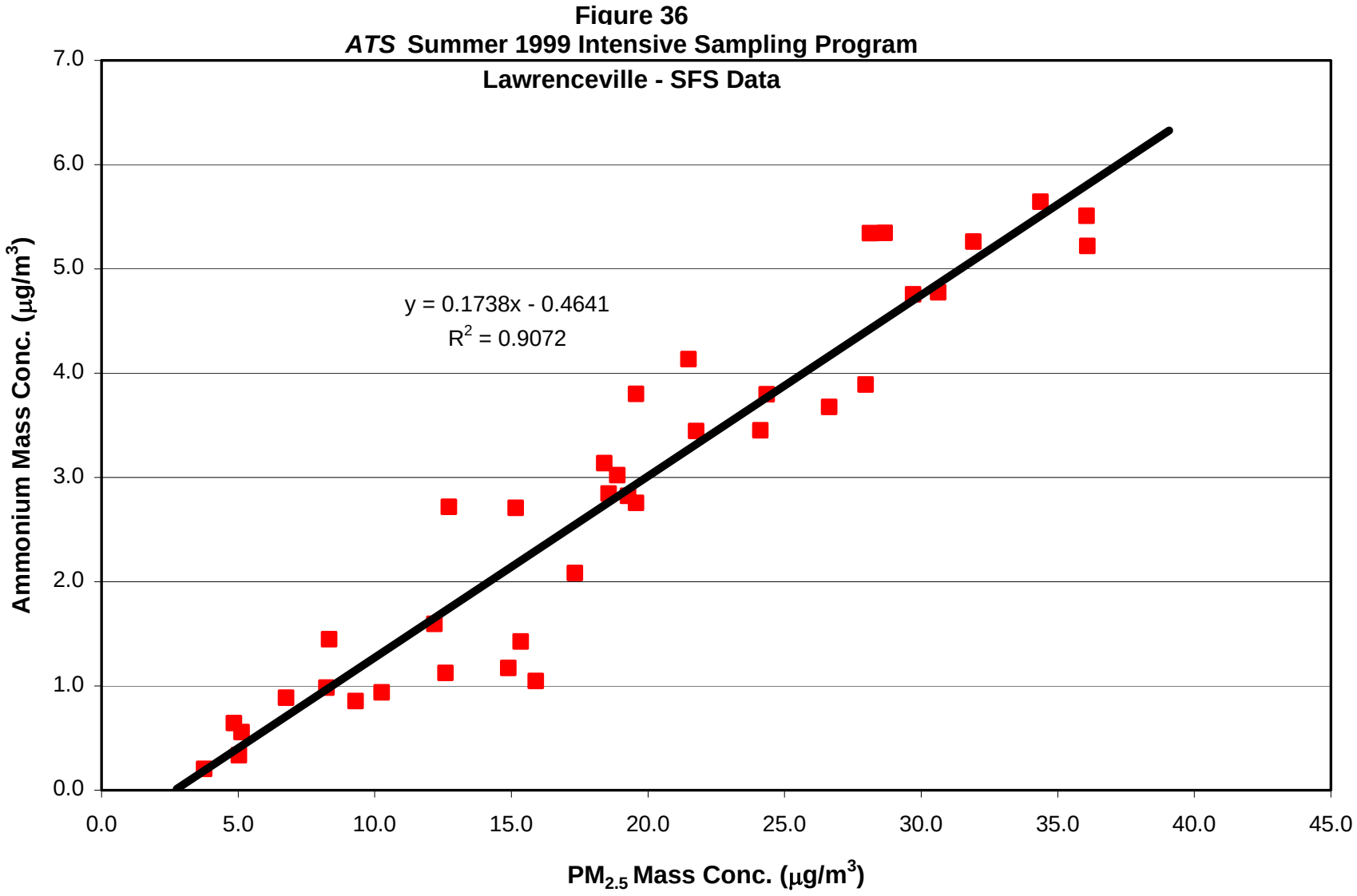


Figure 36
ATS Summer 1999 Intensive Sampling Program
Lawrenceville - SFS Data
y = 0.1738x - 0.4641
R2 = 0.9072
Ammonium Mass Conc. (µg/m3)
PM2.5 Mass Conc. (µg/m3)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0

Figure 37

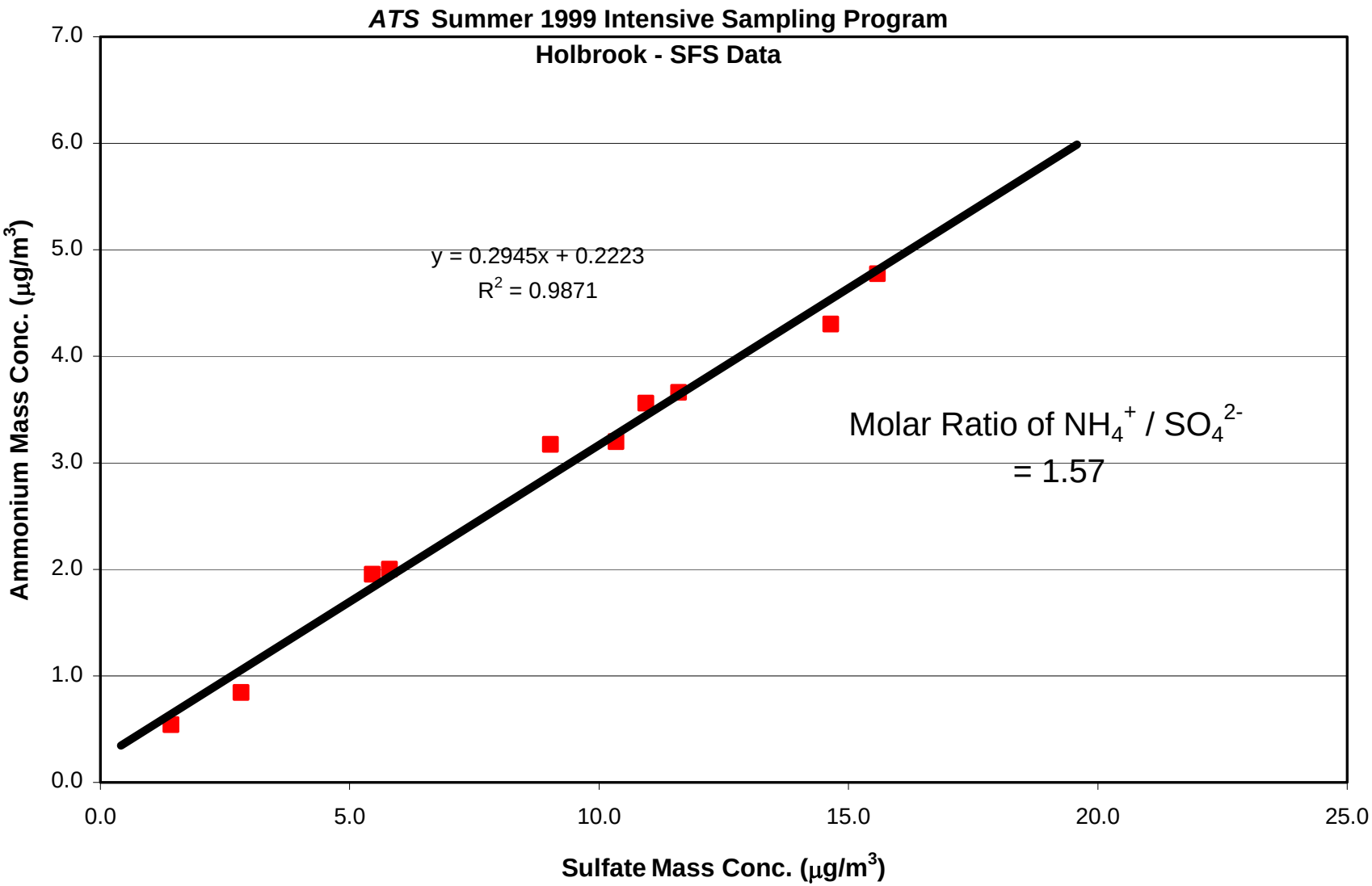
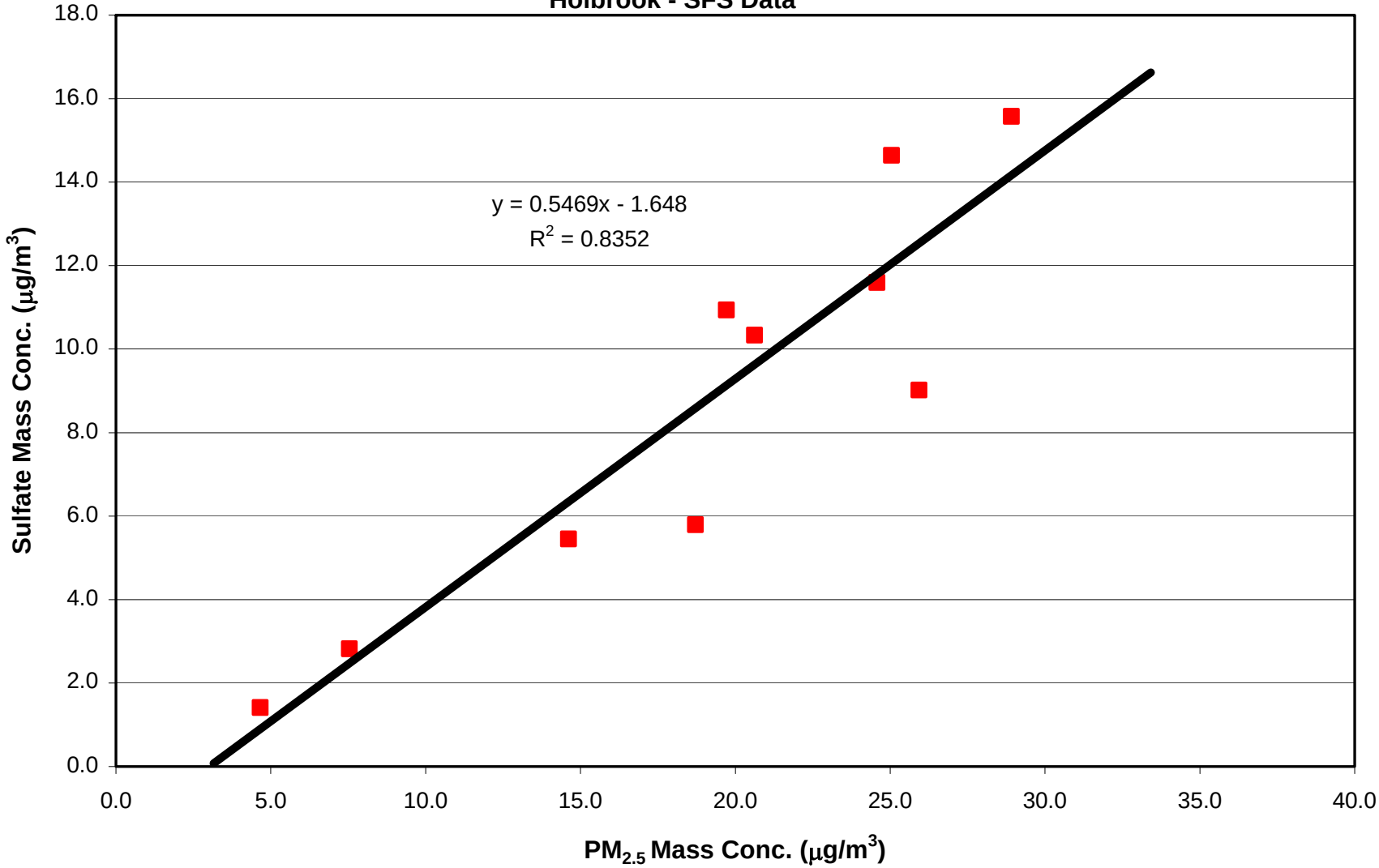

ATS Summer 1999 Intensive Sampling Program
Holbrook - SFS Data
y = 0.2945x + 0.2223
R^2 = 0.9871
Molar Ratio of NH_4^+ / SO_4^{2-}
= 1.57
Ammonium Mass Conc. (μg/m^3)
Sulfate Mass Conc. (μg/m^3)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
0.0
5.0
10.0
15.0
20.0
25.0

Figure 38

***ATS* Summer 1999 Intensive Sampling Program**

Holbrook - SFS Data



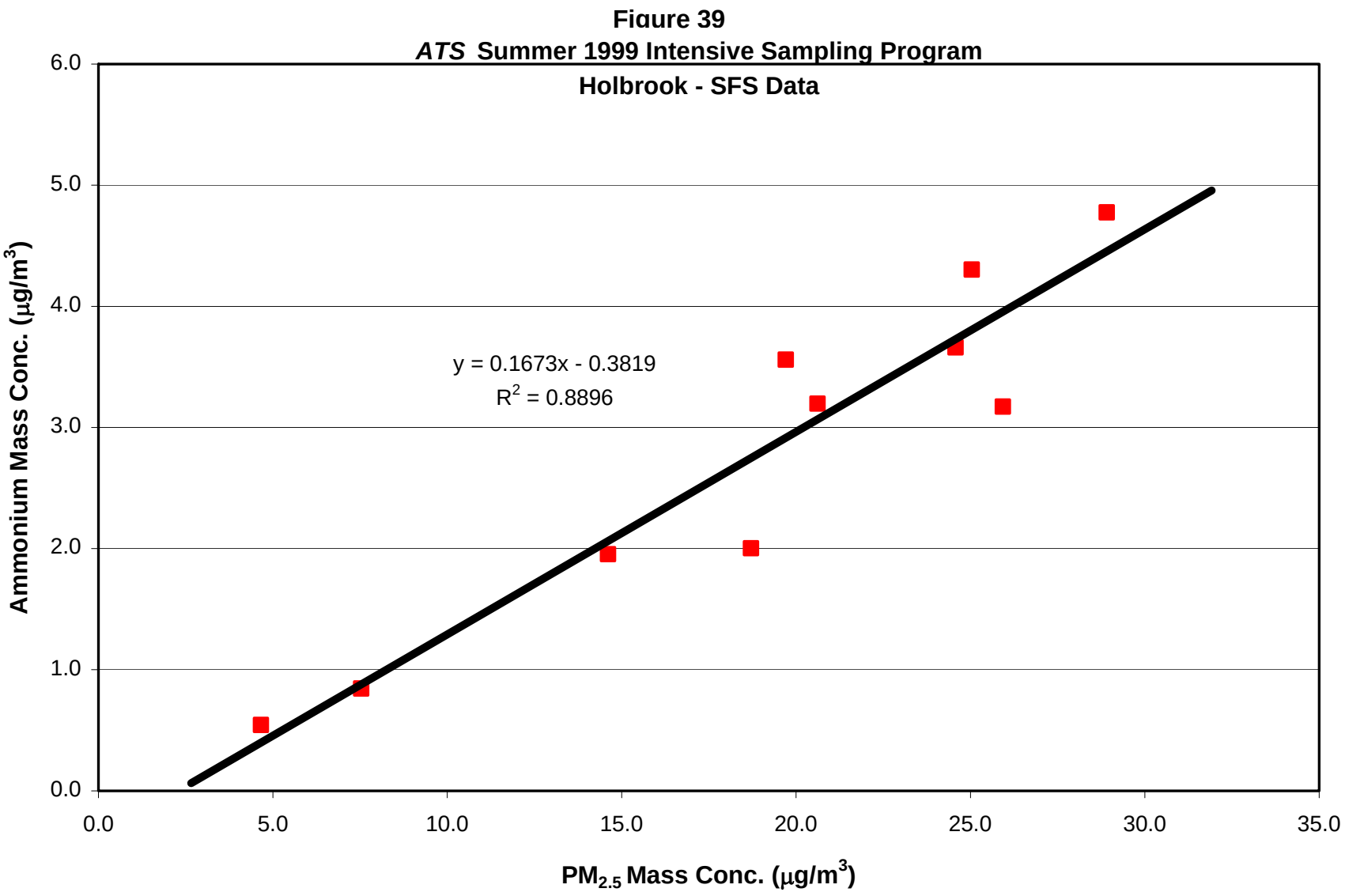


Figure 39
ATS Summer 1999 Intensive Sampling Program
Holbrook - SFS Data
y = 0.1673x - 0.3819
R2 = 0.8896
Ammonium Mass Conc. (µg/m3)
PM2.5 Mass Conc. (µg/m3)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0

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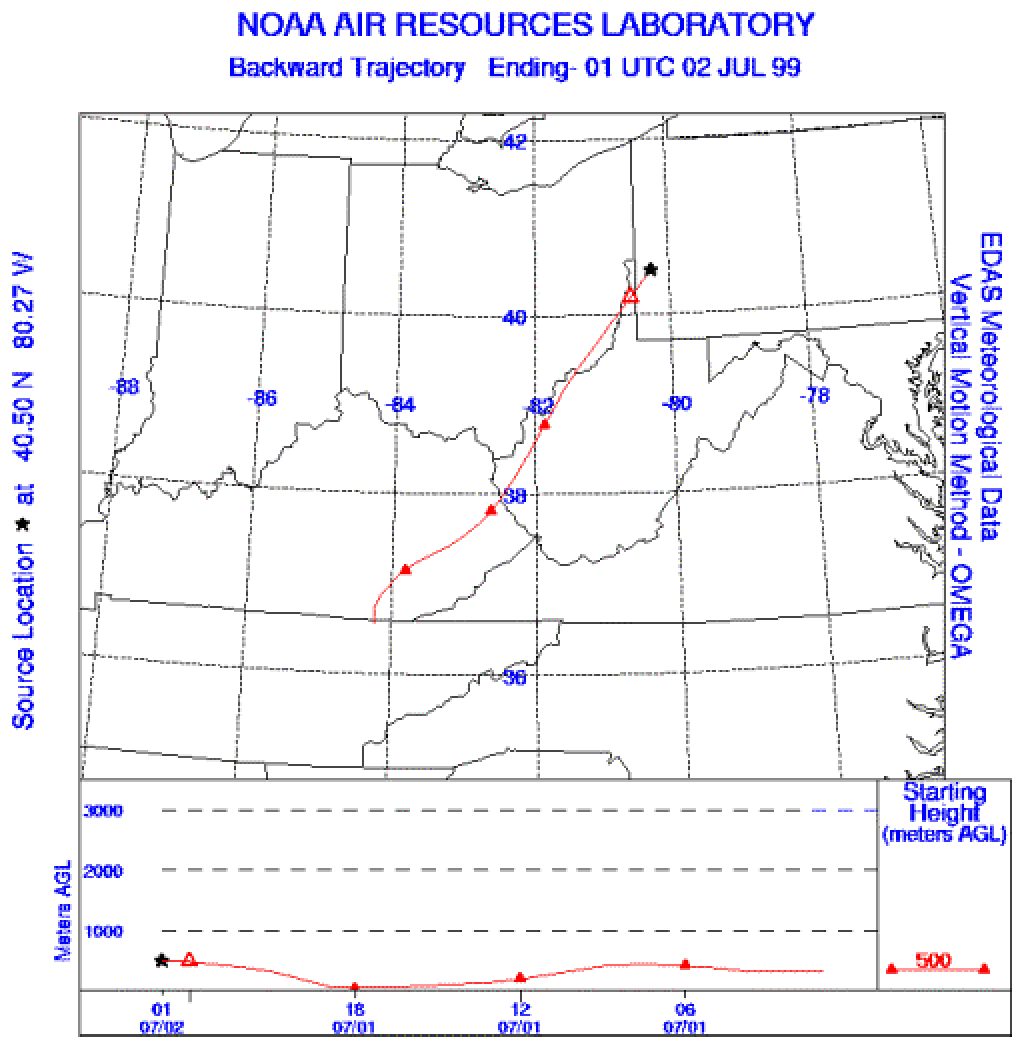

FIGURE 40: Results from typical wind trajectory calculation

Figure 41

$PM_{2.5}$ Lawrenceville - July 1999

Polar Coordinate Plot

TEOM Conc. (r) vs. Wind Direction (θ)

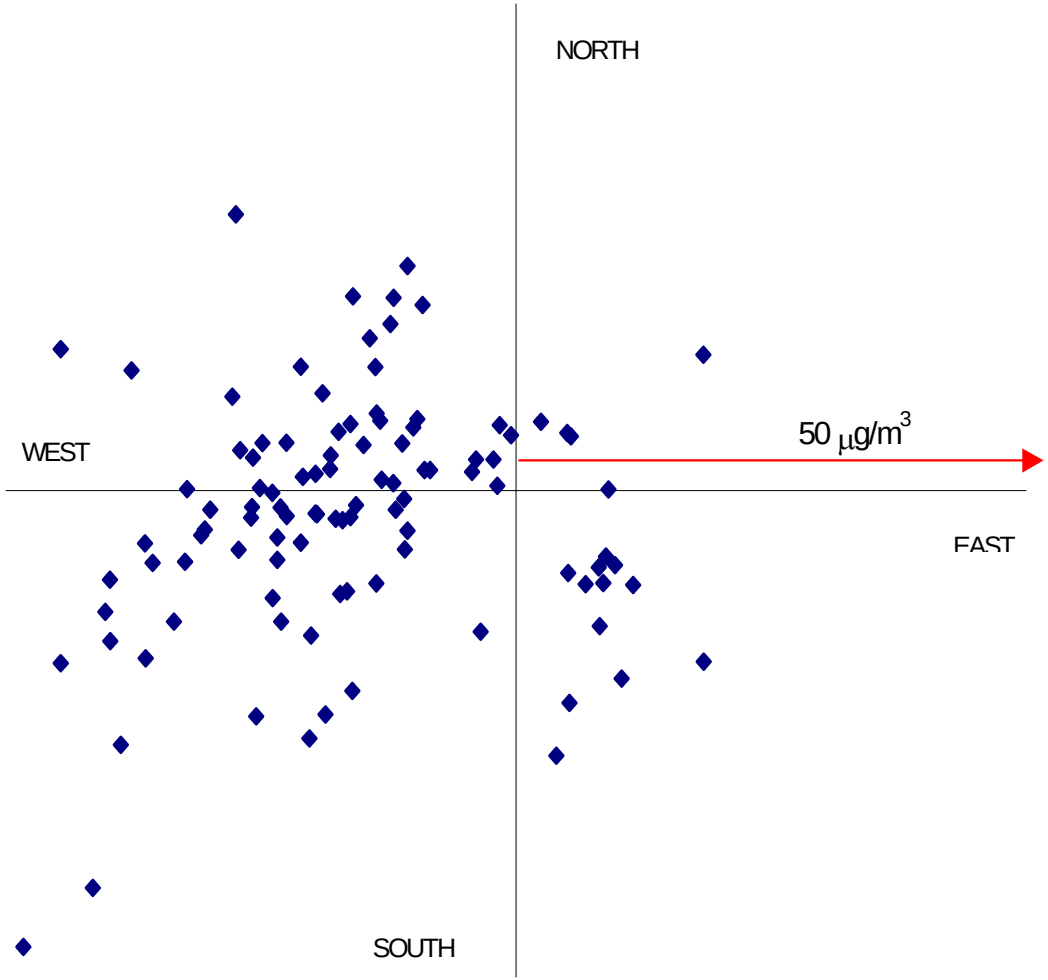

Figure 42
$PM_{2.5}$ Lawrenceville - July 2000
Polar Coordinate Plot
TEOM Conc. (r) vs. Wind Direction (θ)

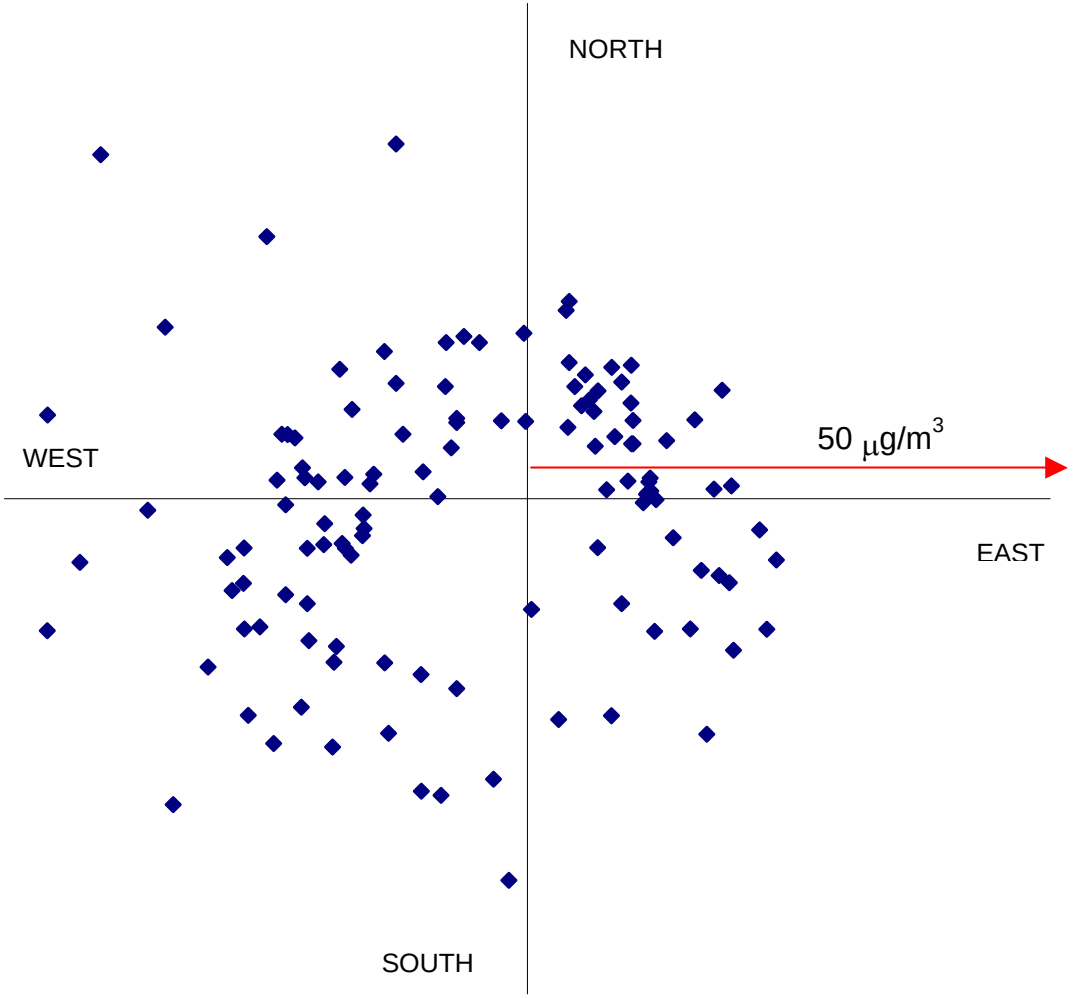

Figure 43

July 1999 & July 2000

Lawrenceville $PM_{2.5}$ 6-Hour Average TEOM Data Distribution

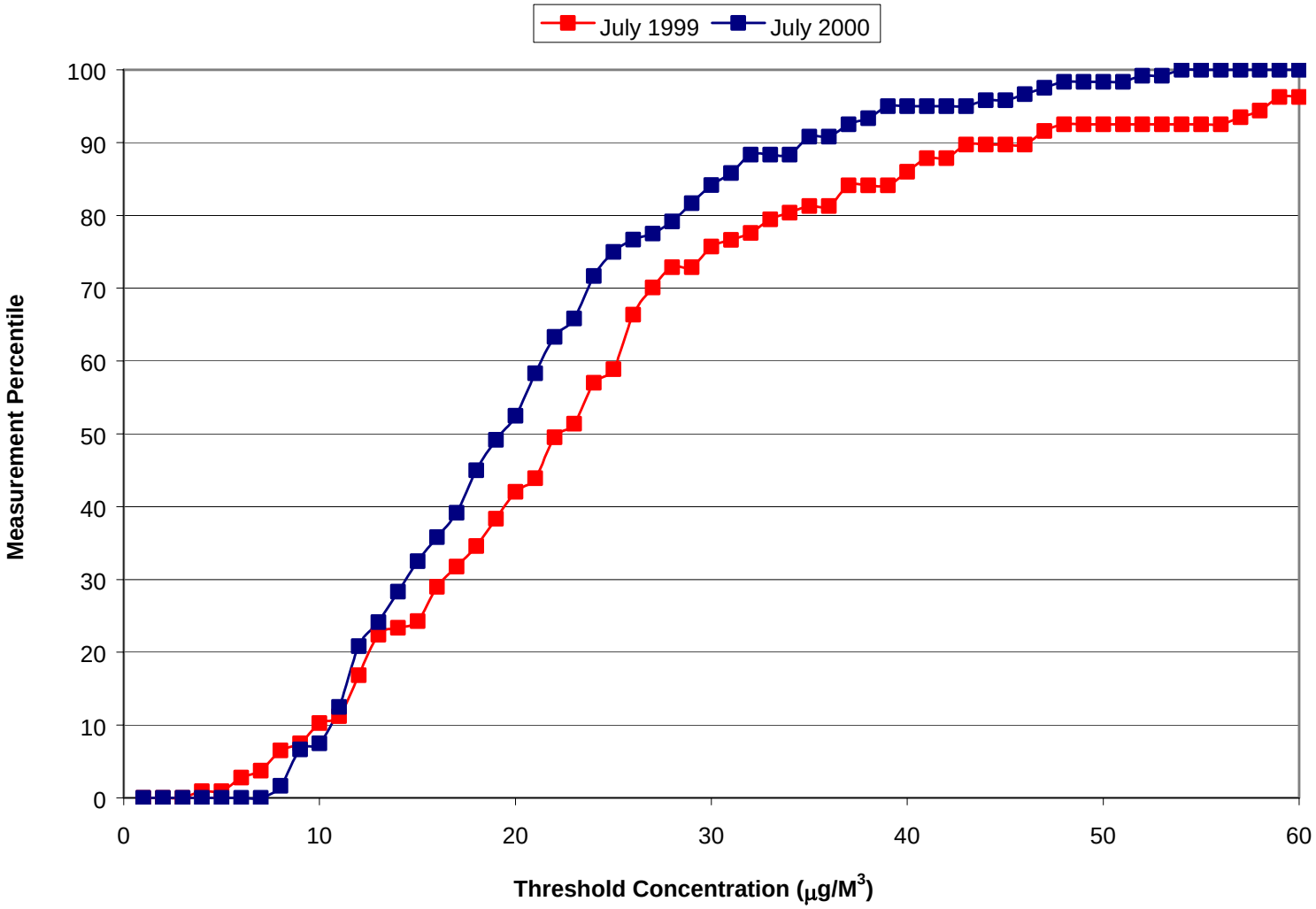

FIGURE 44
Ozone vs Nox Concentrations
Lawrenceville June – August 2001

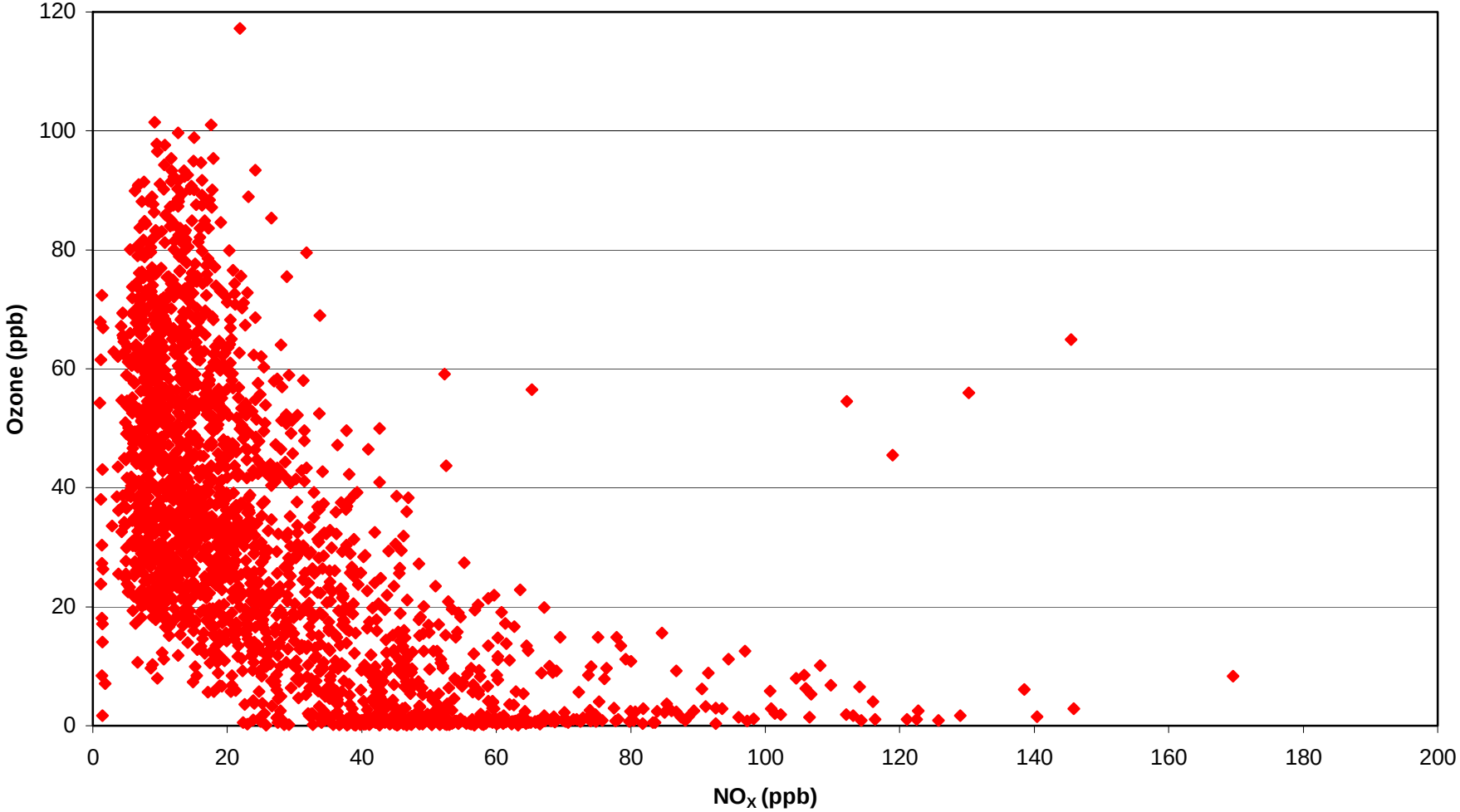

FIGURE 45

Ozone vs. NO_X Lawrenceville January-February 2000

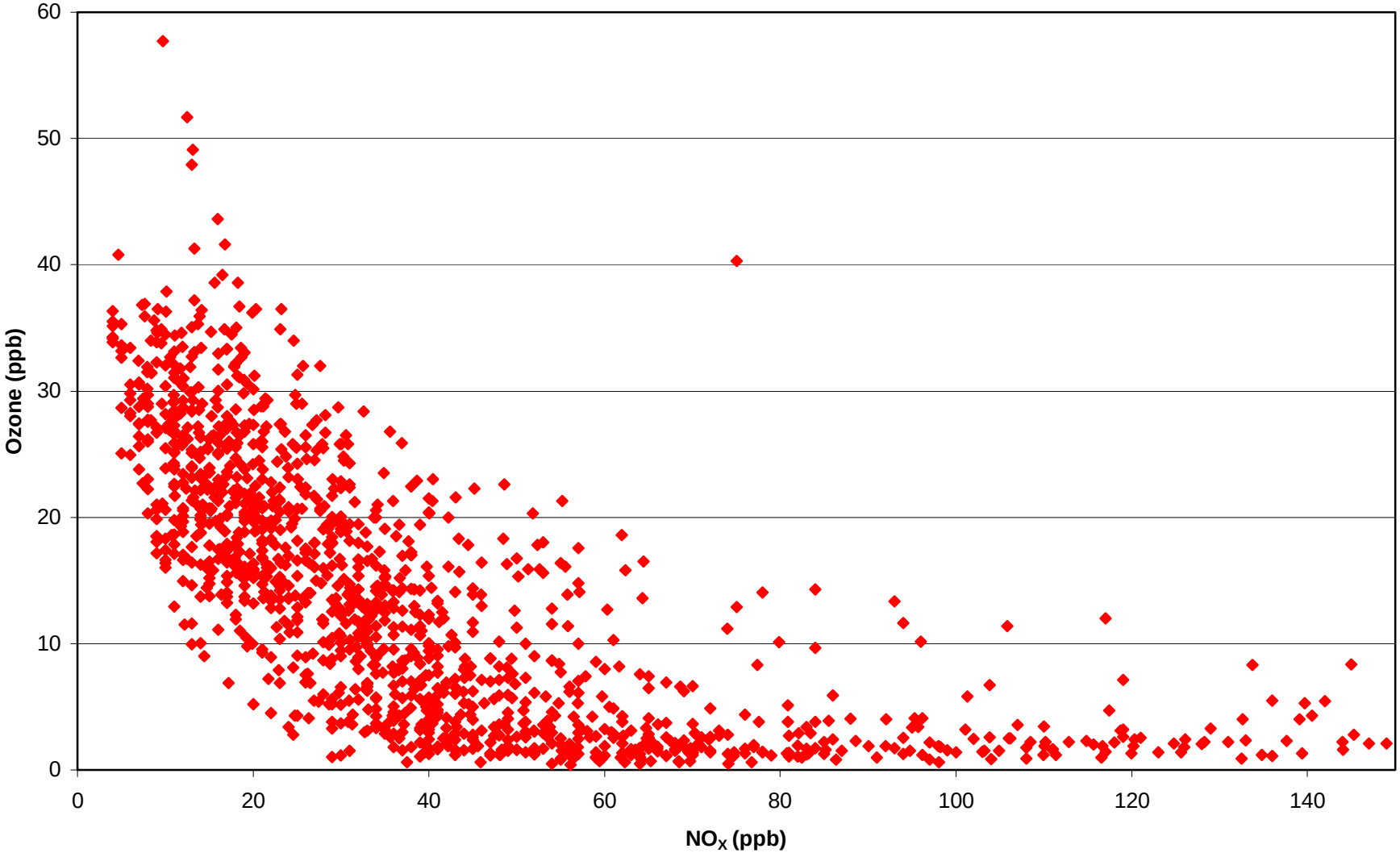

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TABLE 2

INTEGRATED $PM_{2.5}$ SAMPLERS -
SAMPLING AND ANALYSIS LOG

Sampling Period Type	Site ID	Measurement Technique	Start Date	Stop Date	Sampling Frequency	Nominal Sampling Duration (hrs)	No. Valid Samples Collected and Analyzed *	
							Mass	Constituents #
Intensive (winter)	AT	Anderson SFS	2/17/1999	2/26/1999	Every 3rd Day	24	4	0
	AT	Met One SASS	2/17/1999	2/26/1999	Every 3rd Day	24	0	0
	HB	DRI SFS	2/17/1999	2/28/1999	Once per day	24	12	9
	HB	R&P FRM	2/17/1999	2/28/1999	Every 6th Day	24	2	0
	LW	DRI SFS	2/17/1999	2/28/1999	4 times per day	6	46	25
	LW	R&P FRM	2/17/1999	2/28/1999	Every 6th Day	24	2	1
	MO	DRI SFS	2/17/1999	2/28/1999	Every 3rd Day	24	0	0
	MO	R&P FRM	2/17/1999	2/26/1999	Every 3rd Day	24	4	0
Background	AT	Anderson SFS	3/1/1999	7/29/1999	Every 3rd Day	24	40	0
	AT	Met One SASS	3/1/1999	7/29/1999	Every 6th Day	24	0	0
	HB	DRI SFS	3/1/1999	7/29/1999	Every 6th Day	24	22	4
	HB	R&P FRM	3/1/1999	7/29/1999	Every 6th Day	24	23	0
	LW	DRI SFS	3/1/1999	7/29/1999	Every 6th Day	24	23	4
	LW	R&P FRM	3/1/1999	7/29/1999	Every 6th Day	24	21	4
	MO	DRI SFS	3/1/1999	7/29/1999	Every 6th Day	24	0	0
	MO	R&P FRM	3/1/1999	7/29/1999	Every 3rd Day	24	49	0
Intensive (summer)	AT	Anderson SFS	8/1/1999	9/12/1999	Every 3rd Day	24	15	0
	AT	Met One SASS	8/3/1999	9/11/1999	Every 3rd Day	24	13	10
	HB	DRI SFS	8/3/1999	9/11/1999	Once per day	24	31	4
	HB	R&P FRM	8/3/1999	9/11/1999	Every 6th Day	24	6	0
	LW	DRI SFS	8/3/1999	9/11/1999	4 times per day	6	149	30
	LW	R&P FRM	8/3/1999	9/11/1999	Every 6th Day	24	0	0
	MO	DRI SFS	8/21/1999	9/11/1999	Every 3rd Day	24	4	0
	MO	R&P FRM	8/1/1999	9/12/1999	Every 3rd Day	24	14	0
Background	AT	Anderson SFS	9/15/1999	1/7/2000	Every 3rd Day	24	35	0
	AT	Met One SASS	9/15/1999	1/7/2000	Every 6th Day	24	15	14
	HB	DRI SFS	9/15/1999	1/7/2000	Every 6th Day	24	16	0
	HB	R&P FRM	9/15/1999	1/7/2000	Every 6th Day	24	18	0
	LW	DRI SFS	9/15/1999	1/7/2000	Every 6th Day	24	20	0
	LW	R&P FRM	9/15/1999	1/7/2000	Every 6th Day	24	0	0
	MO	DRI SFS	9/15/1999	1/7/2000	Every 6th Day	24	19	0
	MO	R&P FRM	9/15/1999	1/7/2000	Every 3rd Day	24	38	0

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TABLE 2

INTEGRATED $PM_{2.5}$ SAMPLERS -
SAMPLING AND ANALYSIS LOG

Sampling Period Type	Site ID	Measurement Technique	Start Date	Stop Date	Sampling Frequency	Nominal Sampling Duration (hrs)	No. Valid Samples Collected and Analyzed *	
							Mass	Constituents #
Intensive (winter)	AT	Anderson SFS	1/10/2000	2/18/2000	Every 3rd Day	24	12	0
	AT	Met One SASS	1/10/2000	2/18/2000	Every 3rd Day	24	12	6
	HB	DRI SFS	1/12/2000	2/18/2000	Once per day	24	34	4
	HB	R&P FRM	1/12/2000	2/18/2000	Every 6th Day	24	4	2
	LW	DRI SFS	1/12/2000	2/18/2000	4 times per day	6	137	8
	LW	R&P FRM	1/12/2000	2/18/2000	Every 6th Day	24	1	1
	MO	DRI SFS	1/13/2000	2/18/2000	Every 3rd Day	24	8	0
	MO	R&P FRM	1/10/2000	2/18/2000	Every 3rd Day	24	13	0
Background	AT	Anderson SFS	2/21/2000	7/11/2000	Every 3rd Day	24	15	0
	AT	Met One SASS	2/24/2000	7/11/2000	Every 6th Day	24	22	16
	HB	DRI SFS	2/24/2000	7/11/2000	Every 6th Day	24	13	1
	HB	R&P FRM	2/24/2000	7/11/2000	Every 6th Day	24	18	0
	LW	DRI SFS	2/24/2000	7/11/2000	Every 6th Day	24	19	2
	LW	R&P FRM	2/24/2000	7/11/2000	Every 6th Day	24	5	0
	MO	DRI SFS	2/24/2000	7/11/2000	Every 6th Day	24	16	0
	MO	R&P FRM	2/21/2000	7/11/2000	Every 3rd Day	24	47	0
Intensive (summer)	AT	Anderson SFS	7/14/2000	8/25/2000	Every 3rd Day	24	13	0
	AT	Met One SASS	7/17/2000	8/25/2000	Every 3rd Day	24	8	7
	HB	DRI SFS	7/17/2000	8/25/2000	Once per day	24	37	12
	HB	R&P FRM	7/17/2000	8/25/2000	Every 6th Day	24	7	7
	LW	DRI SFS	7/17/2000	8/25/2000	4 times per day	6	145	38
	LW	R&P FRM	7/17/2000	8/25/2000	Every 6th Day	24	3	3
	MO	DRI SFS	7/17/2000	8/25/2000	Every 3rd Day	24	10	0
	MO	R&P FRM	7/14/2000	8/25/2000	Every 3rd Day	24	15	0
Background	AT	Anderson SFS	8/28/2000	6/24/2001	Every 3rd Day	24	96	0
	AT	Met One SASS	8/28/2000	6/24/2001	Every 6th Day	24	41	32
	HB	DRI SFS	8/28/2000	6/24/2001	Every 6th Day	24	33	2
	HB	R&P FRM	8/28/2000	6/24/2001	Every 6th Day	24	42	15
	LW	DRI SFS	8/28/2000	6/24/2001	Every 6th Day	24	49	1
	LW	R&P FRM	8/28/2000	6/24/2001	Every 6th Day	24	36	0
	MO	DRI SFS	8/28/2000	6/24/2001	Every 6th Day	24	42	0
	MO	R&P FRM	8/28/2000	6/24/2001	Every 3rd Day	24	94	0

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TABLE 2

INTEGRATED $PM_{2.5}$ SAMPLERS -
SAMPLING AND ANALYSIS LOG

Sampling Period Type	Site ID	Measurement Technique	Start Date	Stop Date	Sampling Frequency	Nominal Sampling Duration (hrs)	No. Valid Samples Collected and Analyzed *	
							Mass	Constituents #
Intensive (summer)	AT	Anderson SFS	6/27/2001	8/8/2001	Every 3rd Day	24	15	0
	AT	Met One SASS	6/30/2001	8/8/2001	Every 3rd Day	24	9	6
	HB	DRI SFS	6/30/2001	8/8/2001	Once per day	24	28	9
	HB	R&P FRM	6/30/2001	8/8/2001	Every 6th Day	24	6	1
	LW	DRI SFS	6/30/2001	8/8/2001	4 times per day	6	157	65
	LW	R&P FRM	6/30/2001	8/8/2001	Every 6th Day	24	5	2
	MO	DRI SFS	6/30/2001	8/5/2001	Every 3rd Day	24	11	0
	MO	R&P FRM	6/27/2001	8/8/2001	Every 3rd Day	24	15	0
Intensive (winter)	AT	Anderson SFS	1/2/2002	1/23/2002	Every 3rd Day	24	8	0
	AT	Met One SASS	1/2/2002	1/22/2002	Every 3rd Day	24	0	0
	HB	DRI SFS	1/2/2002	1/22/2002	Once per day	24	20	0
	HB	R&P FRM	1/2/2002	1/22/2002	Every 6th Day	24	0	0
	LW	DRI SFS	1/2/2002	1/22/2002	Once per day	24	21	0
	LW	R&P FRM	1/2/2002	1/22/2002	Every 6th Day	24	0	0
	MO	DRI SFS	1/2/2002	1/22/2002	Every 3rd Day	24	0	0
	MO	R&P FRM	1/2/2002	1/23/2002	Every 3rd Day	24	8	0
Intensive (fall & winter)	AT	Anderson SFS	10/2/2002	2/26/2003	Every 3rd Day	24	50	0
	AT	Met One SASS	10/1/2002	2/28/2003	Every 3rd Day	24	0	0
	HB	DRI SFS	10/1/2002	2/28/2003	Once per day	24	0	0
	HB	R&P FRM	10/1/2002	2/28/2003	Every 6th Day	24	0	0
	LW	DRI SFS	10/1/2002	2/28/2003	Once per day	24	145	57
	LW	R&P FRM	10/1/2002	2/28/2003	Every 6th Day	24	0	0
	MO	DRI SFS	10/1/2002	2/28/2003	Every 3rd Day	24	0	0
	MO	R&P FRM	10/2/2002	2/26/2003	Every 3rd Day	24	50	0

#: For samples collected using the DRI SFS, constituents included 38 elements (primarily metals), organic and elemental carbon, inorganic ions, artifact organic and elemental carbon, and volatilized nitrate
For samples collected using the SASS, constituents included 36 elements (primarily metals), organic and elemental carbon, inorganic ions, artifact organic and elemental carbon, and volatilized nitrate

*: Excludes field blanks, samples voided by DRI, Chester LabNet or ATS (please see Section 4.1)
Please see Table 1 for the Measurement Technique Legend

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TABLE 3

INTEGRATED PM_{10} SAMPLERS -
SAMPLING AND ANALYSIS LOG

Sampling Period Type	Site ID	Measurement Technique	Start Date	Stop Date	Sampling Frequency	Nominal Sampling Duration (hrs)	No. Valid Samples Collected and Analyzed *	
							Mass	Constituents #
Intensive (winter)	AT	Anderson Hi-Vol	2/17/1999	2/23/1999	Every 6th Day	24	2	0
	HB	DRI SFS	2/17/1999	2/28/1999	Once per day	24	11	8
	LW	DRI SFS	2/17/1999	2/28/1999	4 times per day	6	45	31
	MO	Anderson Hi-Vol	2/17/1999	2/23/1999	Every 6th Day	24	2	0
Background	AT	Anderson Hi-Vol	3/1/1999	7/29/1999	Every 6th Day	24	24	0
	HB	DRI SFS	3/1/1999	7/29/1999	Every 6th Day	24	23	4
	LW	DRI SFS	3/1/1999	7/29/1999	Every 6th Day	24	24	5
	MO	Anderson Hi-Vol	3/1/1999	7/29/1999	Every 6th Day	24	26	0
Intensive (summer)	AT	Anderson Hi-Vol	8/4/1999	9/9/1999	Every 6th Day	24	7	0
	HB	DRI SFS	8/3/1999	9/11/1999	Once per day	24	35	0
	LW	DRI SFS	8/3/1999	9/11/1999	4 times per day	6	152	0
	MO	Anderson Hi-Vol	8/4/1999	9/9/1999	Every 6th Day	24	7	0
Background	AT	Anderson Hi-Vol	9/15/1999	1/7/2000	Every 6th Day	24	18	0
	HB	DRI SFS	9/15/1999	1/7/2000	Every 6th Day	24	15	0
	LW	DRI SFS	9/15/1999	1/7/2000	Every 6th Day	24	18	0
	MO	Anderson Hi-Vol	9/15/1999	1/7/2000	Every 6th Day	24	18	0
Intensive (winter)	AT	Anderson Hi-Vol	1/13/2000	2/18/2000	Every 6th Day	24	7	0
	HB	DRI SFS	1/12/2000	2/18/2000	Once per day	24	34	0
	LW	DRI SFS	1/12/2000	2/18/2000	4 times per day	6	127	0
	MO	Anderson Hi-Vol	1/13/2000	2/18/2000	Every 6th Day	24	7	0
Background	AT	Anderson Hi-Vol	2/24/2000	7/11/2000	Every 6th Day	24	19	0
	HB	DRI SFS	2/24/2000	7/11/2000	Every 6th Day	24	18	0
	LW	DRI SFS	2/24/2000	7/11/2000	Every 6th Day	24	18	0
	MO	Anderson Hi-Vol	2/24/2000	7/11/2000	Every 6th Day	24	23	0
Intensive (summer)	AT	Anderson Hi-Vol	7/17/2000	8/22/2000	Every 6th Day	24	7	0
	HB	DRI SFS	7/17/2000	8/25/2000	Once per day	24	33	0
	LW	DRI SFS	7/17/2000	8/25/2000	4 times per day	6	153	0
	MO	Anderson Hi-Vol	7/17/2000	8/22/2000	Every 6th Day	24	7	0

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TABLE 3

INTEGRATED PM_{10} SAMPLERS -
SAMPLING AND ANALYSIS LOG

Sampling Period Type	Site ID	Measurement Technique	Start Date	Stop Date	Sampling Frequency	Nominal Sampling Duration (hrs)	No. Valid Samples Collected and Analyzed *	
							Mass	Constituents #
Background	AT	Anderson Hi-Vol	8/28/2000	6/24/2001	Every 6th Day	24	50	0
	HB	DRI SFS	8/28/2000	6/24/2001	Every 6th Day	24	43	0
	LW	DRI SFS	8/28/2000	6/24/2001	Every 6th Day	24	44	0
	MO	Anderson Hi-Vol	8/28/2000	6/24/2001	Every 6th Day	24	49	0
Intensive (summer)	AT	Anderson Hi-Vol	6/30/2001	8/5/2001	Every 6th Day	24	7	0
	HB	DRI SFS	6/30/2001	8/8/2001	Once per day	24	30	0
	LW	DRI SFS	6/30/2001	8/8/2001	4 times per day	6	143	0
	MO	Anderson Hi-Vol	6/30/2001	8/5/2001	Every 6th Day	24	7	0
Intensive (winter)	AT	Anderson Hi-Vol	1/2/2002	1/20/2002	Every 6th Day	24	4	0
	HB	DRI SFS	1/2/2002	1/22/2002	Once per day	24	0	0
	LW	DRI SFS	1/2/2002	1/22/2002	Once per day	24	0	0
	MO	Anderson Hi-Vol	1/2/2002	1/20/2002	Every 6th Day	24	4	0
Intensive (fall & winter)	AT	Anderson Hi-Vol	10/5/2002	2/26/2003	Every 6th Day	24	24	0
	LW	DRI SFS	10/1/2002	2/28/2003	Once per day	24	0	0
	HB	DRI SFS	10/1/2002	2/28/2003	Once per day	24	0	0
	MO	Anderson Hi-Vol	10/5/2002	2/26/2003	Every 6th Day	24	24	0

#: For samples collected using the DRI SFS, constituents included 38 elements (primarily metals), organic and elemental carbon, inorganic ions, artifact organic and elemental carbon, and volatilized nitrate

*: Excludes field blanks, samples voided by DRI or ATS (please see Section 4.1)

Please see Table 1 for the Measurement Technique Legend

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TABLE 4

INTEGRATED NITRIC ACID (HNO_3) GAS SAMPLER - SAMPLING AND ANALYSIS LOG

Sampling Period Type	Site ID	Measurement Technique	Start Date	Stop Date	Sampling Frequency	Nominal Sampling Duration (hrs)	No. Valid Samples Collected and Analyzed *
Intensive	HB	DRI SGS TP	2/17/1999	2/28/1999	Once per day	24	7
(winter)	LW	DRI SGS TP	2/17/1999	2/28/1999	4 times per day	6	29
Background	HB	DRI SGS TP	3/1/1999	7/29/1999	Every 6th Day	24	5
	LW	DRI SGS TP	3/1/1999	7/29/1999	Every 6th Day	24	4
Intensive	HB	DRI SGS TP	8/3/1999	9/11/1999	Once per day	24	10
(summer)	LW	DRI SGS TP	8/3/1999	9/11/1999	4 times per day	6	38
Background	HB	DRI SGS TP	9/15/1999	1/7/2000	Every 6th Day	24	0
	LW	DRI SGS TP	9/15/1999	1/7/2000	Every 6th Day	24	0
Intensive	HB	DRI SGS TP	1/12/2000	2/18/2000	Once per day	24	10
(winter)	LW	DRI SGS TP	1/12/2000	2/18/2000	4 times per day	6	41
Background	HB	DRI SGS TP	2/24/2000	7/11/2000	Every 6th Day	24	2
	LW	DRI SGS TP	2/24/2000	7/11/2000	Every 6th Day	24	0
Intensive	HB	DRI SGS TP	7/17/2000	8/25/2000	Once per day	24	17
(summer)	LW	DRI SGS TP	7/17/2000	8/25/2000	4 times per day	6	57
Background	HB	DRI SGS TP	8/28/2000	6/24/2001	Every 6th Day	24	2
	LW	DRI SGS TP	8/28/2000	6/24/2001	Every 6th Day	24	2
Intensive	HB	DRI SGS TP	6/30/2001	8/8/2001	Once per day	24	18
(summer)	LW	DRI SGS TP	6/30/2001	8/8/2001	4 times per day	6	72
Intensive	HB	DRI SGS TP	1/2/2002	1/22/2002	Once per day	24	0
(winter)	LW	DRI SGS TP	1/2/2002	1/22/2002	Once per day	24	0
Intensive	HB	DRI SGS TP	10/1/2002	2/28/2003	Once per day	24	0
(fall & winter)	LW	DRI SGS TP	10/1/2002	2/28/2003	Once per day	24	0

*: Excludes field blanks, samples voided by DRI or ATS (please see Section 4.1)
Please see Table 1 for the Measurement Technique Legend

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TABLE 5

INTEGRATED AMMONIA (NH_3) GAS SAMPLER - SAMPLING AND ANALYSIS LOG

Sampling Period Type	Site ID	Measurement Technique	Start Date	Stop Date	Sampling Frequency	Nominal Sampling Duration (hrs)	No. Valid Samples Collected and Analyzed *
Intensive	HB	DRI SGS $PM_{2.5}$	2/17/1999	2/28/1999	Once per day	24	0
(winter)	LW	DRI SGS $PM_{2.5}$	2/17/1999	2/28/1999	4 times per day	6	20
Background	HB	DRI SGS $PM_{2.5}$	3/1/1999	7/29/1999	Every 6th Day	24	5
	LW	DRI SGS $PM_{2.5}$	3/1/1999	7/29/1999	Every 6th Day	24	3
Intensive	HB	DRI SGS $PM_{2.5}$	8/3/1999	9/11/1999	Once per day	24	6
(summer)	LW	DRI SGS $PM_{2.5}$	8/3/1999	9/11/1999	4 times per day	6	38
Background	HB	DRI SGS $PM_{2.5}$	9/15/1999	1/7/2000	Every 6th Day	24	0
	LW	DRI SGS $PM_{2.5}$	9/15/1999	1/7/2000	Every 6th Day	24	0
Intensive	HB	DRI SGS $PM_{2.5}$	1/12/2000	2/18/2000	Once per day	24	6
(winter)	LW	DRI SGS $PM_{2.5}$	1/12/2000	2/18/2000	4 times per day	6	36
Background	HB	DRI SGS $PM_{2.5}$	2/24/2000	7/11/2000	Every 6th Day	24	0
	LW	DRI SGS $PM_{2.5}$	2/24/2000	7/11/2000	Every 6th Day	24	2
Intensive	HB	DRI SGS $PM_{2.5}$	7/17/2000	8/25/2000	Once per day	24	15
(summer)	LW	DRI SGS $PM_{2.5}$	7/17/2000	8/25/2000	4 times per day	6	54
Background	HB	DRI SGS $PM_{2.5}$	8/28/2000	6/24/2001	Every 6th Day	24	1
	LW	DRI SGS $PM_{2.5}$	8/28/2000	6/24/2001	Every 6th Day	24	2
Intensive	HB	DRI SGS $PM_{2.5}$	6/30/2001	8/8/2001	Once per day	24	16
(summer)	LW	DRI SGS $PM_{2.5}$	6/30/2001	8/8/2001	4 times per day	6	45
Intensive	HB	DRI SGS $PM_{2.5}$	1/2/2002	1/22/2002	Once per day	24	0
(winter)	LW	DRI SGS $PM_{2.5}$	1/2/2002	1/22/2002	Once per day	24	0
Intensive	HB	DRI SGS $PM_{2.5}$	10/1/2002	2/28/2003	Once per day	24	0
(fall & winter)	LW	DRI SGS $PM_{2.5}$	10/1/2002	2/28/2003	Once per day	24	0

*: Excludes field blanks, samples voided by DRI or ATS (please see Section 4.1)
Please see Table 1 for the Measurement Technique Legend

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TABLE 6

INTEGRATED $PM_{2.5}$ PARTICLE SIZE SAMPLER - SAMPLING AND ANALYSIS LOG

Sampling Period Type	Site ID	Measurement Technique	Start Date	Stop Date	Sampling Frequency	Nominal Sampling Duration (hrs)	No. of Samples Collected *	No. of Samples Analyzed
Intensive	HB	DRI Portable	2/17/1999	2/28/1999	Once per day	24	12	0
(winter)	LW	DRI Portable	2/17/1999	2/28/1999	4 times per day	6	48	0
Background	HB	DRI Portable	3/1/1999	7/29/1999	Every 6th Day	24	26	0
	LW	DRI Portable	3/1/1999	7/29/1999	Every 6th Day	24	26	0
Intensive	HB	DRI Portable	8/3/1999	9/11/1999	Once per day	24	40	0
(summer)	LW	DRI Portable	8/3/1999	9/11/1999	4 times per day	6	160	0
Background	HB	DRI Portable	9/15/1999	1/7/2000	Every 6th Day	24	20	0
	LW	DRI Portable	9/15/1999	1/7/2000	Every 6th Day	24	20	0
Intensive	HB	DRI Portable	1/12/2000	2/18/2000	Once per day	24	38	0
(winter)	LW	DRI Portable	1/12/2000	2/18/2000	4 times per day	6	152	0
Background	HB	DRI Portable	2/24/2000	7/11/2000	Every 6th Day	24	24	0
	LW	DRI Portable	2/24/2000	7/11/2000	Every 6th Day	24	24	0
Intensive	HB	DRI Portable	7/17/2000	8/24/2000	Once per day	24	39	0
(summer)	LW	DRI Portable	7/17/2000	8/25/2000	4 times per day	6	160	0
Background	HB	DRI Portable	8/28/2000	6/24/2001	Every 6th Day	24	51	0
	LW	DRI Portable	8/28/2000	6/24/2001	Every 6th Day	24	51	0
Intensive	HB	DRI Portable	6/30/2001	8/8/2001	Once per day	24	40	0
(summer)	LW	DRI Portable	6/30/2001	8/8/2001	4 times per day	6	160	0
Intensive	HB	DRI Portable	1/2/2002	1/22/2002	Once per day	24	21	0
(winter)	LW	DRI Portable	1/2/2002	1/22/2002	Once per day	24	21	0
Intensive	HB	DRI Portable	10/1/2002	2/28/2003	Once per day	24	0	0
(fall & winter)	LW	DRI Portable	10/1/2002	2/28/2003	Once per day	24	0	0

*: Excludes Field Blanks

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TABLE 7

CURRENT DATA STATUS SUMMARY FOR THE ATHENS (AT) SITE

Constituent of Concern	Measurement Technique	Data Type	Data Collected	Data Provider	Data Obtained by ATS	Data Validated by Provider	Data Filtering Status #	Notes
$PM_{2.5}$	DRI SFS	Integrated *	No	---	---	---	---	---
	R&P FRM	Integrated *	No	---	---	---	---	---
	R&P TEOM	Real-Time **	No	---	---	---	---	---
	Met One SASS	Integrated *	Yes	LabNet	Yes	Yes	Complete	---
	Anderson SFS	Integrated *	Yes	OH EPA	Yes	Yes	Complete	---
PM_{10}	DRI SFS	Integrated *	No	---	---	---	---	---
	R&P TEOM	Real-Time **	No	---	---	---	---	---
	Anderson Hi-Vol	Integrated *	Yes	OH EPA	Yes	Yes	Complete	---
HNO_3	DRI SGS TP	Integrated *	No	---	---	---	---	---
NH_3	DRI SGS $PM_{2.5}$	Integrated *	No	---	---	---	---	---
Particle Size	DRI Portable	Integrated *	No	---	---	---	---	---
Ozone (O_3)	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Nitrogen Oxides (NO_x)	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Sulfur Dioxide (SO_2)	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Carbon Monoxide (CO)	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Wind Speed / Direction	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Ambient Temperature	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Relative Humidity	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Solar Radiation	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Precipitation Depth	Continuous Analyzer	Real-Time **	No	---	---	---	---	---

Legend

DRI	Desert Research Institute	R&P	Rupprecht & Patashnick Co., Inc.
SFS	Sequential Filter Sampler with Nitric Acid Denuder	FRM	Federal Reference Method
		Hi-Vol	High volume air sampler
SGS TP	Sequential Gas Sampler with Total Particulate Matter Inlet Particle Sizer	Met One	Met One Instruments, Inc.
		TEOM	Tapered Element Oscillating Microbalance - Series 1400a
SGS PM2.5	Sequential Gas Sampler with PM2.5 Inlet Particle Sizer	SASS	Spiral Aerosol Speciation Sampler (no nitric acid denuder)
		*	Over time
Portable	Filter Sampler with PM2.5 Inlet Particle Sizer	**	Continuous
Anderson	Sierra (Thermal) Anderson Instruments	#	Performed by ATS - Goal was to develop a final data set that was utilized for the data analyses and interpretation
OU	Ohio University		
LabNet	Chester LabNet		

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TABLE 8

CURRENT DATA STATUS SUMMARY FOR THE HOLBROOK (HB) SITE

Constituent of Concern	Measurement Technique	Data Type	Data Collected	Data Provider	Data Obtained by ATS	Data Validated by Provider	Data Filtering Status #	Notes
$PM_{2.5}$	DRI SFS	Integrated *	Yes	DRI	Yes	Yes	Complete	---
	R&P FRM	Integrated *	Yes	DRI	Yes	Yes	Complete	---
	R&P TEOM	Real-Time **	Yes	ATS	Yes	No	In Progress	Action item
	Met One SASS	Integrated *	No	---	---	---	---	---
	Anderson SFS	Integrated *	No	---	---	---	---	---
PM_{10}	DRI SFS	Integrated *	Yes	DRI	Yes	Yes	Complete	---
	R&P TEOM	Real-Time **	No	---	---	---	---	---
	Anderson Hi-Vol	Integrated *	No	---	---	---	---	---
HNO_3	DRI SGS TP	Integrated *	Yes	DRI	Yes	Yes	Complete	---
NH_3	DRI SGS $PM_{2.5}$	Integrated *	Yes	DRI	Yes	Yes	Complete	---
Particle Size	DRI Portable	Integrated *	Yes	DRI	No	---	---	No samples analyzed
Ozone (O_3)	Continuous Analyzer	Real-Time **	Yes	PA DEP	Yes	Yes	Complete	---
Nitrogen Oxides (NO_x)	Continuous Analyzer	Real-Time **	Yes	PA DEP	Yes	Yes	Complete	---
Sulfur Dioxide (SO_2)	Continuous Analyzer	Real-Time **	Yes	PA DEP	Yes	Yes	Complete	---
Carbon Monoxide (CO)	Continuous Analyzer	Real-Time **	Yes	PA DEP	Yes	Yes	Complete	---
Wind Speed / Direction	Continuous Analyzer	Real-Time **	Yes	PA DEP	Yes	Yes	Complete	---
Ambient Temperature	Continuous Analyzer	Real-Time **	Yes	PA DEP	Yes	Yes	Complete	---
Relative Humidity	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Solar Radiation	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Precipitation Depth	Continuous Analyzer	Real-Time **	No	---	---	---	---	---

Legend

DRI	Desert Research Institute	R&P	Rupprecht & Patashnick Co., Inc.
SFS	Sequential Filter Sampler with Nitric Acid Denuder	FRM	Federal Reference Method
		Hi-Vol	High volume air sampler
SGS TP	Sequential Gas Sampler with Total Particulate Matter Inlet Particle Sizer	Met One	Met One Instruments, Inc.
		TEOM	Tapered Element Oscillating Microbalance - Series 1400a
SGS PM2.5	Sequential Gas Sampler with PM2.5 Inlet Particle Sizer	SASS	Spiral Aerosol Speciation Sampler (no nitric acid denuder)
		*	Over time
Portable	Filter Sampler with PM2.5 Inlet Particle Sizer	**	Continuous
Anderson	Sierra (Thermal) Anderson Instruments	#	Performed by ATS - Goal was to develop a final data set that was utilized for the data analyses and interpretation
OU	Ohio University		
LabNet	Chester LabNet		

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TABLE 9

CURRENT DATA STATUS SUMMARY FOR THE LAWRENCEVILLE (LW) SITE

Constituent of Concern	Measurement Technique	Data Type	Data Collected	Data Provider	Data Obtained by ATS	Data Validated by Provider	Data Filtering Status #	Notes
$PM_{2.5}$	DRI SFS	Integrated *	Yes	DRI	Yes	Yes	Complete	---
	R&P FRM	Integrated *	Yes	DRI	Yes	Yes	Complete	---
	R&P TEOM	Real-Time **	Yes	ATS	Yes	No	In Progress	Action item
	R&P TEOM	Real-Time **	Yes	ACHD	Yes	Yes	Complete	---
	Met One SASS	Integrated *	No	---	---	---	---	---
	Anderson SFS	Integrated *	No	---	---	---	---	---
PM_{10}	DRI SFS	Integrated *	Yes	DRI	Yes	Yes	Complete	---
	R&P TEOM	Real-Time **	Yes	ATS	Yes	No	In Progress	Action item
	Anderson Hi-Vol	Integrated *	No	---	---	---	---	---
HNO_3	DRI SGS TP	Integrated *	Yes	DRI	Yes	Yes	Complete	---
NH_3	DRI SGS $PM_{2.5}$	Integrated *	Yes	DRI	Yes	Yes	Complete	---
Particle Size	DRI Portable	Integrated *	Yes	DRI	No	---	---	No samples analyzed
Ozone (O_3)	Continuous Analyzer	Real-Time **	Yes	ACHD	Yes	Yes	Complete	---
Nitrogen Oxides (NO_x)	Continuous Analyzer	Real-Time **	Yes	ACHD	Yes	Yes	Complete	---
Sulfur Dioxide (SO_2)	Continuous Analyzer	Real-Time **	Yes	ATS	Yes	No	In Progress	Action item
Carbon Monoxide (CO)	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Wind Speed / Direction	Continuous Analyzer	Real-Time **	Yes	ATS	Yes	No	In Progress	Action item
Ambient Temperature	Continuous Analyzer	Real-Time **	Yes	ATS	Yes	No	In Progress	Action item
Relative Humidity	Continuous Analyzer	Real-Time **	Yes	ATS	Yes	No	In Progress	Action item
Solar Radiation	Continuous Analyzer	Real-Time **	Yes	ATS	Yes	No	In Progress	Action item
Precipitation Depth	Continuous Analyzer	Real-Time **	Yes	ATS	Yes	No	In Progress	Action item

Legend

DRI	Desert Research Institute	R&P	Rupprecht & Patashnick Co., Inc.
SFS	Sequential Filter Sampler with Nitric Acid Denuder	FRM	Federal Reference Method
		Hi-Vol	High volume air sampler
SGS TP	Sequential Gas Sampler with Total Particulate Matter Inlet Particle Sizer	Met One	Met One Instruments, Inc.
		TEOM	Tapered Element Oscillating Microbalance - Series 1400a
SGS PM2.5	Sequential Gas Sampler with PM2.5 Inlet Particle Sizer	SASS	Spiral Aerosol Speciation Sampler (no nitric acid denuder)
		*	Over time
Portable	Filter Sampler with PM2.5 Inlet Particle Sizer	**	Continuous
Anderson	Sierra (Thermal) Anderson Instruments	#	Performed by ATS - Goal was to develop a final data set that was utilized for the data analyses and interpretation
OU	Ohio University		
LabNet	Chester LabNet		

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TABLE 10

CURRENT DATA STATUS SUMMARY FOR THE MORGANTOWN (MO) SITE

Constituent of Concern	Measurement Technique	Data Type	Data Collected	Data Provider	Data Obtained by ATS	Data Validated by Provider	Data Filtering Status #	Notes
$PM_{2.5}$	DRI SFS	Integrated *	Yes	DRI	Yes	Yes	Complete	---
	R&P FRM	Integrated *	Yes	WV DEP	Yes	Yes	Complete	---
	R&P TEOM	Real-Time **	No	---	---	---	---	---
	Met One SASS	Integrated *	No	---	---	---	---	---
	Anderson SFS	Integrated *	No	---	---	---	---	---
PM_{10}	DRI SFS	Integrated *	No	---	---	---	---	---
	R&P TEOM	Real-Time **	No	---	---	---	---	---
	Anderson Hi-Vol	Integrated *	Yes	WV DEP	Yes	Yes	Complete	---
HNO_3	DRI SGS TP	Integrated *	No	---	---	---	---	---
NH_3	DRI SGS $PM_{2.5}$	Integrated *	No	---	---	---	---	---
Particle Size	DRI Portable	Integrated *	No	---	---	---	---	---
Ozone (O_3)	Continuous Analyzer	Real-Time **	Yes	WV DEP	Yes	Yes	Complete	---
Nitrogen Oxides (NO_x)	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Sulfur Dioxide (SO_2)	Continuous Analyzer	Real-Time **	Yes	WV DEP	Yes	Yes	Complete	---
Carbon Monoxide (CO)	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Wind Speed / Direction	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Ambient Temperature	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Relative Humidity	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Solar Radiation	Continuous Analyzer	Real-Time **	No	---	---	---	---	---
Precipitation Depth	Continuous Analyzer	Real-Time **	No	---	---	---	---	---

Legend

DRI	Desert Research Institute	R&P	Rupprecht & Patashnick Co., Inc.
SFS	Sequential Filter Sampler with Nitric Acid Denuder	FRM	Federal Reference Method
		Hi-Vol	High volume air sampler
SGS TP	Sequential Gas Sampler with Total Particulate Matter Inlet Particle Sizer	Met One	Met One Instruments, Inc.
		TEOM	Tapered Element Oscillating Microbalance - Series 1400a
SGS PM2.5	Sequential Gas Sampler with PM2.5 Inlet Particle Sizer	SASS	Spiral Aerosol Speciation Sampler (no nitric acid denuder)
		*	Over time
Portable	Filter Sampler with PM2.5 Inlet Particle Sizer	**	Continuous
Anderson	Sierra (Thermal) Anderson Instruments	#	Performed by ATS - Goal was to develop a final data set that was utilized for the data analyses and interpretation
OU	Ohio University		
LabNet	Chester LabNet		

Table 11: Sample Collection Data February 1999 - October 2001			
Sample Type	**Sampler**	**Inlet Size**	**Total No. Collected**
Discrete Filter Samples	Particulate (SFS)	$PM_{2.5}$	1360
	Particulate (SSAS)	$PM_{2.5}$	162
	Particulate (SFS)	PM_{10}	1201
	Ammonia (SGS)	$PM_{2.5}$	1201
	Nitric Acid (SGS)	TSP	1201
	SEM (MiniVol)	$PM_{2.5}$	1201
	Particulate (FRM-TEF)	$PM_{2.5}$	332
	Particulate (FRM-QRTZ)	$PM_{2.5}$	249
	TOTAL		6907
Precursor Gases	**Gas**		**Collection Period***
	NOx		June 1999 - October 2001
	SO2		June 1999 - October 2001
	O3		June 1999 - October 2001
	CO		June 1999 - October 2001
Meteorological Data	Wind Speed		June 1999 - October 2001
	Wind Direction		June 1999 - October 2001
	Temperature		June 1999 - October 2001
	Relative Humidity		June 1999 - October 2001
	Solar Radiation		June 1999 - October 2001
	Precipitation		June 1999 - October 2001
	Barometric Pressure		June 1999 - October 2001

* See Table 14 for time periods of missing

TABLE 12: Available Mass Concentration Results as of October 2001			
Site	**Inlet Size**	**Sample Type**	**No. of Samples**
Lawrenceville	$PM_{2.5}$	Particulate (SFS)	684
	$PM_{2.5}$	Particulate (FRM)	126
	PM_{10}	Particulate (SFS)	669
	Subtotal		**1479**
Holbrook	$PM_{2.5}$	Particulate (SFS)	253
	$PM_{2.5}$	Particulate (FRM)	133
	PM_{10}	Particulate (SFS)	250
	Subtotal		**636**
Monongalia	$PM_{2.5}$	Particulate (SFS)	115
Athens	$PM_{2.5}$	Particulate (SSAS)	147
TOTAL			**2377**

TABLE 13: Chemical Speciation Sample Data			
Site	**Inlet Size**	**Sample Type**	**TOTAL**
Lawrenceville	$PM_{2.5}$	Particulate (SFS)	264
	$PM_{2.5}$	Particulate (FRM-TEF)	60
	$PM_{2.5}$	Particulate (FRM-QRTZ)	28
	PM_{10}	Particulate (SFS)	45
	$PM_{2.5}$	Ammonia (SGS)	234
	TSP	Nitric Acid (SGS)	234
	$PM_{2.5}$	SEM (MiniVol)	6
	Subtotal		**871**
Holbrook	$PM_{2.5}$	Particulate (SFS)	74
	$PM_{2.5}$	Particulate (FRM-TEF)	59
	$PM_{2.5}$	Particulate (FRM-QRTZ)	20
	PM_{10}	Particulate (SFS)	17
	$PM_{2.5}$	Ammonia (SGS)	60
	TSP	Nitric Acid (SGS)	60
	$PM_{2.5}$	SEM (MiniVol)	6
	Subtotal		**296**
Monongalia	$PM_{2.5}$	Particulate (SFS)	0
Athens	$PM_{2.5}$	Particulate (SSAS)	147
TOTAL			**1314**

TABLE 14: Summary of Continuously Collected Measurements from the UORVP

			1999							2000													2001		
Species	Site	Instrument	**Jun**	Jul	Aug	Sep	Oct	Nov	Dec	**Jan**	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
PM_{10} ($\mu g/m^3$)	LV	TEOM	24.5	35.3	26.9	25.2	23.0	22.8	19.0	18.2	22.4	20.1	18.9	26.5	21.6	26.7	24.3	21.7	28.8	21.5	18.4	24.5	19.5	14.0
$PM_{2.5}$ ($\mu g/m^3$)	LV	TEOM	21.8	25.2	20.0	15.4	15.2	15.2	11.7	12.1	14.3	12.7	12.3	19.7	20.3	20.9	20.4	14.5	18.0	14.5	12.3	16.8	13.0	11.7
$PM_{2.5}$ ($\mu g/m^3$)	HB	TEOM	18.8	24.6	17.5	14.7	12.9	12.9	8.9	9.7	11.4	10.6	10.8	16.2	18.1	18.5	18.9	12.7	14.5	15.8	10.4	10.9	9.6	9.8
Temp (^oC)	LV	Met. Unit		26.4						-0.9	3.4	8.0	11.2	18.4	22.2	21.5	21.7	17.8	13.0	4.9	-3.7	-0.8	2.3	2.5
Temp (^oC)	HB	Met. Unit		24.6	21.0	18.4	12.2	9.0	2.0	-1.7	3.7	7.7	10.8	17.7	20.8	20.3	20.3	16.8	13.4	4.5	-4.5	-1.2	2.3	2.1
R. Humidity (%)	LV	Met. Unit															76.8	77.4	75.9	73.3	73.0	75.9	65.5	70.4
O_3 (ppb)	LV	Gas Anal.	37.9	41.1	28.2	21.6	15.0	14.2	8.7	12.5	14.7	20.7	23.9	30.8	33.2	30.6	28.2	18.2	14.1	7.6	7.5	9.3	13.4	18.0
O_3 (ppb)	HB	Gas Anal.		57.5	49.0	45.1	36.0	35.0	22.5	26.2	34.7	39.4	42.8	53.4	50.0	46.9	41.8	31.7	37.9	20.6	17.2	22.4	27.2	31.7
NO_X (ppb)	LV	Gas Anal.	26.0	26.8	27.1	28.3	55.0	60.1	63.0	44.9	57.4	37.9	32.3	27.7	19.8	22.1	23.9	37.3	72.1	79.4	59.4	69.4	39.1	36.3
NO_X (ppb)	HB	Gas Anal.		0.9						19.3	7.9		5.2	2.2	3.3	3.5	2.2	3.2	5.1	6.5	10.7	15.7	11.9	10.1
NO_2 (ppb)	LV	Gas Anal.	21.6	22.9	20.3	23.0	24.1	24.1	24.7	23.7	23.8	20.5	17.6	18.2	14.9	16.8	17.1	19.9	28.5	29.3	26.5	26.0	19.6	20.3
NO_2 (ppb)	HB	Gas Anal.		1.0						13.7	6.5		4.5	2.0	3.0	3.1	1.9	2.4	4.6	5.7	8.5	11.2	9.0	7.9
SO_2 (ppb)	LV	Gas Anal.		11.5						8.8	8.1			3.5	7.2	6.9	6.3	6.6	6.3	8.5	11.5	12.9	5.0	3.9
SO_2 (ppb)	HB	Gas Anal.		9.9	9.4	8.9	10.3	10.8	11.9	9.5	9.0	7.8	7.9	6.0	7.2	8.2	8.4	5.7	9.9	9.6	12.7	13.0	10.6	9.7

KEY

= **NO DATA**