

Final Report

on

**West Virginia Air Quality Assessment
Near a Surface Coal Mine Blasting Operation**

Prepared for

**West Virginia Department of Environmental Protection
601 57th Street, SE
Charleston, West Virginia 25304**

by

**BATTELLE
505 King Ave.
Columbus, OH 43201**

August 10, 2012

EXECUTIVE SUMMARY

Federal, regional, and local efforts have considerably reduced overall environmental pollution levels in the United States, however, air pollution remains an important public health concern. Ambient air in rural areas of West Virginia can receive contributions of pollutants from a variety of sources: cars and trucks (both gasoline and diesel powered), woodstoves and fires, windblown dust from roadways and industrial operations, construction and farming activities, etc. Pollutants of concern may include particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO/NO₂/NO_x), volatile organic compounds (VOCs), and other species. The objectives of the two-week scoping study described in this report were to assess air quality near a surface coal mine blasting operation in the community of Clear Fork, West Virginia, discern possible sources for air pollutants observed, and compare results to historical levels and regulatory/health-based standards.

Detailed inspection of data collected continuously and at discrete times at two sampling sites during the two-week study was conducted to investigate whether an association between air quality and blasting events could be discerned. That inspection included review of meteorological and blasting records for possible correlation with air pollutant levels. This inspection did not reveal any conclusive evidence of an impact of blast emissions on air quality at the two sampling sites. The overall finding of this scoping study is that local air quality in Clear Fork, WV is within applicable health-based standards and does not appear to be affected by measured emissions from nearby blasting events in surface coal mine operations. The lack of such impact may be due to the difference in elevation of the mine and the air quality sampling sites, causing blast emissions to be dispersed before reaching the valley sampling sites.

Table of Contents

1	BACKGROUND/OBJECTIVES	1
2	EXPERIMENTAL PROCEDURES	2
2.1	Overall Study Design	2
2.2	Sampling Sites	4
2.2.1	<i>Residence Sampling Site</i>	5
2.2.2	<i>School Sampling Site</i>	6
2.2.3	<i>Mine Sampling Site</i>	8
2.2.4	<i>Passive Sampling Sites</i>	8
2.3	Continuous Monitoring Methods	9
2.3.1	<i>Tapered Element Oscillating Microbalance</i>	9
2.3.2	<i>Aethalometer</i>	9
2.3.3	<i>Chemiluminescence NO_x Analyzer</i>	13
2.3.4	<i>Gas Filter Correlation CO Analyzer</i>	13
2.4	Integrated Measurement Procedures	13
2.4.1	<i>TSP Mass</i>	14
2.4.2	<i>PM₁₀ Mass</i>	14
2.4.3	<i>PM_{2.5} Mass</i>	14
2.4.4	<i>Microscopy Substrates</i>	14
2.4.5	<i>Total Nitrate and Ammonia/Ammonium with Filter Packs</i>	15
2.4.6	<i>Passive Samplers for NO₂/NO_x and NH₃ Concentrations</i>	15
2.4.7	<i>VOCs</i>	16
2.5	Meteorological Measurements	16
2.6	Analytical Methods	17
2.6.1	<i>Gravimetric Analysis</i>	17
2.6.2	<i>Metals Analysis</i>	17
2.6.3	<i>VOC Analysis</i>	18
2.6.4	<i>Total Nitrate and Ammonia/Ammonium</i>	18
2.6.5	<i>Passive NO₂/NO_x and NH₃ Analysis</i>	18
3	RESULTS AND DISCUSSION	20
3.1	Blasting Summary	20
3.2	Meteorological Measurements	22
3.2.1	<i>Precipitation</i>	22
3.2.2	<i>Ambient Temperature</i>	24
3.2.3	<i>Barometric Pressure</i>	24
3.2.4	<i>Relative Humidity</i>	26
3.2.5	<i>Wind Speed/Direction</i>	26

3.3	Particulate Matter	29
3.3.1	TEOM.....	29
3.3.2	TSP.....	31
3.3.3	PM ₁₀	32
3.3.4	PM _{2.5}	34
3.3.5	Aethalometer.....	35
3.4	Continuous CO	37
3.5	Continuous NO _x /Total Nitrate/Passive NO ₂ /NH ₃	40
3.6	Particulate Metals Concentrations	47
3.7	VOCs.....	49
3.8	Microscopy/Chemical Analysis of Particles.....	53
3.9	Investigation of Individual Case Studies.....	53
4	SUMMARY AND CONCLUSIONS	58
5	RECOMMENDATIONS	60
6	REFERENCES	61
	APPENDIX A - SITE PHOTOGRAPHS	62
	APPENDIX B - DAILY WIND ROSES.....	69

Figures

Figure 1.	Aerial photograph of study area.....	5
Figure 2.	Private residence used as residence sampling site.....	6
Figure 3.	Clear Fork Elementary School used as school sampling site.	7
Figure 4.	Schematic illustration of Clear Fork Elementary School.	8
Figure 5.	Valley Fill Area #2, location of meteorological measurements.	9
Figure 6.	Approximate locations of sampling sites (blue markers) and blasting events (pink markers) during study period.....	22
Figure 7.	Hourly precipitation measurements during study period at the School.	23
Figure 8.	Hourly average temperature readings during study period.	24
Figure 9.	Hourly average barometric pressure readings during study period.	25
Figure 10.	Wind roses for three study sites during study period.	28
Figure 11.	Wind class frequency distribution for residence sampling site during study period.....	28
Figure 12.	Wind class frequency distribution for school sampling site during study period.	29
Figure 13.	Wind class frequency distribution for mine site during study period.	29

Figure 14. Hourly average PM ₁₀ , PM _{2.5} , and PM _{Coarse} measurements during the study period.....	30
Figure 15. Daily TSP concentrations at residence and school sampling sites.....	32
Figure 16. Daily PM ₁₀ concentrations at the residence and school sampling sites. The 24-hour averages from the TEOM at the residence sampling site are also presented.	33
Figure 17. Daily PM _{2.5} concentrations from the residence and school sampling sites. Results from sampling conducted in Beckley are presented along with 23-hour averages from the TEOM operated at the residence sampling site.....	35
Figure 18. Hourly average soot and UVPM measurements during study period.....	36
Figure 19. Hourly average CO measurements at the residence sampling site.....	38
Figure 20. Hourly average CO measurements at the school sampling site.....	39
Figure 21. Hourly average measurements for NO, NO ₂ , and NO _x at the residence sampling site.....	41
Figure 22. Hourly average measurements for NO, NO ₂ , and NO _x at the school sampling site.....	42
Figure 23. Microscopic images of particles collected on a substrate collected on a non-blasting day.....	54
Figure 24. Images of particles on substrate collected at the residence sampling site during the morning of 2/22/12.....	55
Figure 25. Images of particles on substrate collected at the residence sampling site during the afternoon of 2/22/12.....	56
Figure 26. Photograph of equipment shelter at residence.....	63
Figure 27. Photograph of equipment shelter at school.	63
Figure 28. Photograph of particle sampling and meteorological monitoring equipment at residence.....	64
Figure 29. PM ₁₀ sampler at school.....	64
Figure 30. PM _{2.5} sampler at school.	65
Figure 31. Meteorological monitoring equipment at mine site.	66
Figure 32. Continuous gas analyzers with calibrator and datalogger.....	66
Figure 33. TEOM used to continuously measure PM ₁₀ and PM _{2.5} at residence.	67
Figure 34. Aethalometer used to continuously measure soot concentrations at residence.	68
Figure 35. Wind roses for 2/09/12.....	70
Figure 36. Wind roses for 2/10/12.....	71
Figure 37. Wind roses for 2/11/12.....	72
Figure 38. Wind roses for 2/12/12.....	73
Figure 39. Wind roses for 2/13/12.....	74
Figure 40. Wind roses for 2/14/12.....	75

Figure 41. Wind roses for 2/15/12.....	76
Figure 42. Wind roses for 2/16/12.....	77
Figure 43. Wind roses for 2/17/12.....	78
Figure 44. Wind roses for 2/18/12.....	79
Figure 45. Wind roses for 2/19/12.....	80
Figure 46. Wind roses for 2/20/12.....	81
Figure 47. Wind roses for 2/21/12.....	82
Figure 48. Wind roses for 2/22/12.....	83
Figure 49. Wind roses for 2/23/12.....	84

Tables

Table 1. Sampling and Analysis Methods Employed	3
Table 2. Samples Collected at Residence Sampling Site.....	10
Table 3. Samples Collected at School Sampling Site	11
Table 4. Sampling Collected at Other Sites	12
Table 5. Summary of Blasting Events Conducted at Pioneer Fuels Ewing Fork #2 Area (Permit S-3018-03) during Testing.....	20
Table 6. Summary of Blasting Events Conducted at Horse Creek Surface Mine (Permit S- 3015-99) during Testing.....	21
Table 7. Daily Total Precipitation Amounts during Study Period at School Sampling Site.....	23
Table 8. Daily Average Temperatures during Study Period.....	25
Table 9. Daily Average Barometric Pressure during Study Period	26
Table 10. Daily Average Relative Humidity during Study Period.....	27
Table 11. TSP Concentration Measured During Study Period	31
Table 12. PM ₁₀ Concentration Measured During Study Period	33
Table 13. Daily PM _{2.5} Concentration Measured During Study Period.....	34
Table 14. Daily Average Soot and UVPM Measurements during Study Period.....	37
Table 15. Daily Average CO Concentrations during Study Period.....	40
Table 16. Daily Average NO/NO ₂ /NO _x Concentrations during Study Period.....	43
Table 17. Daily Average Nitrate Concentrations Measured During Study Period	44
Table 18. Short Term (3-Hour) Nitrate Concentrations Measured During Study Period	44
Table 19. Daily Average Ammonium Concentrations Measured During Study Period	45
Table 20. Short Term (3-Hour) Ammonium Concentrations Measured During Study Period	46
Table 21. Summary of Passive NO ₂ Measurements (ppb).....	47
Table 22. Summary of Metals Analysis at Residence	48

Table 23. Summary of Metals Analysis at School.....	48
Table 24. Summary of Canister Collection Times and Blasting Events	49
Table 25. Detection Limits for VOC Analytes Not Detected in Any Analyzed Sample.....	50
Table 26. Summary of VOC Measurements at Residence.....	50
Table 27. Summary of VOC Measurements at School	52

Final Report on West Virginia Air Quality Assessment Near a Surface Coal Mine Blasting Operation

1 BACKGROUND/OBJECTIVES

The intent of the air quality assessment described in this report was to characterize and document air quality in the Clear Fork, West Virginia community while surface coal mine blasting operations were being conducted nearby. Federal, regional, and local efforts to reduce overall pollution levels in the U.S. environment have been generally successful over the years, however, air pollution remains an important public health concern. The United States Environmental Protection Agency (EPA) continues to focus on improving air quality which is one of the five overarching goals outlined in the Agency's current Strategic Plan. The air in rural areas of West Virginia receives contributions of pollutants from a variety of sources: cars and trucks (especially diesel), woodstoves and fires, windblown dust from roadways and industrial operations, construction and farming equipment, etc. Pollutants include particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO₂), volatile organic compounds (VOCs), and other species. Ensuring that such emissions do not pose adverse environmental or health conditions for area residents is best assured through an assessment of air quality. The objectives of this study were to conduct a scoping study of air quality near a surface coal mine blasting operation in rural West Virginia, discern possible sources for air pollutants observed, and compare results to historical levels and regulatory/health-based standards.

2 EXPERIMENTAL PROCEDURES

2.1 Overall Study Design

The intent of the field sampling described in this plan was to begin to characterize and document air quality in the Clear Fork, West Virginia community while surface coal mine blasting operations are being conducted nearby. To meet this goal, a range of sampling and analysis methods were used over a two-week field period in February 2012 to determine gaseous air pollutant concentrations and the mass, particle size distribution, and chemical composition of airborne PM. These species were monitored using a combination of continuous monitoring and integrated sampling techniques. Table 1 presents the sampling and analysis methods that were used for measurement of each species, and indicates which measurements were conducted at which sites. The methods and sites that were used are described further below.

The nature of this field study presented challenges and limitations to the study design including:

- The surface coal mining permit area was large, and the nearby residential community was widely dispersed around it and at much lower elevations.
- The study area was near to several surface mining operations.
- Blasting was conducted at multiple locations within a mining permit area at different times. Thus blast emissions may have originated from multiple locations in the area.
- Mountainous terrain in the study area affects the local meteorology and thus the transport of emissions from the mining permit area into the community.
- Other sources of air pollutants, such as motor vehicles and wood combustion, exist within the community.
- There was a relative scarcity of sites in the community suitable for air quality monitoring (by virtue of location, access, security, availability of electric power and shelter for equipment, etc.).

These challenges and limitations, along with the normal variability of meteorological conditions, added to the complexity of selecting suitable sampling sites that assure inclusion of surface coal mine blast emissions in the air quality characterization during the study period.

The study design attempted to overcome these limitations in several ways:

- Use of two main sampling sites (a residence and a school), selected as representative of the community and equipped with similar sampling and monitoring systems, helped ensure that any mine blast emissions were detected. The sampling sites were located relatively close to the active blasting areas of the surface coal mine.
- The residence and school sampling sites were augmented with four additional passive sampling sites for relevant species, providing a wider geographic range of sampling locations.
- Meteorological measurements were made at the surface coal mine and at both the residence and school sites within the community, allowing evaluation of the likelihood of transport of mine blast emissions.

Table 1. Sampling and Analysis Methods Employed

Species Monitored	Sampling Equipment/Technique	Analysis Method	Sampling			Expected Value ^c	Detection Limit
			Residence	School	Mine		
<i>Continuous Monitoring Methods</i>							
PM ₁₀ , PM _{Coarse} , and PM _{2.5} Mass	Tapered Element Oscillating Microbalance (TEOM)	a	X	--	--	~ 15 ug/m ³	~ 2 ug/m ³
Soot Mass	Aethalometer	a	X	--	--	~ 1 ug/m ³	~ 0.001 ug/m ³
NO/NO ₂ /NO _x	Chemiluminescence NO _x Analyzer	a	X	X	--	~ 10 ppb NO ₂	< 1 ppb
CO	Gas filter correlation CO Analyzer	a	X	X	--	~ 1 ppm	~0.01 ppm
<i>Integrated Measurement Procedures</i>							
Total Suspended PM (TSP) mass	High Volume Sampler	Pre- and post-sampling weighing of filters	X	X	--	>20 ug/m ³	~ 1 ug/m ³
PM ₁₀ Mass	Federal Reference Method (FRM) sampler	Pre- and post-sampling weighing of filters	X	X	--	~ 15 ug/m ³	~ 0.5 ug/m ³
PM _{2.5} Mass	FRM sampler	Pre- and post-sampling weighing of filters	X	X	--	~ 10 ug/m ³	~ 0.5 ug/m ³
Particles (silica)	Passive sampling on microscopy substrates	Microscopy	X	X	--	~ 1000 particles	1 particle
Particles (metals)	b	ICP-MS on PM ₁₀ samples	X	X	--	~ 0.05 ug/m ³ each	~ 0.001 ug/m ³
Total nitrate and ammonia/ammonium	Teflon/nylon/citric acid filter pack	Ion chromatography on filter extract	X	X	--	~ 2 ug/m ³ each	0.1 ug/m ³
Passive Samplers for NH ₃ , NO ₂ /NO _x	Ogawa	Ion chromatography or spectrometry on filter extract	X	X	--	~ 10 ppb NH ₃ and NO ₂	~ 2 ppb for 24-hour sample
VOC	Evacuated Canisters	GC/MS by EPA Method TO-15	X	X	--	~ 0 to 10 ppb each	~0.1 ppb
<i>Meteorological Measurements</i>							
Temperature, Wind Speed, Wind Direction, Barometric Pressure, Rainfall	MetOne Automet Davis Instruments	Meteorological sensors	X	X	X		

a: Continuous monitor, post-sampling analysis not needed;

b: No additional sampling needed for this measurement;

c: Estimated from West Virginia DEP 2010 Air Quality Annual Report.

µg/m³ = micrograms per cubic meter, ppm = parts per million by volume in air, ppb = parts per billion by volume in air

- The impact of local sources was minimized by using sampling and analysis methods that focus on mine emissions, particularly from blasting. For example, monitoring efforts targeted nitrogen oxides (NO_x ($= \text{NO}_2 + \text{nitric oxide (NO)}$)), particulate nitrate (NO_3^-) and ammonium (NH_4^+), and gaseous ammonia (NH_3) which might be expected to be emitted from the mine blasting operations which used ammonium nitrate/fuel oil (ANFO) as the blasting compound.
- Other emissions of NO_x , i.e., from local combustion of wood and other fuels in the community, were distinguished by the co-presence of soot (measured by means of a continuous monitor).
- Sampling focused on a wide range of sizes of PM including Total Suspended Particulate (TSP), as well as PM with aerodynamic diameters below 10 microns (PM_{10}), and below 2.5 microns ($\text{PM}_{2.5}$). Determination of the chemical composition of particles and the trends in these particle size ranges over time was intended to indicate the role of mine blast emissions in the observed PM concentrations. The PM_{10} and $\text{PM}_{2.5}$ size ranges both encompass inhalable particles, and for these ranges U.S. EPA has established National Ambient Air Quality Standards (NAAQS). Thus determination of PM in these size ranges allows comparison of local air quality to those health-based standards.
- Records on the timing and location of blasting at the mine, and available seismological data, were collected to determine whether observed pollutant levels, pollutant composition, and particle size distributions were associated with blasting events.
- Equipment and methods selected for measurement of the target species/parameters were chosen to minimize the frequency of non-detects. Table 1 presents typical expected concentrations for the key target species (estimated from historical regional and state-wide data) and the corresponding typical detection limits for the monitoring/analytical methods.

This study design could not guarantee that blast emissions were transported to or measurable at the sampling sites; however it was intended to provide multiple data sets with which to attempt that identification.

2.2 Sampling Sites

Prior to conducting the field study Battelle made a pre-study site visit to Clear Fork to assess the suitability of candidate monitoring sites that were initially identified by the West Virginia Department of Environmental Protection (WV DEP). The candidate sites were assessed for a number of factors including:

- Availability of sufficient power to operate all the proposed monitoring equipment,
- Presence of other emission sources,
- Proximity to nearby structures and trees, and
- Site security.

Based on this assessment, two sites were selected for the active monitoring. An additional four sites were selected for passive monitoring by Battelle.

Figure 1 shows a map of the surface mine and the nearby community. Sites in and near the Clear Fork community were used for active and passive sampling of gaseous and particulate pollutants,

and for meteorological measurements as described below. Additional photographs of the sampling sites and the equipment used in this study are presented in Appendix A.

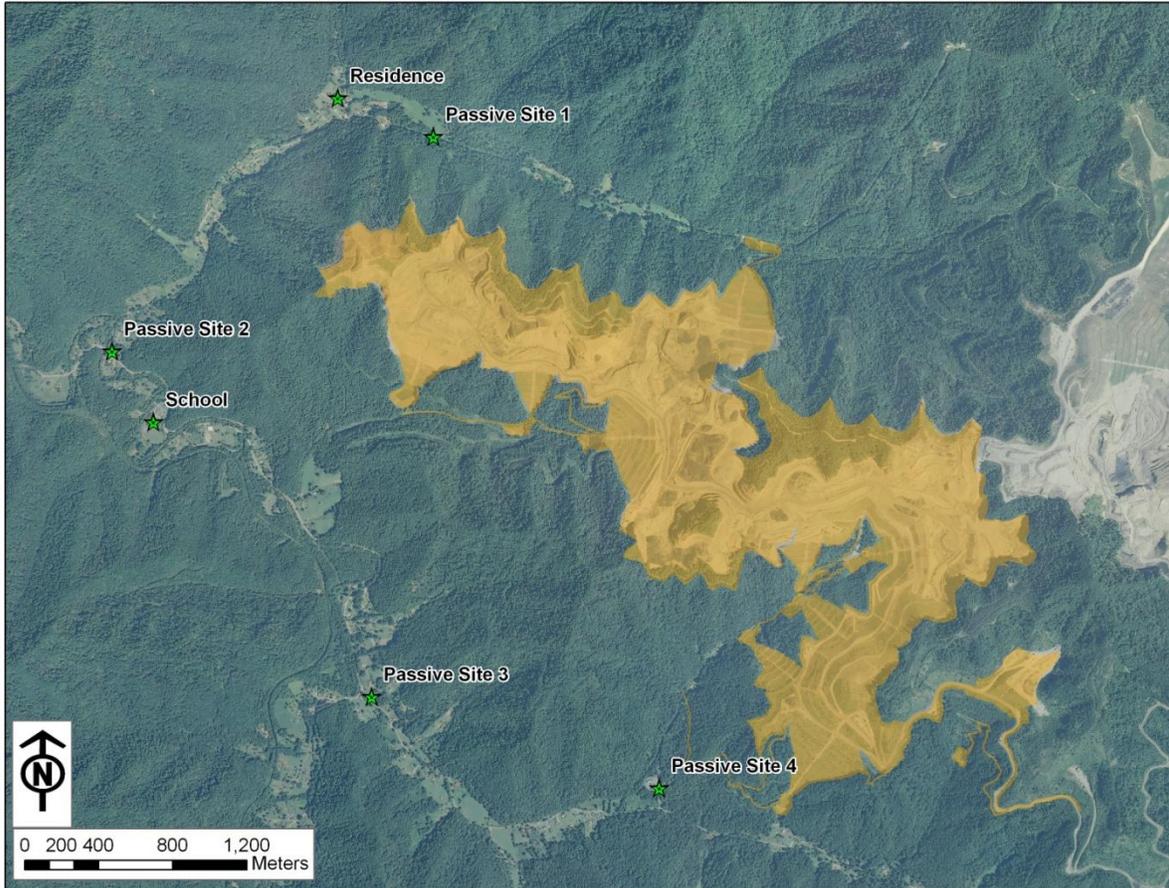


Figure 1. Aerial photograph of study area.

2.2.1 Residence Sampling Site

The residence sampling site is at an occupied residence within approximately one thousand feet of the north boundary of the mine permit area. A schematic illustration of the property surrounding this residence is shown in Figure 2. The private residence includes a covered carport, Quonset hut garage, and well house in addition to the residence. These buildings are surrounded by open space in the front yard and back yard. Electrical power was available from both the garage and well house. The active surface mining area is on a ridge to the south/southeast of the residence. This residence is located on a sparsely traveled narrow dirt road.

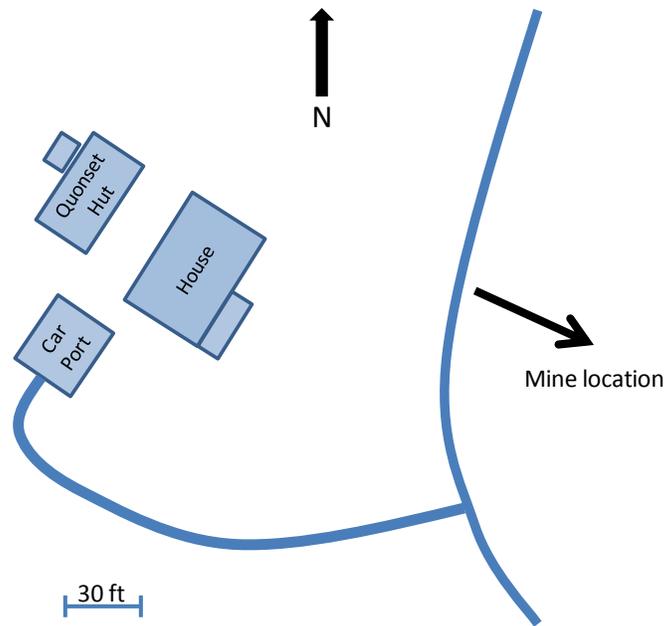


Figure 2. Private residence used as residence sampling site.

A temporary shelter was installed in an open field to the west of the garage and Quonset hut to house the continuous monitoring equipment (i.e., NO_x and CO monitors, TEOM, and aethalometer) and associated calibration and data acquisition equipment. This shelter was equipped with a small electric space heater to maintain moderate temperature control in the shelter. Holes were made in the roof of the shelter for passage of the sample inlets of the particle monitoring equipment. The continuous gas monitors drew sample air through a Teflon tube extended from the wall of the shelter at a height of approximately 2 meters. The sampling line was connected to an inverted funnel to prevent precipitation from accumulating in the sampling line. The integrated PM sampling equipment (i.e., for TSP, PM₁₀, and PM_{2.5} sample collection) is weather-proof and was placed outdoors in an open area away from buildings, trees, or other obstructions. A Partisol sequential sampler provided by the WV DEP was used to perform automated daily PM_{2.5} sampling. An automated meteorological station was also placed in the open area behind the residence and recorded meteorological conditions at 2 meters above ground level.

During the study period, the field operators at the residence sampling site could normally see and smell wood smoke from houses nearby except on February 15 which was an unusually warm and sunny day. Other than Battelle vehicles and the residence's cars, there was rarely any vehicle traffic near the residence. On February 14, the resident stopped by the sampling site with a propane-fueled lantern. Two sides of the residence sampling site were bordered by a farm with many animals. Horses or guinea fowl were frequently within ~5-10 feet of the samplers. On warmer days there was a distinct odor of animal waste.

2.2.2 School Sampling Site

The school sampling site was selected by the WV DEP and located at the Clear Fork Elementary School. Figure 3 shows a view of the front entrance of the school, the playground area behind

the school, and the main roof of the school from a viewpoint on the gymnasium roof. The view in Figure 3 is approximately to the southwest, i.e., approximately 90° clockwise from the direction to the surface mining permit area (see Appendix A for additional photographs).



Figure 3. Clear Fork Elementary School used as school sampling site.

Figure 4 shows a schematic illustration of the school. The mining site was located to the east and northeast of the school, and staff at the school anecdotally suggested that the winds at the school are predominantly from the north. Meteorological measurements at this site were made to assess actual wind directions during the monitoring period. At the school site, the integrated particle samplers for TSP, PM₁₀, and PM_{2.5} were placed on the roof of the school, in the open area over the main entrance. Continuous monitors for NO_x and CO were placed inside a temporary shelter also installed on the school roof. This shelter was equipped with a small space heater to maintain moderate temperature control in the shelter. The continuous gas monitors drew sample air through a Teflon tube extended above the roof of the shelter. A datalogger was installed and connected to the two monitors to record their readings. The PM sampler and the equipment in the temporary shelter drew electrical power from outlets on one or more of the gas fueled heat pumps located on the roof (see Figure 3). A limitation of the Clear Fork Elementary School site was the potential emission of NO_x from the gas fueled heat pumps on the roof.

School buses typically did not idle near the school except for the few minutes while students were leaving or boarding the buses. Occasionally the site operators smelled diesel exhaust in the afternoons while students were boarding the buses. Data from the WV Department of Transportation indicated that the road that passed by the school carried approximately 1,200 vehicles per day in 2006, and the site operators observed that there was relatively frequent traffic from approximately 2 to 4 p.m during the study period. The site operators frequently smelled wood smoke and occasionally saw smoke from a house across the school playground.

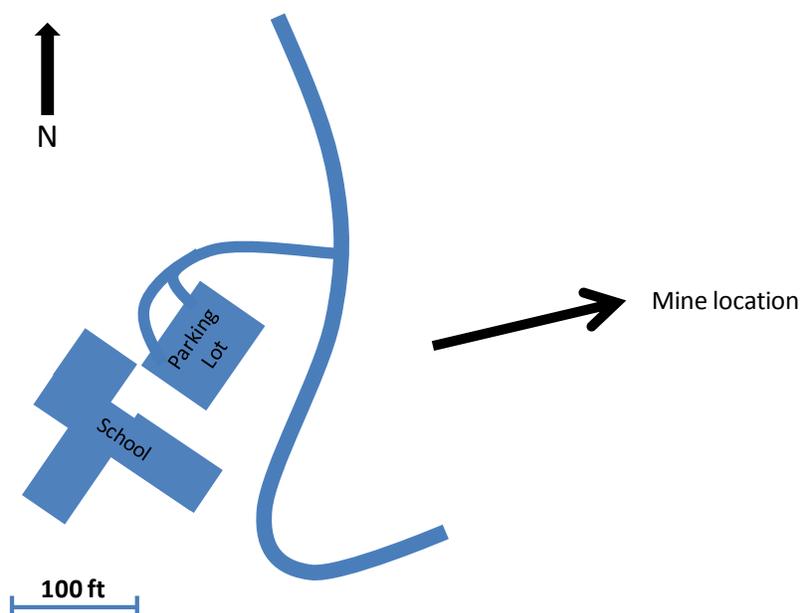


Figure 4. Schematic illustration of Clear Fork Elementary School.

2.2.3 Mine Sampling Site

Meteorological measurements were made within the boundaries of the surface mining permit area, by installation of a solar-powered meteorological station. The location for those measurements was the equipment yard at Valley Fill Area #2, a flat and open equipment storage area at the edge of the Pioneer Fuel Corporation Ewing Fork Number 2 Surface Mine. Figure 5 shows a portion of this area (see Appendix A for additional photographs). The 2 meter tall meteorological station was installed near the outer edge of the open area, for maximum exposure to the local winds. Site operators observed that it was very windy near the meteorological station. Maintenance was occasionally performed on equipment stored in the equipment yard where the meteorological station was located during the study period.

2.2.4 Passive Sampling Sites

Passive sampling of gaseous NO_2/NO_x and ammonia (NH_3) were also carried out at both the residence and school sampling sites, and at four other sites in the community. The field testing activities for this study were conducted over a period of approximately three weeks including set up and tear down, with a minimum of two weeks of sampling.



Figure 5. Valley Fill Area #2, location of meteorological measurements.

As shown in Table 1, a variety of field sampling methods were employed for this study. Brief descriptions of these methods are given below; more complete details of the sampling methods are included in the approved study plan for this project, which is available from the WV DEP. A summary of the field schedule and the number and location of samples collected is provided in Tables 2, 3, and 4.

2.3 Continuous Monitoring Methods

Photographs of sampling equipment used for this study are presented in Appendix A.

2.3.1 Tapered Element Oscillating Microbalance

A Thermo Environmental Tapered Element Oscillating Microbalance (TEOM) was used to measure PM_{10} , PM_{Coarse} , and $PM_{2.5}$ mass in near real-time. The TEOM was installed in a temperature-controlled shelter at the residence sampling site and sampled ambient air at a nominal flow rate of 16.7 liters per minute (L/min) through an inlet extending through the roof of the shelter. The TEOM recorded results approximately every three minutes through the study period. Hourly and daily PM_{10} concentrations in micrograms per cubic meter ($\mu g/m^3$) were calculated from the three-minute data.

2.3.2 Aethalometer

A Magee Scientific Model AE-21 Aethalometer was used to continuously measure airborne soot concentrations during the study period. Ambient air was drawn by the Aethalometer at a flow rate of 5 L/min with no size selection. Measurements were made at two wavelengths, namely 880 nanometers (nm) in the infrared (IR) region of the spectrum and 370 nm in the ultraviolet (UV)

Table 2. Samples Collected at Residence Sampling Site

Species Monitored	No.	Duration	End Date of Daily Sample (February 2012)													
			10 F	11 S	12 S	13 M	14 T	15 W	16 T	17 F	18 S	19 S	20 M	21 T	22 W	23 T
PM ₁₀ Mass PM _{2.5} PMCoarse	14	--	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Soot Mass	14	--	C	C	C	C	C	C	C	C	C	C	C	C	C	C
NO/NO ₂ /NO _x	14	--	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CO	14	--	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Total Suspended PM (TSP) mass	13	Daily	S	NC	S	S	S	S	S	S	S	S	S	S	S	S
PM ₁₀ Mass	13	Daily	S	NC	S	S	S	S	S	S	S	S	S	S	S	S
PM _{2.5} Mass	11	Daily	S	NC	S	NC	S	S	S	S	NC	S	S	S	S	S
Particles (silica)	19	1-2 hour	NC	NC	S	S	S	S	S	S	S	S	S	S	S	S
Particles (metals)	13	Daily	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Total nitrate and ammonia/ammonium	14	24-hour	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Total nitrate and ammonia/ammonium	13	3-hour	S	S	S	S	S	S	S	S	S	S	S	S	S	NC
Passive Samplers for NH ₃	5	48 or 72 hour	S		S/2	S			S			S/2	S			NP
Passive Samplers for NO ₂ /NO _x	5	48 or 72 hour	S		S/2	S			S			S/2	S			NP
VOC	14	1-2 hour	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Temperature, Wind Speed, Wind Direction, Barometric Pressure, Rainfall	--	Hourly Daily	C	C	C	C	C	C	C	C	NC	NC	C	C	C	C

C = Continuous monitoring method obtained data on the indicated day.

NC = Integrated sample not collected; S = Integrated sample collected.

S/2 = Composite sample with half of the sampling conducted on 2/12/12 and half the sampling conducted on 2/19/12.

NP = Not planned

Table 3. Samples Collected at School Sampling Site

Species Monitored	No.	Duration	End Date of Daily Sample (February 2012)													
			10 F	11 S	12 S	13 M	14 T	15 W	16 T	17 F	18 S	19 S	20 M	21 T	22 W	23 T
NO/NO ₂ /NO _x	14	--	C	C	C	C	C	C	C	C	C	C	C	C	C	C
CO	14	--	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Total Suspended PM (TSP) mass	14	Daily	S	S	S	S	S	S	S	S	S	S	S	S	S	S
PM ₁₀ Mass	14	Daily	S	S	S	S	S	S	S	S	S	S	S	S	S	S
PM _{2.5} Mass	11	Daily	NC	NC	NC	S	S	S	S	S	S	S	S	S	S	S
Particles (silica)	19	1-2 hour	NC	NC	S	S	S	S	S	S	S	S	S	S	S	S
Particles (metals)	14	Daily	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Total nitrate and ammonia/ammonium	14	24-hour	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Total nitrate and ammonia/ammonium	8	3-hour	NC	NC	NC	NC	NC	S	S	S	S	S	S	S	S	NC
Passive Samplers for NH ₃	5	72 hour	S		S/2	S			S			S/2	S			NP
Passive Samplers for NO ₂ /NO _x	5	72 hour	S		S/2	S			S			S/2	S			NP
VOC	0	23 hour	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
VOC	14	1-2 hour	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Temperature, Wind Speed, Wind Direction, Barometric Pressure, Rainfall	--	Hourly Daily	C	NC	NC	C	C	C	C	C	C	C	C	C	C	C

C = Continuous monitoring method obtained data on the indicated day.

NC = Integrated sample not collected; S = Integrated sample collected.

S/2 = Composite sample with half of the sampling conducted on 2/12/12 and half the sampling conducted on 2/19/12.

NP = Not planned

Table 4. Samples Collected at Other Sites

Species Monitored	No.	Duration	End Date of Daily Sample (February 2012)													
			10 F	11 S	12 S	13 M	14 T	15 W	16 T	17 F	18 S	19 S	20 M	21 T	22 W	23 T
Passive Samplers for NH ₃ – XtraLocation 1	5	72 hour	S	S/2		S				S		S/2		S		NP
Passive Samplers for NO ₂ /NO _x – XtraLocation 1	5	72 hour	S	S/2		S				S		S/2		S		NP
Passive Samplers for NH ₃ - XtraLocation 2	5	72 hour	S	S/2		S				S		S/2		S		NP
Passive Samplers for NO ₂ /NO _x XtraLocation 2	5	72 hour	S	S/2		S				S		S/2		S		NP
Passive Samplers for NH ₃ - XtraLocation 3	5	72 hour	S	S/2		S				S		S/2		S		NP
Passive Samplers for NO ₂ /NO _x XtraLocation 3	5	72 hour	S	S/2		S				S		S/2		S		NP
Passive Samplers for NH ₃ - XtraLocation 4	5	72 hour	S	S/2		S				S		S/2		S		NP
Passive Samplers for NO ₂ /NO _x XtraLocation 4	5	72 hour	S	S/2		S				S		S/2		S		NP
Temperature, Wind Speed, Wind Direction, Barometric Pressure, Rainfall – Mine Sampling Site	--	Hourly Daily	C	C	C	C	C	C	C	C	C	C	C	C	C	C

C = Continuous monitoring method obtained data on the indicated day.

S = Integrated sample collected.

S/2 = Composite sample with half of the sampling conducted on 2/12/12 and half the sampling conducted on 2/19/12.

NP = Not planned

region of the spectrum. The primary light-absorbing component of atmospheric PM is soot, which comes from combustion of carbon-containing fuels. Soot strongly absorbs both the 880 nm and 370 nm wavelengths of light used in the AE-21, so both wavelengths provide a measure of soot. UV-absorbing organic compounds (such as polycyclic aromatic hydrocarbons (PAHs)) also contribute to absorption of light at 370 nm, so the Aethalometer signal at that wavelength reflects both soot and UV-absorbing organic concentrations. Measurements were made at each wavelength approximately every five minutes throughout the study period. Hourly and daily soot concentrations in $\mu\text{g}/\text{m}^3$ were calculated.

2.3.3 Chemiluminescence NO_x Analyzer

Continuous Thermo Environmental Model 42C chemiluminescence analyzers were used at both the residence and school sampling sites to measure ambient NO/NO₂/NO_x concentrations during the study period. Ambient air was drawn by each Model 42 analyzer at a flow rate of approximately 1 L/min. Hourly and daily NO/NO₂/NO_x concentrations in parts per billion (ppb) were calculated.

2.3.4 Gas Filter Correlation CO Analyzer

Thermo Environmental Model 48C continuous gas filter correlation spectroscopy analyzers were used at both the residence and school sampling sites to continuously measure ambient CO concentrations during the study period. Ambient air was drawn by each Model 48C at a flow rate of approximately 1 L/min. During the study period the analyzers were operated in the 0 to 10 parts per million (ppm) range, which covered the range of ambient CO concentrations during the study period. A multipoint calibration of each analyzer was conducted using NIST-traceable calibration standards prior to testing, and zero/span calibration checks were performed at the beginning of the test and on each test day during the second week to confirm the performance of the analyzers. No adjustments were made to the analyzers during the test. Note that during the first week of testing, the data logger at the school site logged only integer units for the CO concentration. Consequently, since the CO concentrations were below 1 ppm throughout the study period the resolution of the recorded data at the school site could not adequately discern the actual CO concentrations during the first week of the study period. Hourly and daily CO concentrations are reported in ppm.

2.4 Integrated Measurement Procedures

Pre-weighed filters for TSP, PM₁₀, and PM_{2.5} sampling were shipped to the test sites in uniquely labeled protective shipping containers (e.g., Petri dishes for PM₁₀ and PM_{2.5} filters and manila folders for TSP). The filters were stored at room temperature at the residence and school sites and kept in their protective containers until the time of use to prevent contamination. Each filter was visually inspected for integrity before use. After sample collection, the filters were placed in their original containers and kept at room temperature until testing at the site was completed. Upon completion of the testing period, the filters were repackaged and shipped to Battelle for analysis. Samples were collected on each day of the two week study period, which included two Sundays which were used to establish “background” conditions, since no blasting is allowed on Sundays.

2.4.1 TSP Mass

TSP samples were collected using hi-volume samplers at the residence and school sampling sites. The samples were collected from approximately 7:00 p.m. to 6:00 p.m. the next day at the residence and from approximately 6:00 p.m. to 5:00 p.m. the next day at the school. This 23-hour sampling period was necessary to allow time for sample changeover at both sampling sites and the differences in the start and stop times of the sampling were needed to allow completion of all activities at one site prior to going to the other site. Samples were collected using preweighed 8" x 10" glass fiber filters at a flow rate of 1.1 to 1.7 cubic meters per minute (m^3/min). Field blank and trip blank samples were collected during the study period to assess the degree of contamination that occurs during sample handling. Both the field and trip blank samples suggested a systematic positive bias in the post weighing results (11.3 ± 1.5 mg and 11.6 ± 0.3 mg, respectively). This bias was attributed to differences in the procedures for the pre- and post-weights. The balance used for the weighing was not configured with a tray capable of supporting 8" x 10" filters. Consequently, the pre-weighing was conducted by supporting the unfolded filters on a temporary platform placed on the balance pan. After sampling the filters were folded in half and then were folded in half again for the gravimetric analysis. The post weighing was conducted by placing the folded filters directly on the balance pan. The average of the observed field and trip blank results was subtracted from the collected samples to determine the airborne TSP concentrations.

2.4.2 PM₁₀ Mass

BGI PQ200 samplers were used to collect 23-hour PM₁₀ samples at the residence and school sampling sites. PM₁₀ samples were collected from approximately 7:00 p.m. to 6:00 p.m. the next day at the residence and from approximately 6:00 p.m. to 5:00 p.m. the next day at the school on each day of the study period, using uniquely numbered 47 mm PTFE membrane filters (2 μm pore size). The samples were collected a nominal flow rate of 16.7 L/min. Filters from the PM₁₀ and PM_{2.5} samplers were analyzed gravimetrically using a calibrated Mettler Toledo Model AT20 analytical microbalance. All filters were conditioned for not less than 24 hours before both the pre- and post-sampling weighings in an environmentally-controlled facility with a mean temperature of 20 to 23 °C, and a mean humidity of 30 to 50 percent relative humidity. A total of four field blank samples were collected at the two sites and the average mass difference on the filters was 11 ± 4 μg suggesting no substantial systematic bias in the handling procedures. Consequently the PM₁₀ results were not adjusted for the field blank results.

2.4.3 PM_{2.5} Mass

Partisol Model 2025 Sequential Samplers with 47 mm PTFE membrane filters were used to collect daily 23-hour PM_{2.5} filter samples at each of the sampling sites. The PM_{2.5} samples were collected from approximately 7:00 p.m. to 6:00 p.m. the next day at the residence and from approximately 6:00 p.m. to 5:00 p.m. at the school. The Partisol sampled ambient air at a nominal flow rate of 16.7 L/min. A field blank was collected at both the residence and school sampling sites. A total of three field blank samples were collected at the two sites and the average mass gain on the filters was 8 ± 10 μg suggesting no substantial systematic bias in the handling procedures. Consequently the PM_{2.5} results were not adjusted for the field blank results.

2.4.4 Microscopy Substrates

Integrated particle samples were collected passively on conductive TEM/SEM substrates for

chemical/morphological analysis by automated microscopy. At both the residence and school monitoring sites, samples were collected over approximately 3-hour time periods in both the morning and in the afternoon. Samples were also collected on Sundays when no blasting is allowed. Substrates were shipped to the field preloaded in covered, uniquely labeled Petri dishes. To initiate sample collection, the Petri dish was placed on a flat surface and the cover was removed. After sample collection, the cover was replaced and taped to the body of the Petri dish. The sample collection period was determined based on an initial pre-screening sample collection performed at the residence sampling site. For this pre-screening two substrates were exposed for different durations (e.g., 1-hour and 4-hours) and analyzed by scanning electron microscopy to assess particle loading on each substrate. Based on the examination of the exposed substrates, the optimal sampling duration was determined to allow adequate single particle analysis without under- or over-loading the substrates. This assessment was made based on the sizes of the collected particles and the spacing between particles on the substrate. Optimal loading allowed for multiple particles in the field of view while avoiding overlap/contact of particles. No field blank samples were collected for the microscopy analysis since no quantitative analysis was to be performed.

2.4.5 Total Nitrate and Ammonia/Ammonium with Filter Packs

Open-face 47 mm diameter filter packs were used to sample for determination of total (i.e., particle plus vapor phase) NO_3^- and $\text{NH}_3/\text{NH}_4^+$. The filter packs employed a front Teflon filter for collection of PM, followed by a nylon filter for collection of vapor phase nitric acid (HNO_3), and a final citric acid-coated cellulose filter for collection of vapor phase NH_3 . Ambient air was drawn through each total NO_3^- and NH_4^+ filter pack by a pump at a flow rate of 10 L/min. Sampling for total NO_3^- and $\text{NH}_3/\text{NH}_4^+$ was carried out at both the residence and school sampling sites over the same 23-hour sampling interval as the PM samples on each day of the field period. In addition, at both the residence and the school, one sample per day was taken with a second Teflon/nylon/cellulose filter pack, over a 3-hour period spanning potential blasting periods. Field blank samples collected at both sites were analyzed and showed no detectable results for $\text{NH}_3/\text{NH}_4^+$, so no corrections to the $\text{NH}_3/\text{NH}_4^+$ results were made based on the field blank results. Field blank samples collected at both sites showed consistent NO_3^- results approximately 3-4 times above the method detection limit. Since these blank levels were approximately the same as many of the 3-hour filter pack results, the average of these field blank results was subtracted from the results for the filter pack analyses to determine the airborne concentrations.

2.4.6 Passive Samplers for NO_2/NO_x and NH_3 Concentrations

In addition to the active sampling for nitrate and ammonium, integrated passive samples were collected for NO_2 and NH_3 using Ogawa samplers. The passive samplers used for this purpose are very small (approximately 2 inches in diameter), required no electrical power, and needed only minimal shelter from weather. They sample by absorbing the gaseous pollutants from the air as the air moves naturally around the samplers. Passive sampling provides only long-term average readings, but this approach allowed comparison of results from more sites than can be equipped with continuous monitoring equipment.

The passive samplers were placed at both the residence and school sites as well as at other locations in the Clear Fork community as shown in Figure 1. The sites for passive sampling

were chosen by Battelle staff once the residence and school sampling sites were set up and in operation. The criteria for siting of the passive samplers included:

- Relatively unrestricted movement of ambient air,
- Freedom from disturbance of the sampler, and
- Locations in different directions from the expected mining area. For example, passive samplers were located to southerly, westerly, northerly directions from the mine permit area. (Note: access to suitable sites to the east of the mine permit area was impractical.)

One NO₂ and one NH₃ passive sampler were placed at each passive sampling site, and left there through three sampling days from (e.g.) Monday through Wednesday (approximately 72 hours). Those passive samples were recovered and replaced with new passive samplers for Thursday through Saturday. The replacement samplers were then also recovered and replaced with new passive samplers for Sunday, which constitutes a “background” sampling day due to the absence of blasting on that day. On Sunday, the background samplers were recovered and the sequence was repeated with two successive 3-day sampling periods followed by a 1-day background sampling period. Note that for the “background” samples, the same “background” passive samplers used during the previous “background” day were unsealed and redeployed for sampling on Sunday to generate a composite sample collected over two Sundays. In this way the “background” passive samplers accumulated sampling on Sundays only. A total of five NO₂ and five NH₃ passive samplers were collected at each of four sites at each site (four 3-day samples and one “background” sample collected as a composite sample over two Sundays).

A total of four field blanks were collected for each type of passive sampler. The field blank sampling media were installed in the sampler, and promptly removed and placed in uniquely labeled vials for storage until shipment to the laboratory. The results of the field blank samples showed no detectable amounts of either NH₃ or NO₂, so no corrections to the results of the passive samplers were made based on field blank results.

2.4.7 VOCs

Air samples for VOCs were collected in cleaned, evacuated, 6 liter stainless steel SUMMA-type canisters. Prior to shipment of the canister to the field, the interior surfaces of the canisters were pre-conditioned to be inert to compounds that may be present in collected air samples. Samples were collected daily at both the residence and the school sampling sites. Sampling was initiated by opening the canister valve and allowing ambient air to enter the canister through a critical orifice for approximately 3 hours. Since the times of the blasting events were not known by the site operators in advance, the sampling was initiated at times that were expected to overlap the blasting events. Field blank samples were collected at each site and a single field blank sample was analyzed along with the samples that were selected for analysis. The results of the field blank sample are presented along with the analyzed samples and no correction to the sample concentrations was made based on the field blank.

2.5 Meteorological Measurements

Meteorological measurements were made at the residence sampling site (see Figure 1) and at the mine sampling site (see Figure 5) using MetOne meteorological stations. Each station was

operated using solar-panel/battery power and provided measurements of temperature, relative humidity, barometric pressure, and wind speed/direction. Measurements were made at approximately 2 meters above ground level. Additionally, a portable Davis Instruments meteorological station was used at the school sampling site to record temperature, relative humidity, barometric pressure, wind speed/direction, and rainfall. Hourly and daily averages were calculated for each of the measured meteorological parameters.

2.6 Analytical Methods

All sample analyses and laboratory activities were performed based on available Standard Operating Procedures or applicable published protocols and were documented in accordance with Battelle's Quality Management Plan.

2.6.1 Gravimetric Analysis

Filters from the PM₁₀ and PM_{2.5} samplers were analyzed gravimetrically using a calibrated Mettler Toledo Model AT20 analytical microbalance. Filters for TSP were weighed using a calibrated Mettler Toledo Model PM300 analytical balance. Calibration checks were performed during all weighing sessions using calibrated weights. All filters were conditioned for not less than 24 hours before both the pre- and post-sampling weighings in an environmentally controlled facility. The airborne PM concentrations were determined from the differences in the pre- and post-weights of each sample divided by the respective volume of air sampled. Concentrations are reported as 23-hour averages in $\mu\text{g}/\text{m}^3$.

2.6.2 Metals Analysis

Particulate metal concentrations were determined from analysis of collected PM₁₀ filter samples. After review of the gravimetric results for these samples and the real-time particle measurements a subset of 10 of the collected PM₁₀ filter samples was selected for metals analysis; the rationale for sample selection is presented in Section 3.6. A total of 10 samples (five from the residence and five from the school) and a field blank were analyzed for metals. The PM₁₀ filter samples were digested in concentrated acid using microwave extraction procedures based on Compendium Method IO-3.1.¹ The extracts were analyzed by ICP-MS using using an Elan DRC-e ICP-MS with Elan v 3.3 software and procedures based on Compendium Method IO 3-5.² Analysis involved the measurement of metals most indicative of the presence of crustal materials: Mg, Al, Si, Ca, Cr, Fe, Mn, Cu, Zn, and Pb.

Continuing calibration blanks were analyzed with the samples. These blanks showed levels of Ca, Fe, and Cu well below the lowest calibration level; all other metals were not detected. One laboratory blank filter and one matrix spike (blank filter spiked with the analytes of interest) were processed with the samples. All analytes except Mg, Cu, and Pb were detected in the laboratory blank filter above the level of the lowest calibration standard. The recovery of the matrix spike (corrected for the amount detected in the corresponding laboratory blank sample) ranged from 38% to 106%. For all but one of the analytes, the matrix recovery was below the acceptance criterion of Method IO-3.5 ($100 \pm 25\%$) suggesting a possible negative bias. No corrections to measured results were made based on the matrix spike. Two samples were measured in duplicate to assess the reproducibility of the duplicate measurements. For each of the individual metals, the relative percent difference (RPD) between the duplicate analyses

ranged from 0 to 15%, where the RPD was calculated as the difference between the duplicates divided by their mean, and a zero percent difference indicates perfect agreement between the duplicate results. The method acceptance criterion for duplicates is $\pm 20\%$.

2.6.3 VOC Analysis

A subset of the canister samples were analyzed for VOCs; the decision on which canister samples to analyze is described in Section 3.7. Canister analysis followed Battelle SOP No. ENV-VOC-003-05 which is based on procedures outlined in U.S. EPA Compendium Method TO-15.³ The VOCs listed in EPA Method TO-15A were identified in the analysis by retention time and by comparison with known standards. Under these conditions, the individual VOC detection limits were ~ 0.1 ppb. Individual VOC concentrations are reported in ppb. Duplicate injections for one sample were analyzed to assess method reproducibility. For those analytes detected above the method detection limit, the percent difference between the duplicate results ranged from 0-20%, which is consistent with the results presented in Method TO-15.

2.6.4 Total Nitrate and Ammonia/Ammonium

Following the study period, the 23-hour and 3-hour samples collected at both sampling sites were extracted and analyzed by ion chromatography (IC) for NO_3^- and NH_4^+ . The extraction and analysis of the filter pack samples followed Dionex Application Note 154 which is based on EPA's Method 300.0⁴ for analysis of anions and cations. The three filters comprising each filter pack sample were extracted together in sealable vials to which was added 25 mL of distilled, deionized water. The vials were placed on an orbital shaker and shaken for 1 hour at approximately 250 rpm. In addition to the field samples and field blanks, for both NO_3^- and NH_4^+ , an additional filter was spiked with standard solution at the midpoint of the calibration range and extracted for use as a laboratory QC sample. These samples were each analyzed after every 10th sample. The percent recoveries ranged from 100-110% for the NO_3^- analyses, which meets the acceptance criterion for Method 300.0. For NH_4^+ , the percent recoveries ranged from 103-119% suggesting a small potential positive bias in the results.

2.6.5 Passive NO_2/NO_x and NH_3 Analysis

NO_2 Determination. Samples were received from the field in small opaque white plastic bottles. Samples were stored refrigerated at $\sim 6^\circ\text{C}$ from time of receipt in the laboratory until processed. Samples were processed on March 6 and 7, 2012 following Ogawa Sampler Protocol for NO , NO_2 , NO_x , and SO_2 , version 6.06 for NO_2 . Sample processing involved placing 8.0 mL aliquots of high purity water into glass vials using a glass pipette. One sample filter was added to each vial and the vials were capped with Teflon-lined caps and shaken by hand. The samples were placed on an orbital shaker and shaken for 30 minutes at approximately 130 rpm. The samples were placed in a water bath at 4°C . An aliquot (2 mL) of Color Producing Reagent (CPR) was added to each vial using a glass pipette. The vials were capped and shaken vigorously. The samples remained in the 4°C water bath for 30 minutes. The bath temperature was increased to 21.5°C ; the vials remained at this temperature for approximately 20 minutes. The absorbance of each sample was measured at a wavelength of 545 nm on an Ocean Optics HR4000 spectrometer using a tungsten halogen source and 1.00-cm cuvettes.

Two blank filters and two matrix spikes (blank filters spiked with $0.4\ \mu\text{g}$) were also processed with the samples. The blank filters had an absorbance of ≤ 0.002 . The recovery of the two

matrix spikes was 104% and 102%. No acceptance criteria for percent recovery are provided in the analytical protocol, however, these results fall within the acceptance criteria of $100 \pm 10\%$ for EPA Method 350.1.⁵ Four samples were measured in duplicate; the percent reproducibility for the duplicate measurements, calculated as the difference between the duplicates divided by their mean, was $\leq 6\%$.

Ammonium Determination

Samples were received from the field in small opaque white plastic bottles. Samples were stored refrigerated at $\sim 6^\circ\text{C}$ from time of receipt in the laboratory until processed. Samples were processed following “NH₃ Sampling Protocol Using the Ogawa Sampler”. Sample processing involved placing 8.0 mL of high purity water into plastic vials using a glass pipette. The vials were capped and shaken for 1 hour at approximately 250 rpm on an orbital shaker. An aliquot of each sample was transferred to an autosampler vial and analyzed by IC based on Method 300.0.

Milli-q[®] water blanks were analyzed with the samples. Ammonium was not detected in the water blanks. Two blank filters and two matrix spikes (blank filters spiked with $20\ \mu\text{g NH}_4^+$) were processed with the samples. Ammonium was not detected in the blanks. The recovery values of the two matrix spikes were 121% and 116%, respectively. These recoveries exceed the acceptance criterion of $100 \pm 10\%$ for Method 300.0, suggesting a small positive bias in the results. Four samples were measured in duplicate; the percent reproducibility for the duplicate measurements was not determined because no ammonium was detected in the samples.

3 RESULTS AND DISCUSSION

3.1 Blasting Summary

Blasting was performed at various times throughout the study period within two different permit areas in the vicinity of the test area. The data in Table 5 and Table 6 were provided by the WV DEP and summarize the times and approximate locations of the individual blasts performed during the study for the two permit areas. In these tables the GPS coordinates provided represent the mid-point of the grid location identified on the blasting maps for the two permits. Blasts which were detected by seismographs located in the community are indicated by an asterisk and footnote in Tables 5 and 6. Blasting was not conducted on Sundays, thus February 12 and 19, the two Sundays that fell within the study period, are considered as “background” days relative to any blasting impacts on air quality.

Table 5. Summary of Blasting Events Conducted at Ewing Fork #2 Area (Permit S-3018-03) during Testing

Date	Time	Approximate GPS Coordinates
2/9/12	16:02	37°55'45" N 81°18'38.5" W
2/10/12	16:27	37°55'21.5" N 81°19'25.5" W
2/10/12 *	16:27 ^a	37°55'39" N 81°19'25.5" W
2/11/12	13:18	37°55'26.5" N 81°19'12.5" W
2/13/12	16:30 ^a	37°55'21.5" N 81°19'25.5" W
2/14/12	11:29	37°55'41.5" N 81°18'29.5" W
2/15/12	9:34	37°55'41.5" N 81°18'29.5" W
2/15/12	16:30 ^a	37°55'21.5" N 81°19'28.5" W
2/16/12	17:11	37°55'45" N 81°18'38.5" W
2/17/12	11:39	37°55'45" N 81°18'26" W
2/18/12	13:18	37°55'41.5" N 81°18'29.5" W
2/18/12	13:18	37°55'45" N 81°18'35.5" W
2/18/12	13:51 ^a	37°55'21.5" N 81°19'28.5" W
2/21/12	9:19	37°55'45" N 81°18'38.5" W
2/23/12	8:25	37°55'45" N 81°18'38.5" W
2/23/12	16:38	37°55'21.5" N 81°19'19.5" W

a: Triggered seismograph readings.

Table 6. Summary of Blasting Events Conducted at Horse Creek Surface Mine (Permit S-3015-99) during Testing

Date/	Time	Approximate GPS Coordinates
2/11/12	8:08	37°56'3.5" N 81°19'56.5" W
2/14/12	9:03	37°56'3.5" N 81°19'56.5" W
2/14/12	16:28	37°56'1" N 81°19'44.5" W
2/15/12	10:46	37°55'58.5" N 81°19'47.5" W
2/16/12	9:43	37°56'15.5" N 81°20'27.5" W
2/16/12	9:44	37°56'13" N 81°20'9.5" W
2/16/12	16:27	37°56'1" N 81°19'50.5" W
2/16/12	16:43	37°56'3.5" N 81°19'59.5" W
2/17/12	8:33	37°56'13" N 81°20'9.5" W
2/17/12	16:28	37°55'53.5" N 81°19'28.5" W
2/18/12	8:14	37°56'18" N 81°20'9.5" W
2/18/12	13:17	37°55'53.5" N 81°19'28.5" W
2/20/12	16:24	37°56'3.5" N 81°19'28.5" W
2/21/12	7:25	37°56'15.5" N 81°20'9.5" W
2/21/12	13:16	37°56'10.5" N 81°20'40.5" W
2/21/12	16:24	37°56'1" N 81°19'28.5" W
2/22/12	8:24	37°56'18" N 81°20'9.5" W
2/22/12	9:24	37°56'1" N 81°20'3" W
2/22/12	14:00	37°56'10.5" N 81°20'40.5" W
2/22/12	16:22 ^a	37°56'1" N 81°19'28.5" W
2/22/12	16:23	37°55'56" N 81°19'22.5" W

a: Triggered seismograph readings.

Figure 6 shows the approximate locations of the sampling sites and the blasting events during the study period.

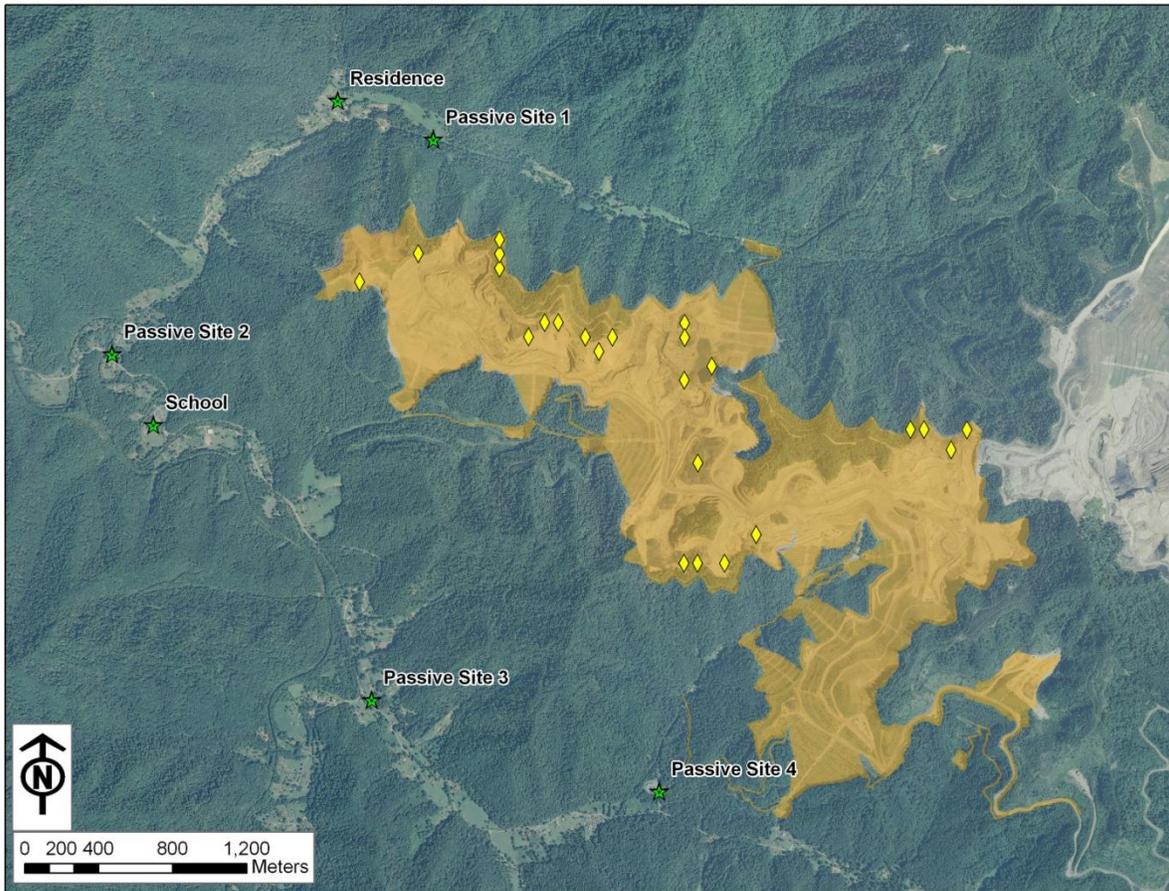


Figure 6. Approximate locations of sampling sites (green markers) and blasting events (yellow markers) during study period.

3.2 Meteorological Measurements

3.2.1 Precipitation

Figure 7 shows the hourly total precipitation amounts at the school site during the study period. Table 7 presents the daily total precipitation amounts measured at that site during the study period. These results indicate that there was some precipitation on 9 of the 14 days in the study period, although only two days experienced rainfall amounts above 0.14 inches (3.6 millimeters (mm)).

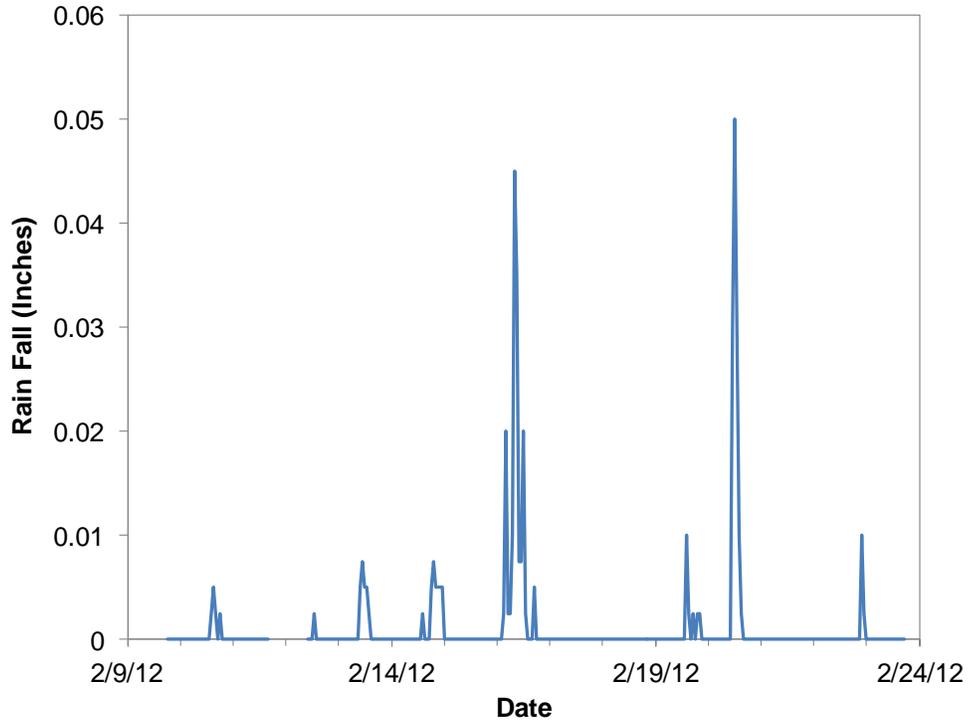


Figure 7. Hourly precipitation measurements during study period at the School.

Table 7. Daily Total Precipitation Amounts during Study Period at School Sampling Site

Date	Total Rainfall (in)
2/9/12	0
2/10/12	0.05
2/11/12	0
2/12/12 (Non-blasting)	0.01
2/13/12	0.1
2/14/12	0.14
2/15/12	0.09
2/16/12	0.54
2/17/12	0
2/18/12	0
2/19/12 (Non-blasting)	0.08
2/20/12	0.49
2/21/12	0
2/22/12	0.05
2/23/12	0

3.2.2 Ambient Temperature

The hourly temperature measurements recorded at the residence sampling site, school, and mine sites are presented in Figure 8, and the daily average results are presented in Table 8. In general, the temperatures measured at the three sites track very closely with each other, although the temperature at the mine site tended to be slightly lower than at the other two sites. Also, a general warming trend was observed over the course of the study period. The temperatures during the study period tended to be higher than historical averages for that time period, consistent with relatively warm conditions throughout the eastern United States in this period.

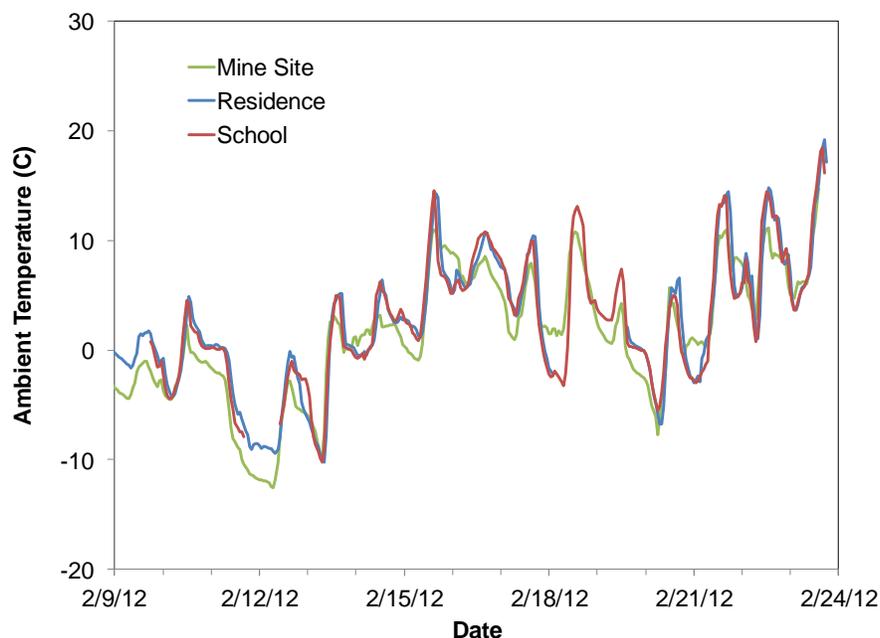


Figure 8. Hourly average temperature readings during study period.

3.2.3 Barometric Pressure

The hourly barometric pressure measurements at the three sites are presented in Figure 9 and the daily average results are shown in Table 9. In general, the pressure readings at the residence sampling site and the school agree very well with each other both in terms of temporal variation and in absolute magnitude. The temporal trends in measurements at the mine site agree with the other sites, but the magnitude of the measurements shows a negative offset of approximately 28 mm Hg relative to the measurements at the other sites, which is attributed to the differences in elevation between the sites.

Table 8. Daily Average Temperatures during Study Period

Date	Average Temperature (°C)		
	Residence	School	Mine
2/9/12	-0.1	-0.5	-2.5
2/10/12	-0.2	-0.4	-1.7
2/11/12	-3.9	^a	-7.0
2/12/12 (Non-blasting)	-5.7	^a	-7.8
2/13/12	-2.2	-2.1	-2.1
2/14/12	2.1	2.4	1.9
2/15/12	5.8	5.6	4.9
2/16/12	7.7	8.1	7.2
2/17/12	5.5	5.2	3.8
2/18/12	^b	4.1	5.5
2/19/12 (Non-blasting)	^b	2.7	0.5
2/20/12	-0.5	-0.6	-1.0
2/21/12	5.4	4.8	5.5
2/22/12	8.7	8.5	7.4
2/23/12	9.8	9.6	7.7

(a) Datalogger failure.

(b) Power failure.

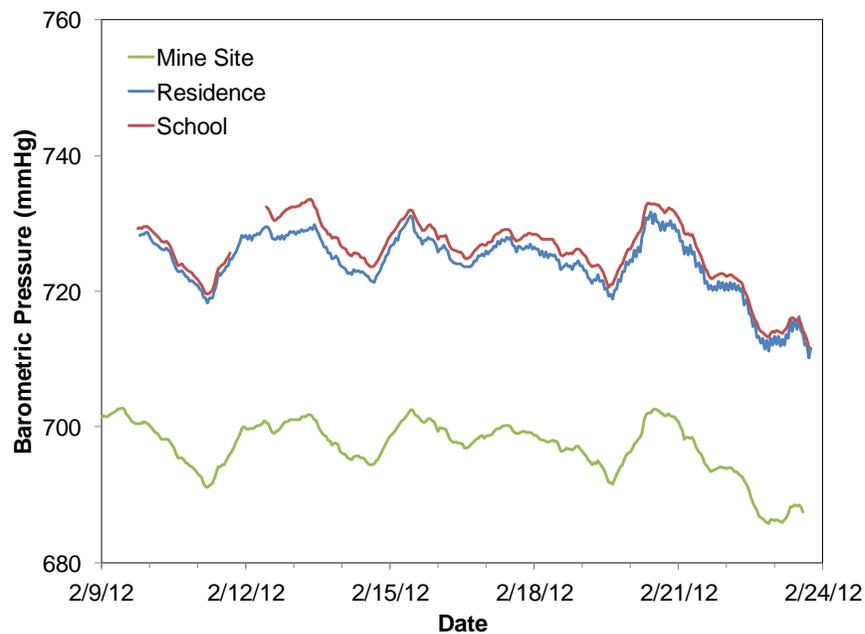


Figure 9. Hourly average barometric pressure readings during study period.

Table 9. Daily Average Barometric Pressure during Study Period

Date	Average Barometric Pressure (mmHg)		
	Residence	School	Mine
2/9/12	728.5	729.5	700.5
2/10/12	724.4	725.6	696.8
2/11/12	722.7	<i>a</i>	694.7
2/12/12 (Non-blasting)	728.4	<i>a</i>	700.1
2/13/12	727.5	730.8	699.8
2/14/12	723.0	725.3	695.6
2/15/12	728.2	729.9	700.9
2/16/12	724.8	726.4	698.2
2/17/12	726.7	728.2	699.4
2/18/12	<i>b</i>	726.7	697.5
2/19/12 (Non-blasting)	<i>b</i>	723.5	694.2
2/20/12	728.8	731.0	700.7
2/21/12	723.4	725.4	696.2
2/22/12	716.6	718.0	690.0
2/23/12	713.3	714.5	687.2

a: Datalogger failure.

b: Power failure.

3.2.4 Relative Humidity

Table 10 shows the daily average relative humidity (RH) at the sampling sites. Substantial differences were occasionally observed between the results at the three sites, suggesting potentially localized variations in the RH levels.

3.2.5 Wind Speed/Direction

Figure 10 shows the summary wind roses for the mine site, the residence sampling site, and the school site for the entire study period. The wind roses present the hourly average wind direction and wind speed data. The positioning of the “petals” show the direction that the wind was coming from, while the colors represent the wind speeds, and the lengths of the “petals” represent the percentage of time that the winds were from the corresponding direction and exhibited the corresponding speeds. Wind roses for the individual days during the study period are included in Appendix B. Figure 11 through Figure 13 show the wind class frequency distributions for the residence, school, and mine sites, respectively. In general, the wind at the mine site was largely from southerly and easterly directions, with the majority of wind speeds in the 0.5 to 2.1 and 2.1 to 3.6 m/s wind classes. At both the residence sampling site and the school sites, the winds were typically from the southeasterly directions, and the majority of wind speeds

were below 2.1 m/s, with relatively substantial portions of the study period exhibiting calm conditions.

Table 10. Daily Average Relative Humidity during Study Period

Date	Average Relative Humidity (%)		
	Residence	School	Mine
2/9/12	79.1	78.3	74.9
2/10/12	63.4	87.1	82.4
2/11/12	79.1	^a	79.3
2/12/12	78.6	^a	64.5
2/13/12	58.6	73.5	58.2
2/14/12	65.5	84.3	70.2
2/15/12	79.2	78.3	65.5
2/16/12	71.5	89.6	80.8
2/17/12	85.8	74.9	70.6
2/18/12	^b	72.8	52.2
2/19/12	^b	82.2	76.8
2/20/12	84.1	87.6	73.7
2/21/12	78.0	72.6	54.0
2/22/12	62.0	72.2	68.2
2/23/12	65.7	82.1	84.3

a: Datalogger failure.

b: Power failure.

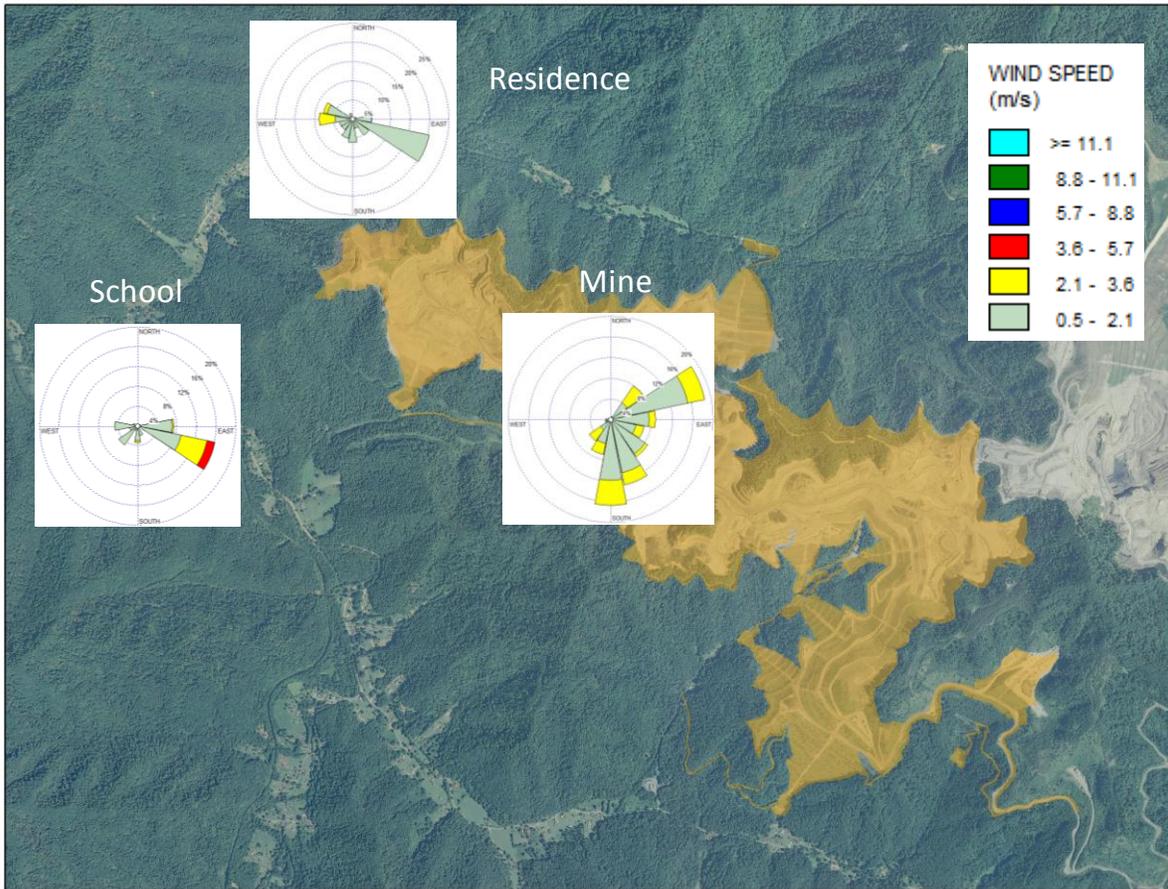


Figure 10. Wind roses for three study sites during entire study period.

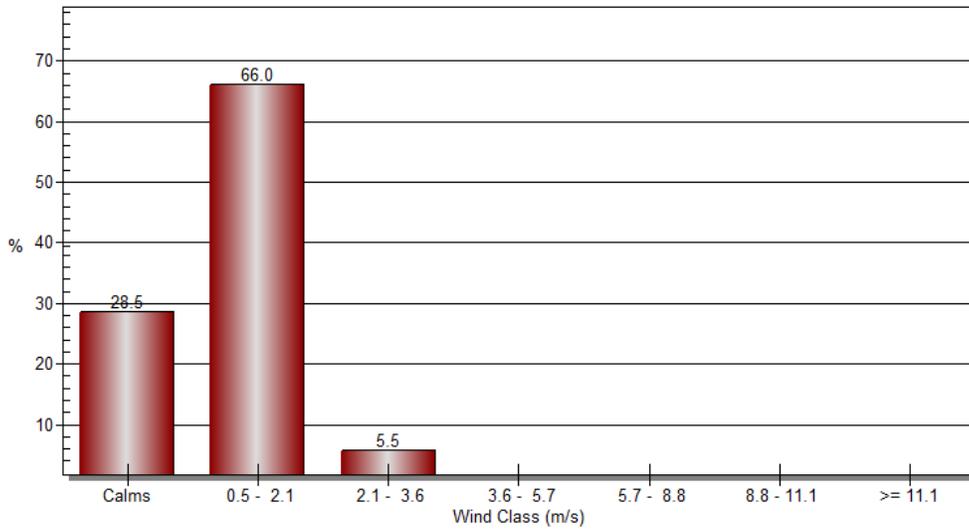


Figure 11. Wind class frequency distribution for residence sampling site during study period.

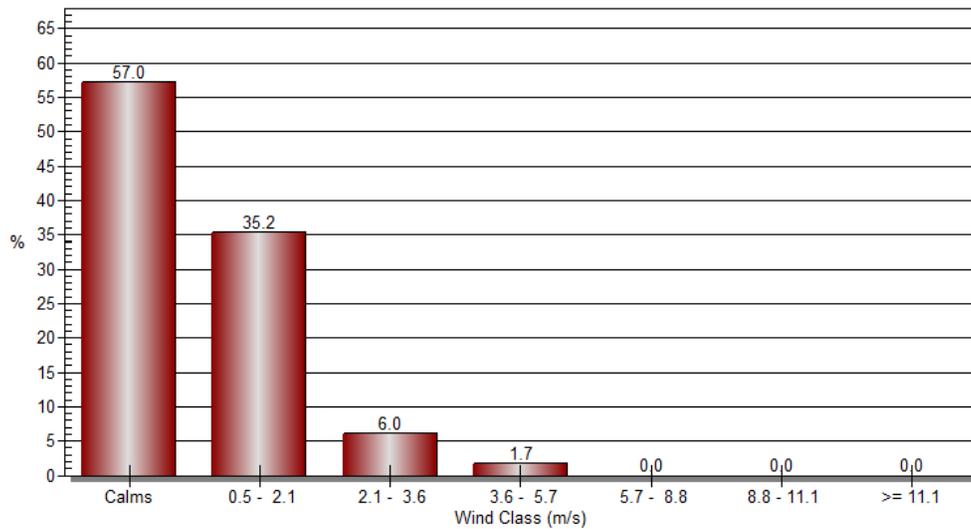


Figure 12. Wind class frequency distribution for school sampling site during study period.

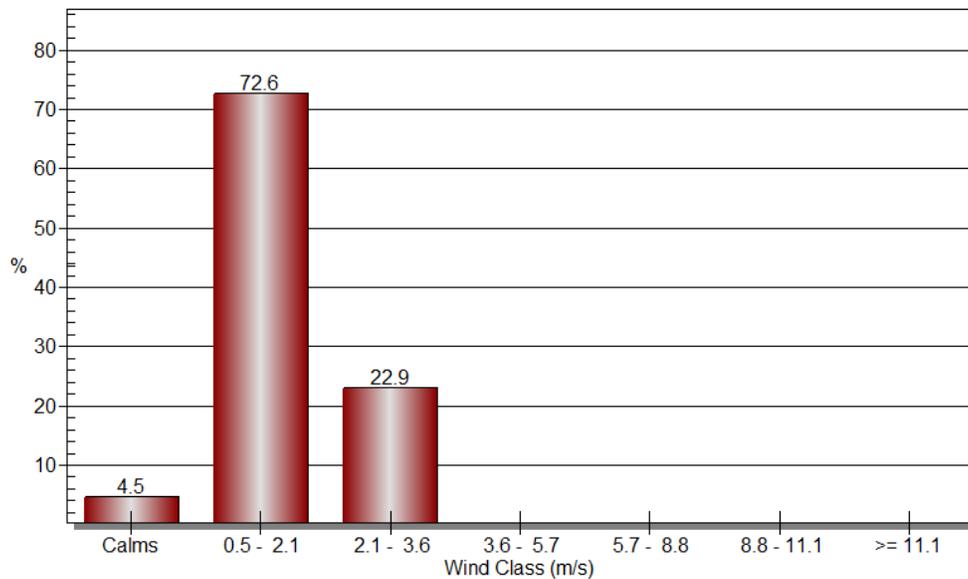


Figure 13. Wind class frequency distribution for mine site during study period.

3.3 Particulate Matter

3.3.1 TEOM

Figure 14 shows the hourly average PM_{10} , $PM_{2.5}$, and PM_{Coarse} results from the continuous TEOM monitor operated at the residence sampling site during the study period. This figure indicates that the PM_{10} and $PM_{2.5}$ fractions tracked reasonably closely with each other and that the PM_{Coarse} fraction (i.e., the difference between PM_{10} and $PM_{2.5}$) was generally a relatively small component of the PM_{10} . This suggests that wind-blown crustal material, which is a

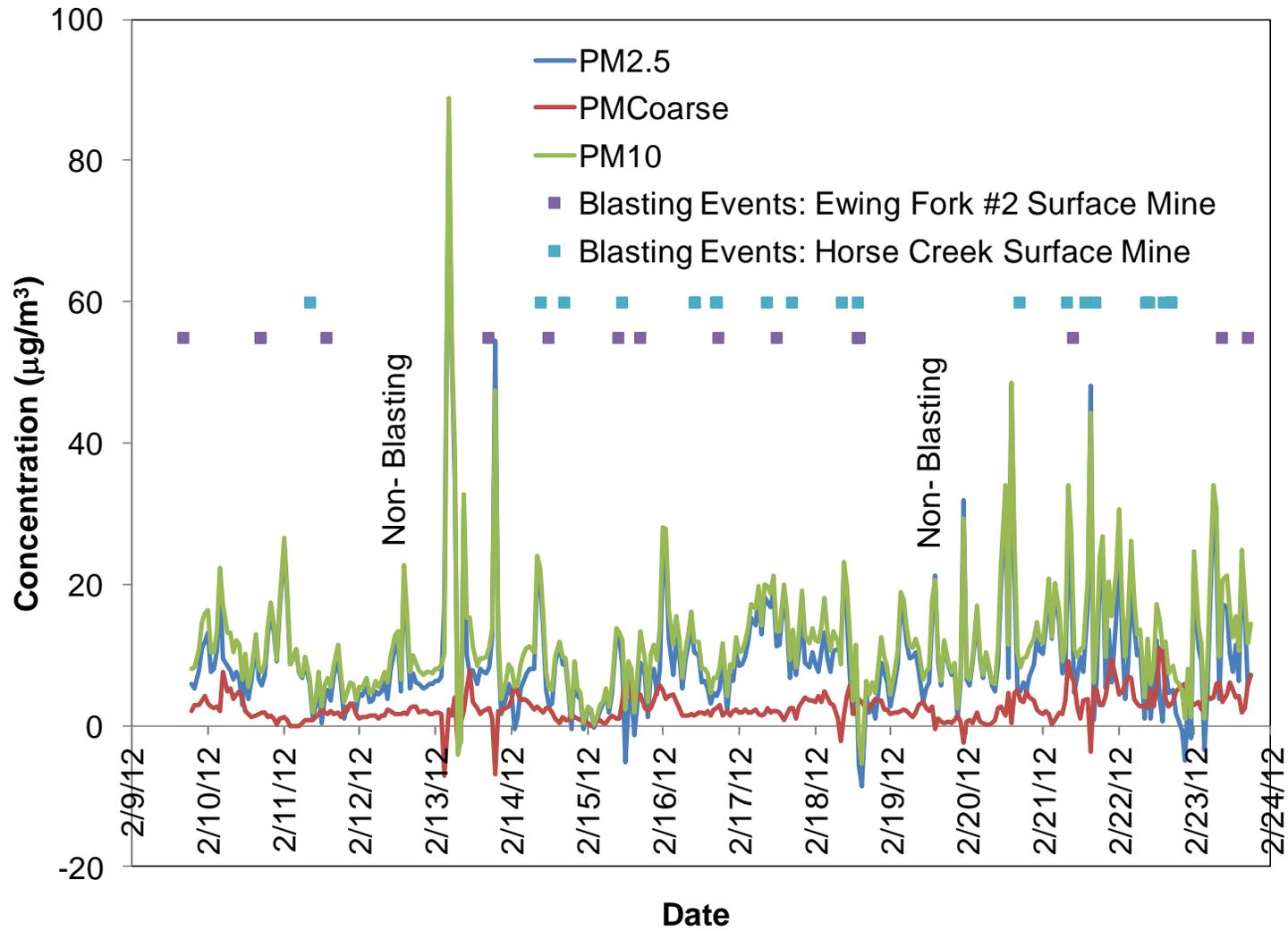


Figure 14. Hourly average PM₁₀, PM_{2.5}, and PM_{Coarse} measurements during study period.

frequent source of coarse PM, was not a major component of the PM₁₀ measured during the study period. Figure 14 also shows the times when blasting events occurred at the two permit areas. Since the blasts were nearly instantaneous events, the blast markers in this graph are not meant to show the duration of the events but merely to illustrate the times of the events. There is no obvious correlation between the occurrence of blasting events and the peaks in the PM data. However, any potential impact of blasting on PM at the residential site would depend on wind direction and individual blasting events. Several relatively strong spikes in the measured PM concentrations were observed during the study period. The strongest of these spikes occurred at between about 4:00 and 6:00 a.m. on February 12. It is not clear what caused this spike, as it is not associated with any blasting event or any spike in the aethalometer data (see Section 3.3.5) and it may be an anomaly in the TEOM results.

3.3.2 TSP

Table 11 and Figure 15 present the measured TSP concentrations at the residence sampling site and school sampling sites. Usually the TSP concentrations measured at the residence sampling site exceeded those measured at the school. No clear temporal pattern exists in the daily TSP data. The TSP concentrations measured on the two non-blasting days (i.e., sample periods ending on February 12 and 19) were among the lowest measured concentrations, but were not the lowest. The lower concentrations on these days may indicate the absences of specific sources on those days, but does not conclusively point to individual sources.

Table 11. TSP Concentrations Measured During Study Period

Stop Date	TSP Concentration ($\mu\text{g}/\text{m}^3$)	
	Residence	School
2/10/12	22.4	13.5
2/11/12	NS	NS
2/12/12 (Non-Blasting)	14.1	9.7
2/13/12	18.6	14.4
2/14/12	15.3	13.2
2/15/12	10.5	5.8
2/16/12	21.1	9.0
2/17/12	17.3	16.6
2/18/12	22.6	23.6
2/19/12 (Non-Blasting)	14.5	22.5
2/20/12	19.5	16.4
2/21/12	33.7	20.6
2/22/12	25.9	30.8
2/23/12	25.5	22.2

NS- No sample collected.

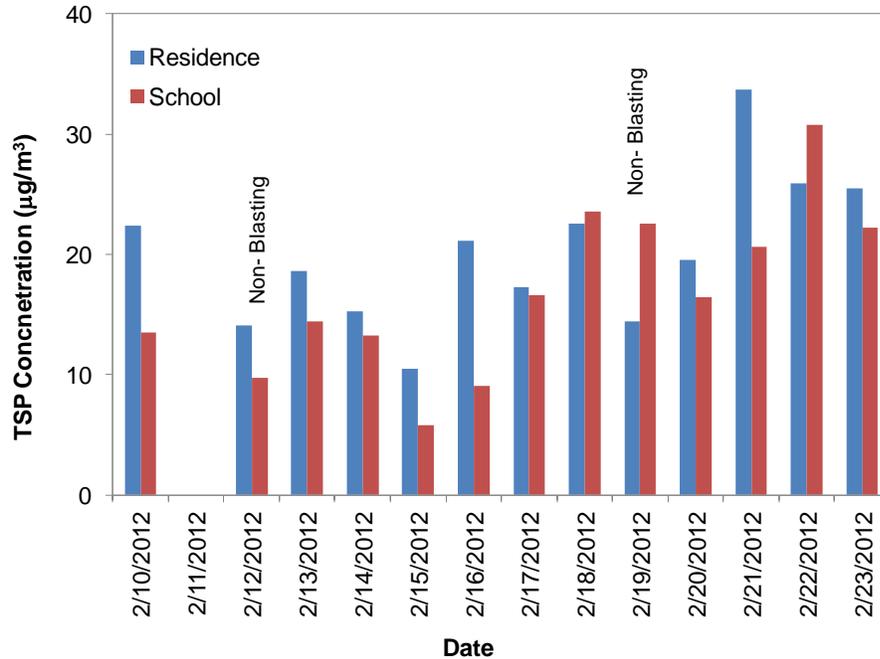


Figure 15. Daily TSP concentrations at residence and school sampling sites. (Date shown is the end date for sampling).

3.3.3 PM_{10}

Table 12 and Figure 16 present the daily integrated (filter-based) PM_{10} concentrations at the residence and school sampling sites. The corresponding 23-hour average results from the TEOM operated at the residence sampling site are also included in the figure and agreed with the filter based results at the residence sampling site typically within $3 \mu\text{g}/\text{m}^3$. The cause for greater differences between the filter-based sample and the TEOM on three study days is not apparent. In general, the PM_{10} concentrations measured at the two sites were similar, although the measurements at the residence sampling site were almost always greater than at the school. There is a large difference between the TEOM results and the filter based results on February 13, which may suggest that the spike observed in the TEOM data in the early morning of that day was an anomaly. At both sites the PM_{10} results were below $15 \mu\text{g}/\text{m}^3$ with the exception of the sample collected on the first day at the residence sampling site. These results are consistent with, and somewhat lower than, the results reported in the WV DEP Annual Air Quality Report for 2010. For example, the annual average PM_{10} concentration for Charleston, West Virginia for 2010 was $18.9 \mu\text{g}/\text{m}^3$. For reference, the 24-hour National Ambient Air Quality Standard (NAAQS) for PM_{10} is $150 \mu\text{g}/\text{m}^3$.

Table 12. PM₁₀ Concentration Measured During Study Period

End Date	PM ₁₀ Concentration (µg/m ³)		
	Residence (Integrated)	School (Integrated)	TEOM (Continuous)
2/10/12	17.9	13.8	11.5
2/11/12	NS	12.6	9.9
2/12/12 (Non-Blasting)	9.3	6.4	7.9
2/13/12	11.3	8.8	16.0
2/14/12	11.1	9.7	11.5
2/15/12	8.2	4.6	5.7
2/16/12	12.7	7.8	11.6
2/17/12	14.0	10.6	13.9
2/18/12	12.3	13.1	11.0
2/19/12 (Non-Blasting)	11.1	13.2	10.9
2/20/12	11.6	8.4	13.5
2/21/12	12.5	10.8	16.2
2/22/12	14.3	13.0	14.4
2/23/12	12.1	10.3	14.3
Average	12.2	10.2	12.0
2010 Annual Average for Charleston	18.9		

NS- No sample.

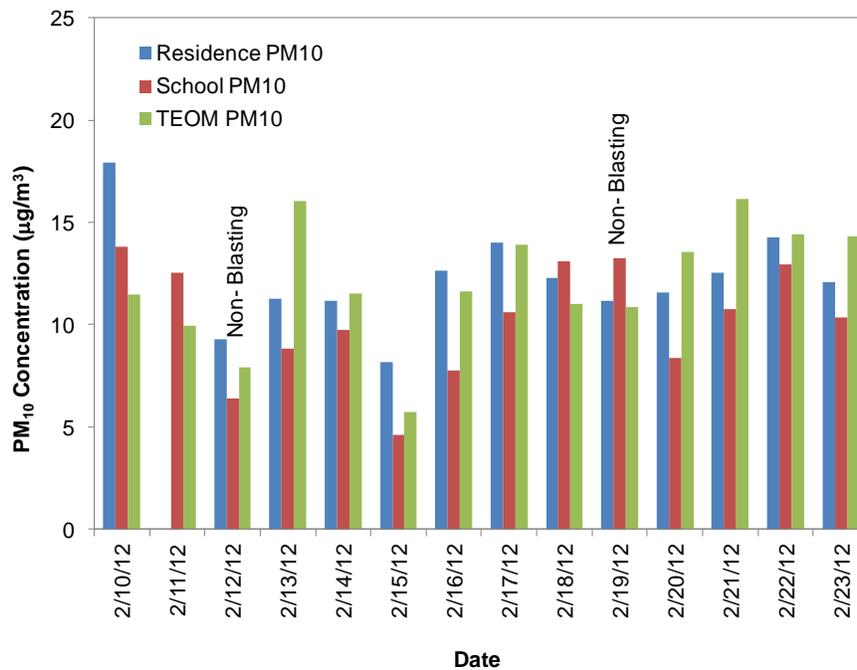


Figure 16. Daily PM₁₀ concentrations at the residence and school sampling sites. The 24-hour averages from the TEOM at the residence sampling site are also presented. (Date shown is the end date for sampling).

3.3.4 PM_{2.5}

Table 13 presents the measured daily PM_{2.5} concentrations at the residence and school sampling sites as well as the PM_{2.5} concentrations measured at a DEP monitoring site in Beckley, West Virginia, which is located approximately 20 miles south of the study location. These data are shown graphically in Figure 17 along with the 23-hour average data from the TEOM that was operated at the residence sampling site. In general there is reasonable agreement among the results from the residence, the school, and the monitoring site in Beckley. The TEOM results tended to overestimate the PM_{2.5} concentration relative to the filter based results and may indicate the presence of a volatile fraction that was lost in the 23-hour integrated samples. These results are consistent with the results for Beckley reported in the WV DEP Annual Air Quality Report for 2010. For example, the annual average PM₁₀ concentration for Beckley for 2010 was 10.2 µg/m³. In all cases the daily PM_{2.5} results from both sampling sites were below the NAAQS annual limit of 15 µg/m³ and the 24-hour limit of 35 µg/m³. A substantial discrepancy between the TEOM results and the filter based results was observed on February 13, which may suggest that the spike observed in the TEOM data on that day (see Figure 14) was an anomaly.

Table 13. Daily PM_{2.5} Concentration Measured During Study Period

End Date	PM _{2.5} Concentration (µg/m ³)			
	Residence (Integrated)	School (Integrated)	Beckley (Integrated)	TEOM (Continuous)
2/10/12	NS	NS	13.1	8.3
2/11/12	NS	NS	5.5	8.9
2/12/12 (Non-Blasting)	5.7	NS	3.9	6.1
2/13/12	NS	5.5	4.7	14.2
2/14/12	7.7	6.9	8.7	9.4
2/15/12	5.2	5.6	4.5	3.7
2/16/12	8.9	8.9	5.8	8.9
2/17/12	10.2	9.4	8.4	12.0
2/18/12	8.9	8.8	10.6	8.1
2/19/12 (Non-Blasting)	NS	6.7	7.4	8.9
2/20/12	8.0	7.4	7.4	12.1
2/21/12	8.4	6.3	7.3	13.1
2/22/12	6.9	6.1	5.5	9.3
2/23/12	9.2	NS	4.9	10.0
Average	7.3	7.1	7.0	9.5
2010 Annual Average for Beckley	10.3			

NS - No sample.

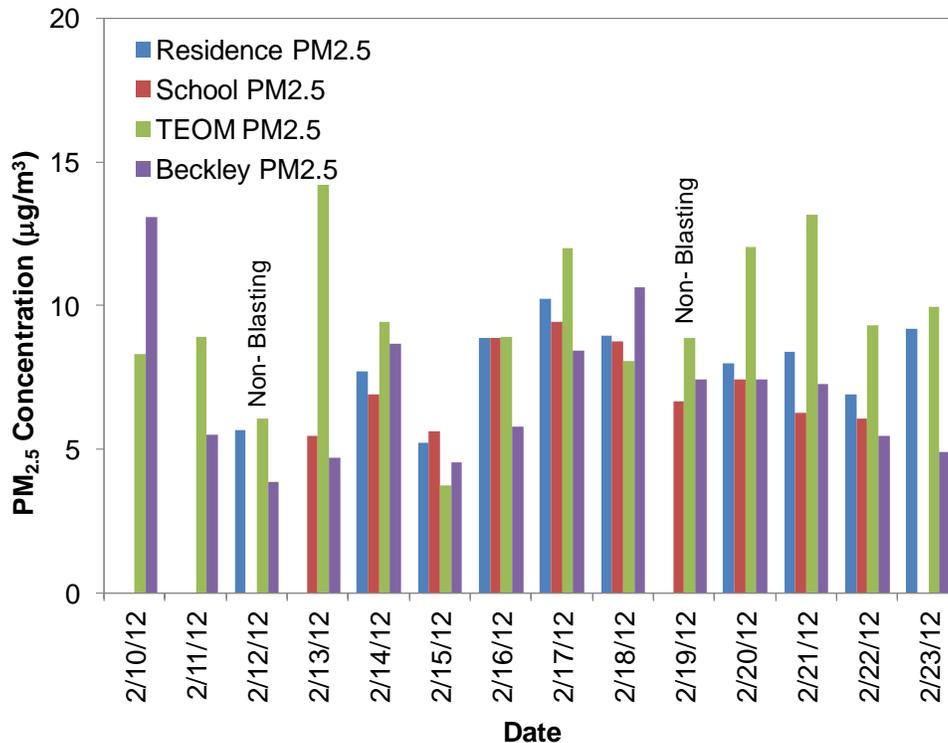


Figure 17. Daily PM_{2.5} concentrations from the residence and school sampling sites. Results from sampling conducted in Beckley are presented along with 23-hour averages from the TEOM operated at the residence sampling site. (Date shown is the end date for sampling).

3.3.5 Aethalometer

Figure 18 presents the hourly average results for both wavelength channels measured with the Aethalometer during the study period, and also indicates the occurrence of blasting events. In this figure the results for the 880 nm channel are labeled as soot and the 370 nm channel results are labeled UVPM. In general, the results were higher for the UVPM channel than for the soot channel, indicating the presence of UV-absorbing organic compounds, and both channels typically showed concentrations below $\sim 1 \mu\text{g}/\text{m}^3$. No correspondence of soot or UVPM readings with blasting events is apparent. Spikes in the measured concentrations typically occurred during overnight periods or during the early morning (i.e., before 9 a.m.) and may be attributable to local wood burning. For example, the largest spike in the data occurred on February 13 at approximately 8:10 am, and cannot be attributed to any blasting in the two permit areas. All but one of the 12 episodes in which one or both of the Aethalometer channels had an average hourly reading above $3 \mu\text{g}/\text{m}^3$ occurred between 11:00 p.m. and 9:00 a.m. Of those 12 episodes, only two occurred within 1 hour of a blast. Table 14 presents the daily average concentrations for the two channels throughout the study period and shows that the maximum daily average for the two channels was $1.16 \mu\text{g}/\text{m}^3$ for the soot channel and $1.59 \mu\text{g}/\text{m}^3$ for the UVPM channel. These results indicate a small contribution of organic compounds to the light absorption at 370 nm.

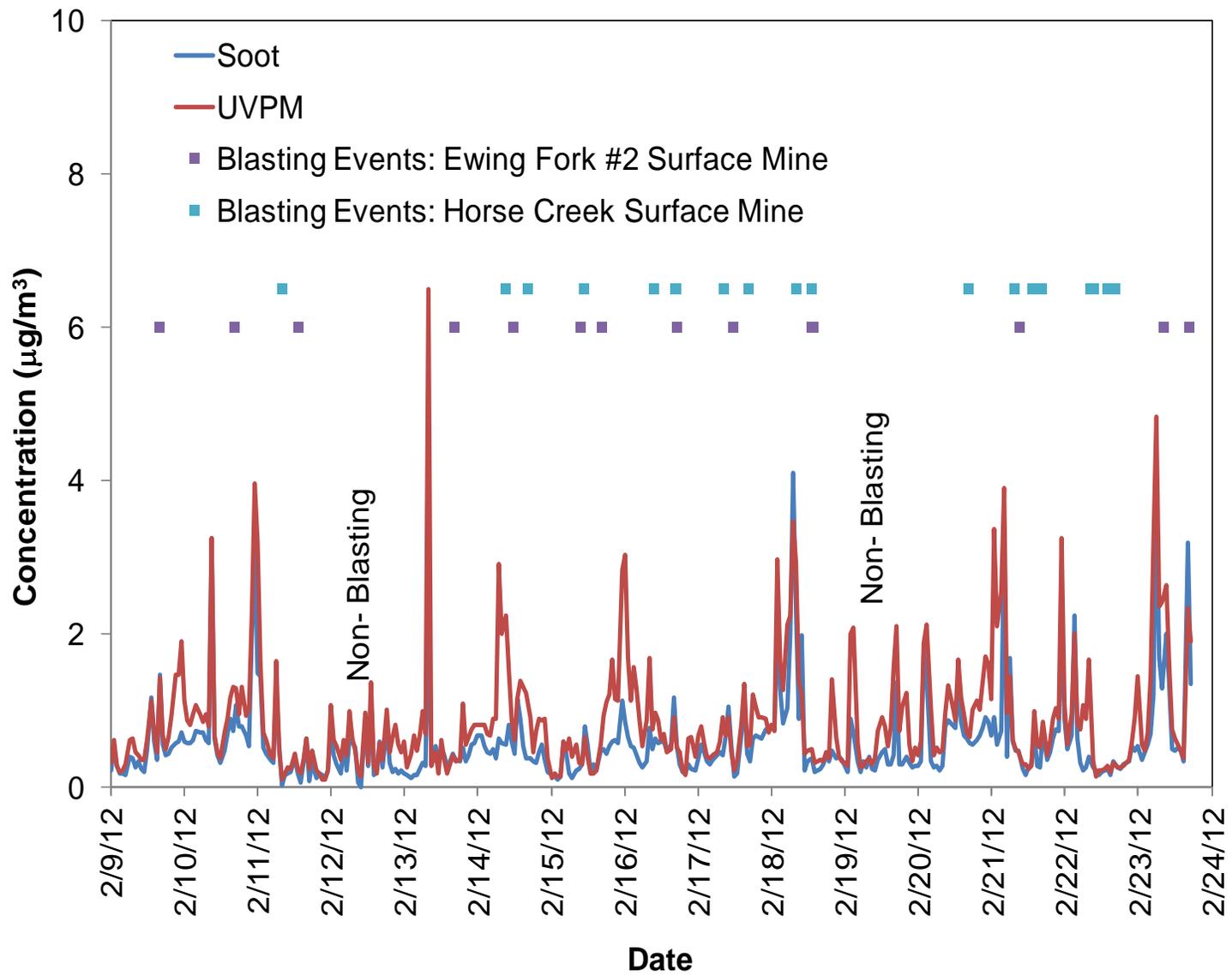


Figure 18. Hourly average soot and UVPM measurements during study period.

Table 14. Daily Average Soot and UVPM Measurements during Study Period

Date	Concentration ($\mu\text{g}/\text{m}^3$)	
	Soot	UVPM
2/9/12	0.46	0.69
2/10/12	0.92	1.20
2/11/12 (Non-Blasting)	0.41	0.55
2/12/12	0.40	0.58
2/13/12	0.43	0.77
2/14/12	0.53	1.08
2/15/12	0.39	0.67
2/16/12	0.49	0.89
2/17/12	0.54	0.69
2/18/12 (Non-Blasting)	0.93	1.13
2/19/12	0.40	0.79
2/20/12	0.70	1.04
2/21/12	0.75	1.17
2/22/12	0.43	0.61
2/23/12	1.16	1.59

3.4 Continuous CO

Figure 19 and Figure 20 present the hourly average CO measurements at the residence sampling site and school, respectively. Table 15 presents the daily average CO concentrations at the two sites. Note that during the first week of testing, the data logger at the school site logged only integer units for the CO concentration. Consequently, since the CO concentrations were below 1 ppm throughout the study period the resolution of the recorded data masks the actual CO concentrations. In general the measured CO concentrations were very low and showed no clear evidence of impacts from blasting events. These results are consistent with the results reported in the WV DEP Annual Air Quality Report for 2010. For example, the highest 1-hour average CO concentration reported in West Virginia during 2010 was 1.8 ppm, and the highest 8-hour average concentration was 0.9 ppm. For reference, the 1-hour NAAQS limit for CO is 35 ppm, and the 8-hour standard is 9 ppm. Inspection of the site visit records suggests that many of the abrupt changes in the concentrations corresponded to site visits and may have been the result of the CO monitor's sensitivity to temperature changes in the shelters when the shelters were opened to check on the continuous monitors.

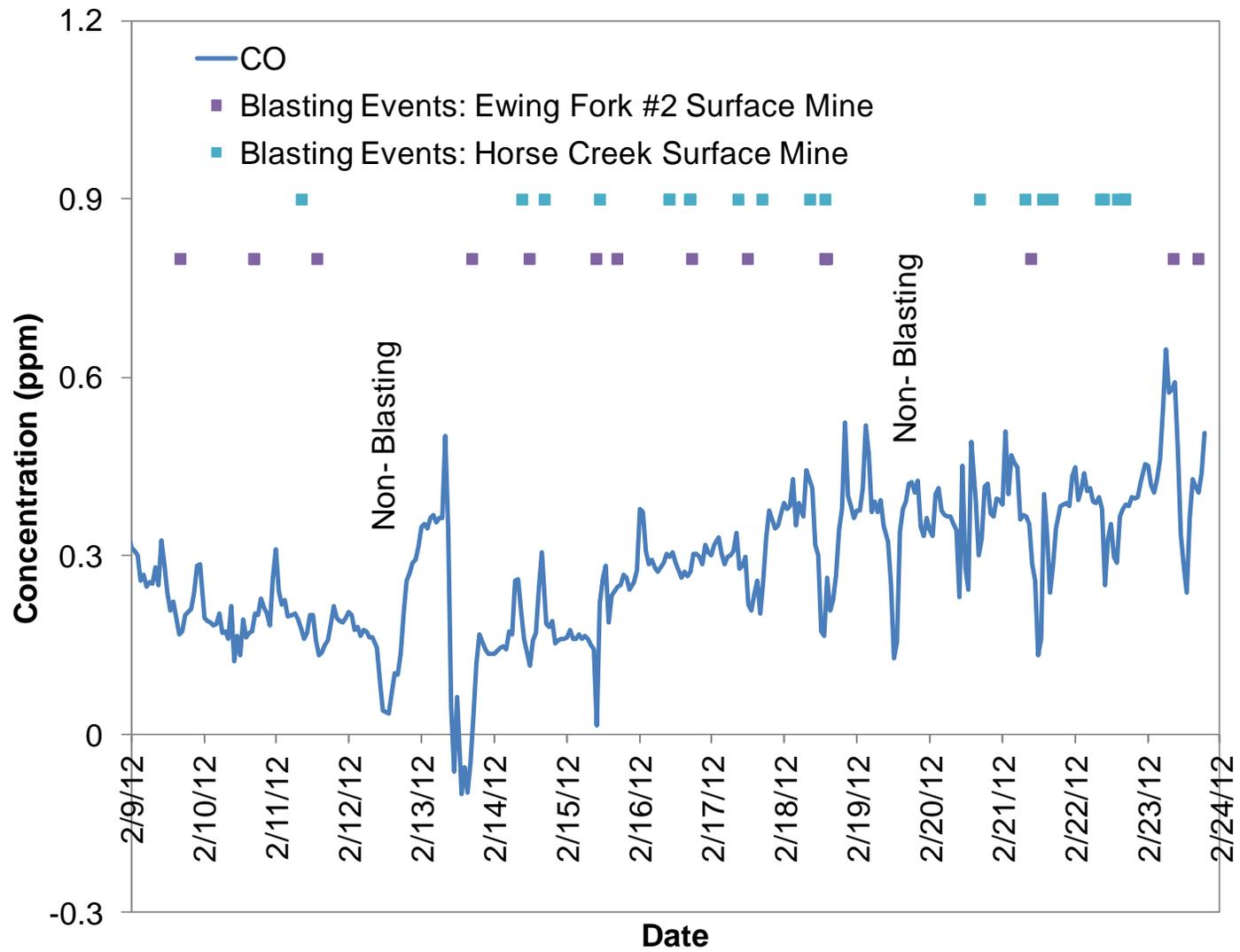


Figure 19. Hourly average CO measurements at the residence sampling site.

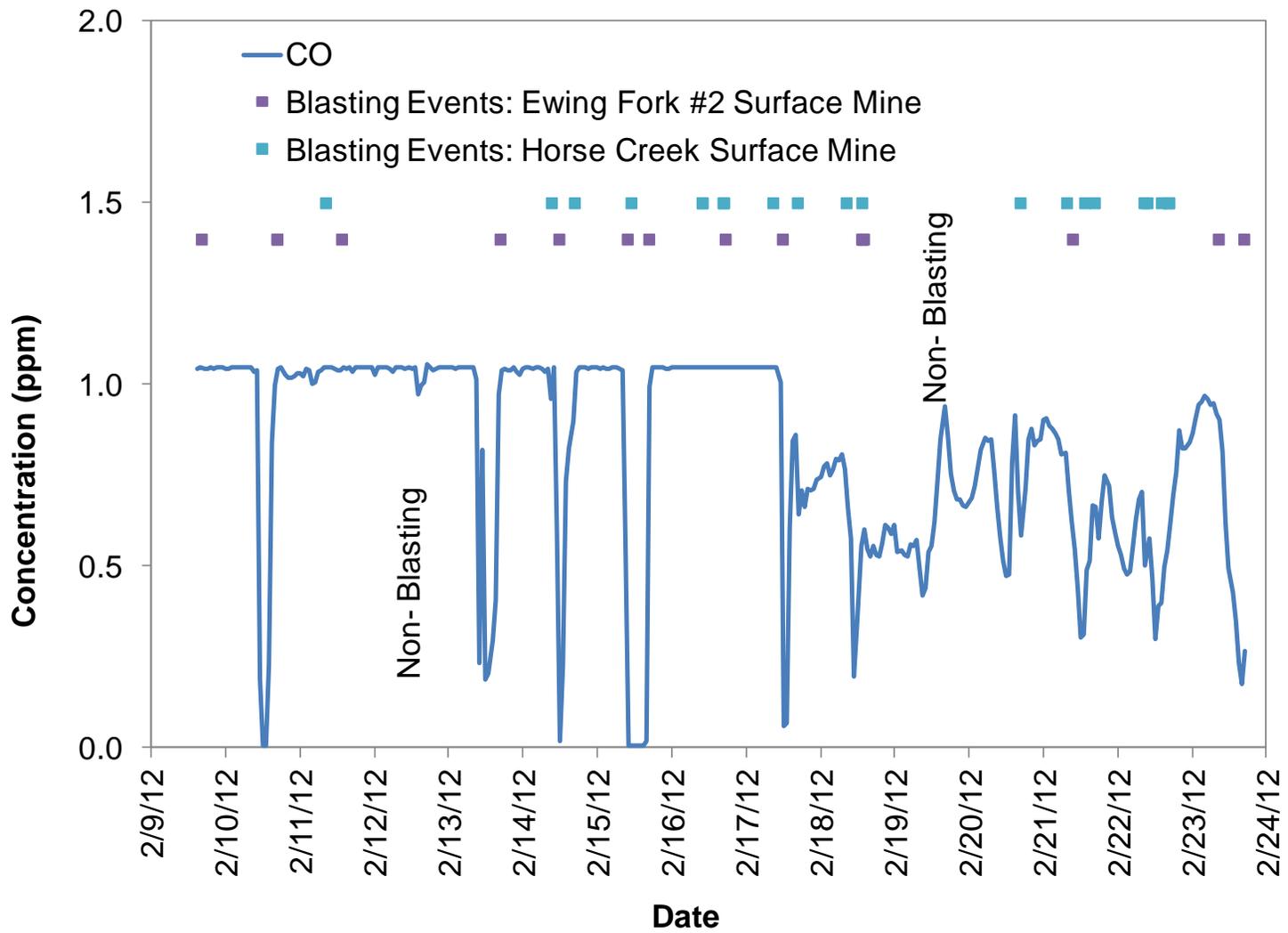


Figure 20. Hourly average CO measurements at the school sampling site.

Table 15. Daily Average CO Concentrations during Study Period

Date	Concentration (ppm)	
	Residence	School
2/9/12	0.23	1.04
2/10/12	0.19	0.87
2/11/12 (Non-Blasting)	0.19	1.04
2/12/12	0.17	1.04
2/13/12	0.18	0.87
2/14/12	0.18	0.91
2/15/12	0.20	0.72
2/16/12	0.30	1.04
2/17/12	0.30	0.83
2/18/12 (Non-Blasting)	0.35	0.62
2/19/12	0.36	0.63
2/20/12	0.36	0.73
2/21/12	0.36	0.67
2/22/12	0.38	0.59
2/23/12	0.45	0.70

3.5 Continuous NO_x/Total Nitrate/Passive NO₂/NH₃

Figure 21 and Figure 22 present the hourly average measurements of NO, NO₂, and NO_x during the study period at the residence and at the school sampling sites, respectively. Table 16 shows the daily average values of NO, NO₂, and NO_x at these sites, averaged over the 23-hour sampling periods corresponding to the total nitrate filter pack collection times. For reference, the 1-hour and annual NAAQS levels for NO₂ are 100 ppb and 53 ppb, respectively. The NO₂ data at the two sites are clearly well below the NAAQS levels. In addition, the NO, NO₂, and NO_x levels shown in Figure 21 and Figure 22 do not show a consistent relation to the occurrence of blasting events.

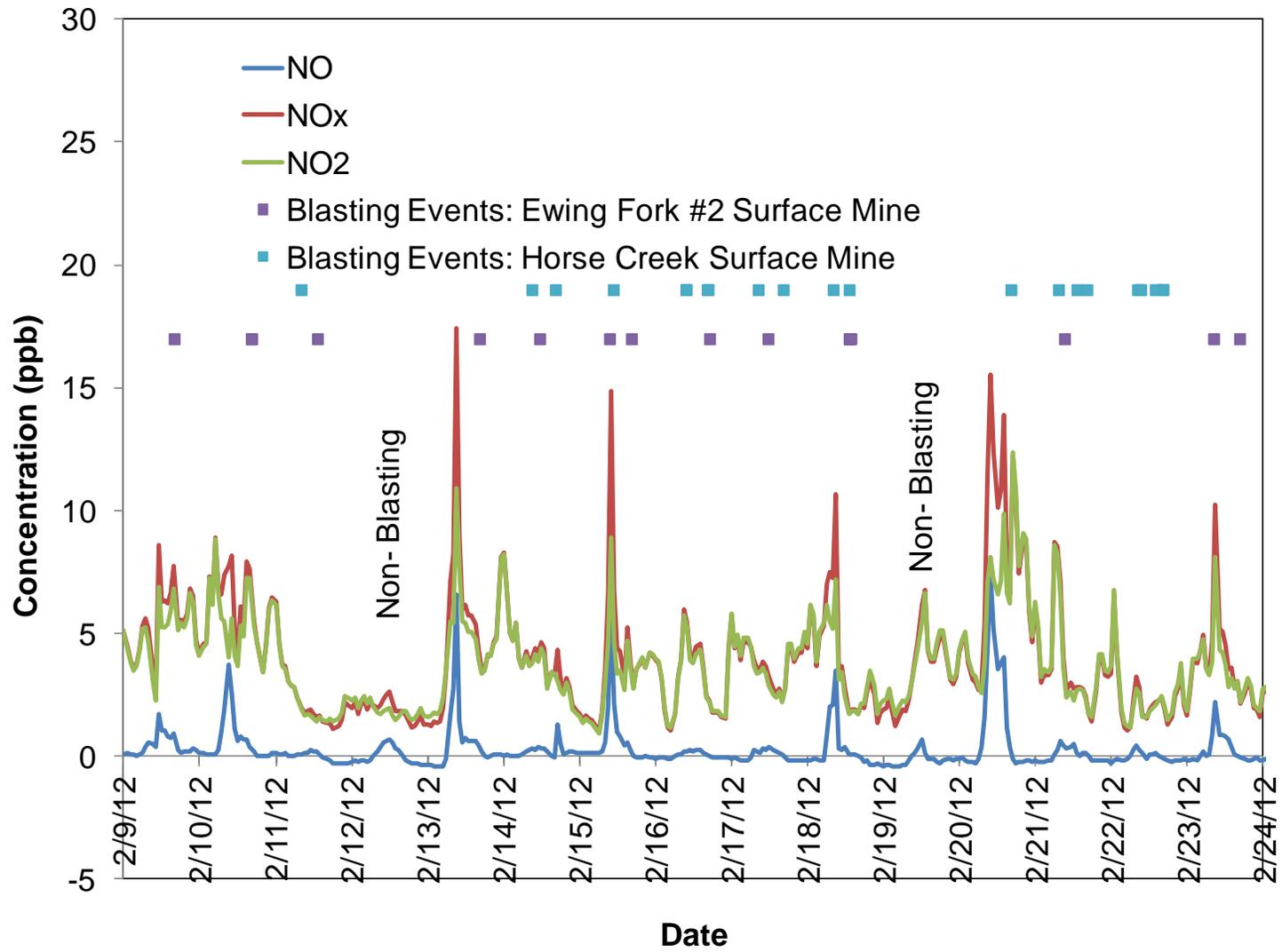


Figure 21. Hourly average measurements for NO, NO₂, and NO_x at the residence sampling site.

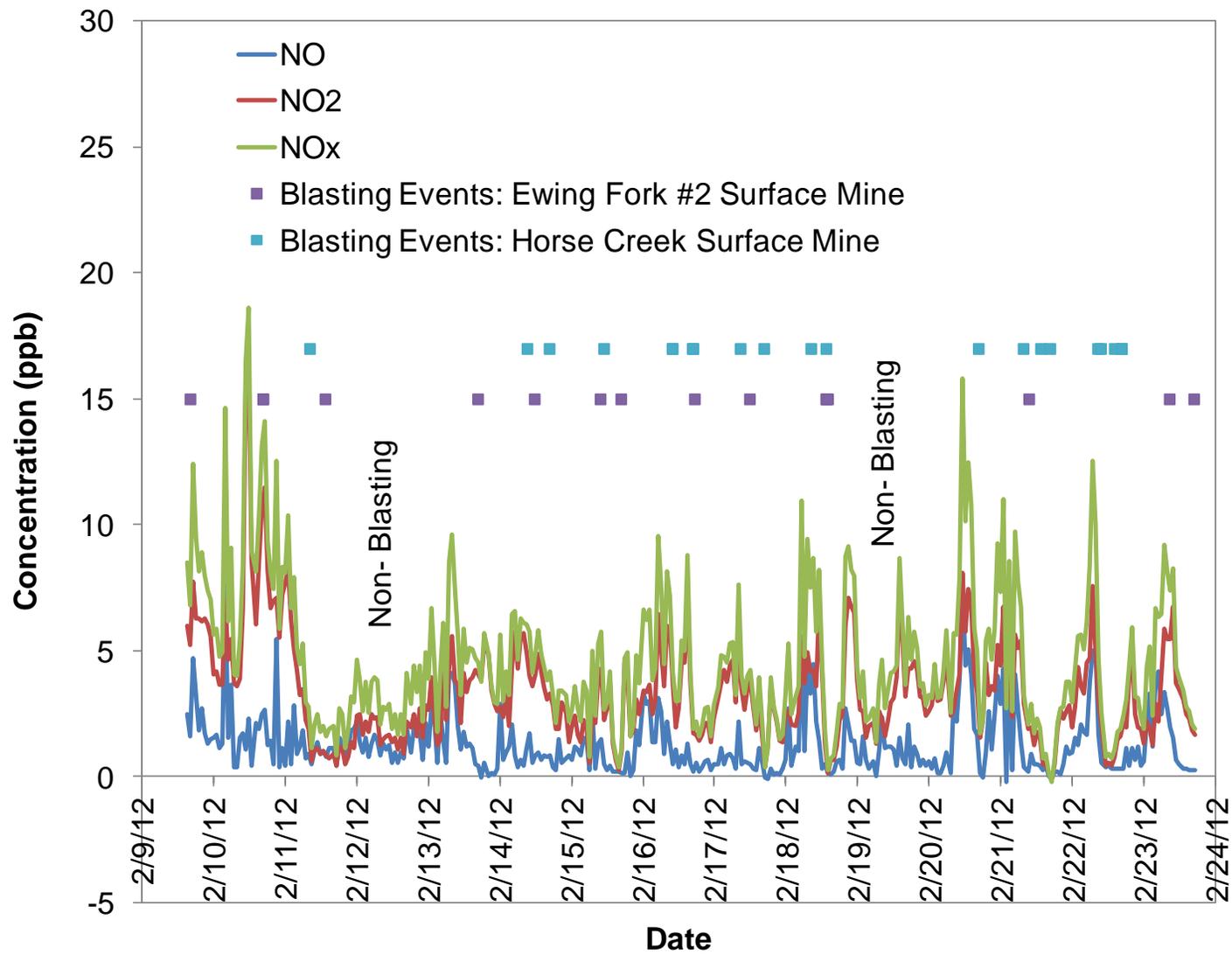


Figure 22. Hourly average measurements for NO, NO₂, and NO_x at the school sampling site.

Table 16. Daily Average NO/NO₂/NO_x Concentrations during Study Period

Date	Residence			School		
	NO (ppb)	NO ₂ (ppb)	NO _x (ppb)	NO (ppb)	NO ₂ (ppb)	NO _x (ppb)
2/9/12	0.7	5.5	6.2	1.8	6.1	7.9
2/10/12	0.0	2.9	3.0	1.9	7.0	8.9
2/11/12 (Non-Blasting)	0.0	1.9	1.9	1.2	2.3	3.5
2/12/12	0.5	3.7	4.2	1.3	1.9	3.1
2/13/12	0.2	4.4	4.6	1.4	3.5	4.9
2/14/12	0.6	2.8	3.5	0.9	3.5	4.5
2/15/12	0.0	3.4	3.4	0.8	2.3	3.0
2/16/12	0.0	3.4	3.4	1.2	3.5	4.7
2/17/12	0.3	4.1	4.4	0.5	2.9	3.4
2/18/12 (Non-Blasting)	-0.2	3.3	3.1	1.6	3.5	5.1
2/19/12	1.2	5.6	6.8	0.9	3.2	4.1
2/20/12	0.0	4.6	4.6	2.0	4.0	6.0
2/21/12	0.0	2.6	2.6	1.1	2.6	3.7
2/22/12	0.2	3.4	3.7	1.3	2.8	4.1
2/23/12	-0.1	2.3	2.4	1.7	3.2	4.8

Table 17 presents the results of the daily average concentrations of nitrate determined from the 23-hour filter pack samples. The nitrate results have been corrected for a positive bias observed in the field blank results that was equivalent to approximately 0.8 µg/m³. The 23-hour samples at the two sites were generally closely similar to each other on individual days. The average corrected nitrate concentrations were between 0.1 and 1.6 µg/m³ at the residence sampling site and between 0.1 and 1.2 µg/m³ at the school. It should be noted that these nitrate measurements do not differentiate between gaseous nitric acid (HNO₃) and particulate nitrate.

The 3-hour nitrate sample results are presented in Table 18 and have also been blank corrected. After correction, only nine samples had results that exceeded the field blank results, which were equivalent to approximately 5.8 µg/m³. These results potentially suggest somewhat higher short term nitrate concentrations during the 3-hour sampling periods than the overall 23-hour sampling periods. The results showed somewhat higher concentrations at the school relative to the concentrations at the residence on three of the five days when the short term results were detectable. On the other two days with detectable measurements, the concentrations at the two sites were approximately equal.

Table 17. Daily Average Nitrate Concentrations Measured During Study Period

End Date	Nitrate Concentration ($\mu\text{g}/\text{m}^3$)	
	Residence	School
2/10/12	1.5	0.6
2/11/12	1.1	0.5
2/12/12 (Non-Blasting)	0.3	0.8
2/13/12	0.6	0.6
2/14/12	0.2	0.2
2/15/12	0.2	0.2
2/16/12	0.1	0.1
2/17/12	1.6	1.2
2/18/12	0.4	0.5
2/19/12 (Non-Blasting)	1.0	0.8
2/20/12	1.0	0.7
2/21/12	0.5	0.4
2/22/12	0.3	0.3
2/23/12	0.6	0.3

Table 18. Short Term (3-Hour) Nitrate Concentrations Measured During Study Period

Date	Nitrate Concentration ($\mu\text{g}/\text{m}^3$)	
	Residence	School
2/10/12	ND	NS
2/11/12	ND	NS
2/12/12 (Non-Blasting)	ND	NS
2/13/12	ND	NS
2/14/12	ND	NS
2/15/12	ND	ND
2/16/12	ND	ND
2/17/12	1.6	3.8
2/18/12	0.4	2.6
2/19/12 (Non-Blasting)	2.2	1.9
2/20/12	0.7	0.5
2/21/12	ND	ND
2/22/12	ND	4.0

ND - Not detected above field blank results.

NS - No sample.

Table 19 presents the measured ammonium concentrations from the 23-hour samples. It should be noted that these ammonium measurements do not differentiate between gaseous ammonia (NH₃) and particulate ammonium. Field blank samples showed no evidence of ammonium contamination. Measurable amounts of ammonium were detected in all but one of the samples. The measured concentrations at the two sites are similar on individual days and ranged from 0.4 to 3.1 µg/m³ at the residence sampling site and from 0.8 to 2.7 µg/m³ at the school.

Table 19. Daily Average Ammonium Concentrations Measured During Study Period

End Date	Ammonium Concentration (µg/m ³)	
	Residence	School
2/10/12	2.0	1.6
2/11/12	< 0.3	1.1
2/12/12 (Non-Blasting)	0.4	0.8
2/13/12	1.3	1.1
2/14/12	1.6	1.0
2/15/12	1.6	0.8
2/16/12	1.4	1.5
2/17/12	3.1	2.7
2/18/12	2.9	2.6
2/19/12 (Non-Blasting)	2.8	2.5
2/20/12	2.2	1.5
2/21/12	1.9	1.4
2/22/12	1.9	1.5
2/23/12	2.5	1.7

Table 20 presents the 3-hour ammonium results. These results show only two episodes in which ammonium was detected above the method detection limit in the short term samples, i.e., at the school on February 12 and 22. The higher detection limits for the 3-hour samples was the result of the shorter sampling time. The highest concentration was measured at the school in the sample collected on February 22, which also showed the highest measured 3-hour nitrate concentration. The collection of this sample was initiated at 9:48 a.m., which was approximately 20 minutes after a blasting event in the Horse Creek Surface Mine permit area. During this period, the winds measured at the mine site were from the east, northeasterly direction, which would transport pollutants approximately in the direction of the school. However, the winds measured at school during that period were from the southwest, in approximately the opposite direction. Thus it is not clear that the measured concentrations can be attributed to blasting activities.

Table 20. Short Term (3-Hour) Ammonium Concentrations Measured During Study Period

Date	Ammonium Concentration ($\mu\text{g}/\text{m}^3$)	
	Residence	School
2/10/12	< 2.2	NS
2/11/12	< 1.7	NS
2/12/12 (Non-Blasting)	< 0.9	NS
2/13/12	< 2.2	NS
2/14/12	< 1.6	NS
2/15/12	< 7.0	<1.5
2/16/12	< 2.3	<1.6
2/17/12	< 5.9	7.5
2/18/12	< 5.5	< 4.3
2/19/12 (Non-Blasting)	< 5.5	< 5.0
2/20/12	< 6.1	< 4.2
2/21/12	< 3.6	< 1.4
2/22/12	< 4.5	15.1

NS - No sample.

In addition to the active sampling for nitrate and ammonium, integrated passive samples were collected for NO_2 and NH_3 using Ogawa samplers. The passive samplers were placed at the primary and secondary sites and at other locations in the Clear Fork community as shown in Figure 1. The samples were collected for approximately 72 hours, with the exception of the background samples which were composited over two 24 hour Sunday periods over successive weekends. Field blanks were collected at a rate of one for each type of passive sampler at each passive sampling site. The field blank sampling media were installed in the sampler, and promptly removed and placed in uniquely labeled vials for storage until shipment to the laboratory. The field blank samples showed no detectable NO_2 or NH_3 , indicating no evidence of contamination from sample handling activities.

With the exception of a single sample, none of the passive samples contained detectable amounts of NH_3 . It is likely that at the ambient temperatures experienced during the study period, any ammonia present was in the form of particulate ammonium rather than gaseous NH_3 . It is not clear how effective the passive samplers were at collecting particulate ammonium species. Table 21 presents a summary of the passive NO_2 measurements during the study period. For comparison, the corresponding averaged NO_2 results from the continuous $\text{NO}/\text{NO}_2/\text{NO}_x$ analyzers at the residence sampling site and school are also shown parenthetically. In general, the NO_2 results from the passive samplers were similar to those from the continuous analyzers, considering the relatively low concentrations measured. The samples collected during the two background periods tended to indicate somewhat lower NO_2 concentrations than during the other sampling periods. However this difference might be attributable to reduced emissions from other

NO_x sources (e.g., motor vehicles) on Sundays, rather than to the absence of blast emissions. The relatively narrow range of measured concentrations between sites does not suggest a strong spatial variability of NO₂ within the study area.

Table 21. Summary of Passive NO₂ Measurements (ppb)

Sampling Period	Detection Limit	Sampling Site					
		School ^a	Residence ^a	Passive Site 1	Passive Site 2	Passive Site 3	Passive Site 4
Non-Blasting 2/11/12-2/13/12 & 2/18/12-2/19/22	1.1	3.6 (3.0)	1.9 (3.2)	2.8	3.8	4.2	b
2/9/12-2/11/12	1.1	b (4.3)	4.1 (3.9)	2.4	5.3	5.6	5.9
2/13/12-2/16/12	0.8	5.1 (3.2)	4.2 (3.9)	5.3	4.8	3.8	4.5
2/16/12-2/18/12	0.8	4.3 (2.9)	6.9 (3.9)	b	4.9	4.1	<0.8
2/19/12-2/22/12	0.8	3.0 (3.2)	4.3 (4.8)	6.0	4.5	3.9	3.4

a: Values in parentheses are averages of continuous monitor data over passive sampling periods.

b: Missing sample.

3.6 Particulate Metals Concentrations

A subset of the PM₁₀ filters collected during the study period was analyzed for metals content. This subset included samples collected at the residence and school sampling sites on days when the measured TSP, PM₁₀, or PM_{2.5} concentrations were elevated with respect to other days or with respect to the other sampling site. The samples collected from February 9 to 10 were analyzed because of the elevated PM₁₀ concentrations observed which corresponded to the highest observed PM_{2.5} concentrations at the Beckley site. The samples collected from February 15 to 16 exhibited relatively high PM₁₀ concentrations at the residence but not at the school, suggesting a possibly localized source. These samples also exhibited somewhat elevated PM_{2.5} concentrations at the residence and the school relative to the Beckley site, suggesting a possible community-scale source. The samples collected from February 20 to 21 and from February 12 to 22 were analyzed because both days were characterized by relatively high concentrations of TSP, PM₁₀, and PM_{2.5}. The samples collected from February 18 to 19 were analyzed to characterize metals concentrations on non-blasting days.

The calculated airborne concentrations of the metals in the samples collected at the residence sampling site and the school are presented in Table 22 and Table 23, respectively. Included in these tables are the method detection limit (MDL) for each metal and the results of the field blank sample, both presented in terms of airborne concentrations assuming a 23 m³ sample volume. The field blank sample showed some evidence of elevated levels of aluminum, silicon, iron, and chromium. The sample results have not been corrected for the field blank, and show concentrations of the common crustal metals (Mg, Al, Si, Ca, Fe) that range from tens to hundreds of ng/m³. The concentrations of the toxic metals (Cr, Mn, Cu, Zn, Pb) are rarely more than 5 ng/m³ above the field blank. None of the samples analyzed shows concentrations of the

Table 22. Summary of Metals Analysis at Residence

Metal	Concentration (ng/m ³)							R _f C _i (ng/m ³)	Accute Toxicity Level (ng/m ³)
	MDL ^a	Field Blank ^a	2/9/12 2/10/12	2/15/12 2/16/12	2/18/12- 2/19/12(Non- Blasting)	2/20/12 2/21/12	2/21/12 2/22/12		
Mg	22	ND	41	24	54	35	74	NA	NA
Al	8.3	145	171	109	109	138	183	3,000 (b)	3x10 ⁶ (c)
Si	8.0	64	104	66	99	56	211	NA	NA
Ca	385	202	342	323	520	430	585	NA	NA
Cr	0.7	17	20	21	20	17	19	100 (d)	NA
Fe	18	157	215	221	307	256	375	NA	6x10 ⁶ (c)
Mn	0.07	0.5	2.1	2.0	4.8	2.9	4.6	50 (d)	1.7x10 ³ (e)
Cu	0.07	ND	11	2.0	8.5	3.5	10	4x10 ⁴ (b)	1x10 ⁵ (f)
Zn	6.5	7.1	19	12	21	12	15	3x10 ⁵ (b)	3x10 ⁶ (c)
Pb	0.06	ND	2.3	1.0	2.8	1.7	1.4	NA	1.5x10 ⁵ (c)

a: Assumes a sample volume of 23 m³.

b: U.S. EPA Region 9 Regional Screening Levels. Available at www.epa.gov/region9/superfund/prg/

c: U.S Department of Energy 15-Minute Temporary Emergency Exposure Limits (TEELs)

d: U.S. EPA Integrated Risk Information System (IRIS). Available at: www.epa.gov/iris/

e: California EPA 8-hour Reference Exposure Limit (REL)

f: California EPA 1-hour (REL)

ND: Not detected

NA: Data not available

Table 23. Summary of Metals Analysis at School

Metal	Concentration (ng/m ³)							R _f C _i (ng/m ³)	Accute Toxicity Level (ng/m ³)
	MDL ^a	Field Blank ^a	2/9/12 2/10/12	2/15/12 2/16/12	2/18/12- 2/19/12(Non- Blasting)	2/20/12 2/21/12	2/21/12 2/22/12		
Mg	22	ND	43	28	36	65	40	NA	NA
Al	8.3	145	126	135	123	155	182	3,000 (b)	3x10 ⁶ (c)
Si	8.0	64	76	99	55	194	122	NA	NA
Ca	385	202	369	276	340	425	332	NA	NA
Cr	0.7	17	16	20	14	19	20	100 (d)	NA
Fe	18	157	276	221	227	351	289	NA	6x10 ⁶ (c)
Mn	0.07	0.5	2.9	2.3	3.6	4.5	3.4	50 (d)	1.7x10 ³ (e)
Cu	0.07	ND	7.2	2.2	8.3	2.6	12	4x10 ⁴ (b)	1x10 ⁵ (f)
Zn	6.5	7.1	15	11	13	13	13	3x10 ⁵ (b)	3x10 ⁶ (c)
Pb	0.06	ND	2.4	1.0	2.4	1.5	1.6	NA	1.5x10 ⁵ (c)

a: Assumes a sample volume of 23 m³.

b: U.S. EPA Region 9 Regional Screening Levels. Available at www.epa.gov/region9/superfund/prg/

c: U.S Department of Energy 15-Minute Temporary Emergency Exposure Limits (TEELs)

d: U.S. EPA Integrated Risk Information System (IRIS). Available at: www.epa.gov/iris/

e: California EPA 8-hour Reference Exposure Limit (REL)

f: California EPA 1-hour (REL)

ND: Not detected

NA: Data not available

measured metals that are substantially different from the other samples. Where available, the chronic inhalation reference concentration (R_fC_i) for these metals is shown. The R_fC_i is a toxicological estimate of the daily inhalation exposure that is likely to be without an appreciable risk of deleterious effects during a lifetime. In all cases where the R_fC_i is available the measured metals concentrations were well below the chronic toxicity value. Acute toxicity levels are also included in these tables since exposure to emissions from blasting would likely be acute in nature. The values shown represent maximum safe exposure levels for the given time periods (e.g., 15-minutes, 1-hour, 8-hour). In all cases, the integrated 24-hour concentrations are well below the acute exposure limits, even when accounting for the difference in the timescales for the sample collection period (e.g., 23-hours) and the exposure limits (e.g., 15-minutes, 1-hour, and 8-hours).

3.7 VOCs

A subset of the canister samples collected during the study period was analyzed for VOC content. The samples that were analyzed included samples collected on days when no blasting events occurred (February 19) in order to characterize representative “background” conditions as well as samples whose collection times overlapped blasting events (February 14, 18, and 21). Additionally, the samples collected on February 23, which did not overlap blasting events, were analyzed to assess whether VOC concentrations on blasting days differed substantially from those of non-blasting days (e.g., February 19). Table 24 summarizes the times of sample collection for the samples that were analyzed, along with the blasting events that occurred on the corresponding days.

Table 24. Summary of Canister Collection Times and Blasting Events

Date	Canister Collection		Blasting Events
	Residence	School	
2/14/12	10:37 - 14:02	10:02 - 13:12	9:03 11:29 16:28
2/18/12	10:32 - 13:21	10:12 - 12:55	8:14 13:17 13:18 13:51
2/19/12	10:31 - 13:27	10:04 - 13:05	Non-Blasting
2/21/12	10:48 - 13:48	10:28 - 13:27	7:25 9:19 13:16 16:24
2/23/12	9:15 - 12:15	10:04 - 13:34	8:25 16:38

Of the 69 individual VOCs measured, detectable levels were measured in at least one sample for only 25 of the compounds. Table 25 presents a summary of the method detection limits for the 44 VOCs that were not detected in any of the analyzed samples along with the chronic and acute toxicity levels for those compounds. For the 25 VOCs that were detected in at least one sample, the VOC results are presented Table 26 and Table 27 for the samples collected at the residence and school sites, respectively. The measured concentrations from a field blank sample are included in these tables for reference as are the compound specific chronic and acute toxicity levels. The blank results have not been subtracted from the sample results in Tables 26 and 27. In these tables, when a VOC was detected but could not be accurately quantified above the reporting limit, the result is presented as being below the reporting limit. The reporting limits are based on the lowest concentration standard used in the instrument calibration and are dependent upon the degree of sample dilution and therefore vary among the different samples.

Table 25. Detection Limits for VOC Analytes Not Detected in Any Sample

Analyte	MDL (ppb)	R _i C _i (ppb)	Acc. Tox. Level (ppb)
Propylene	0.02	5,200 (a)	1.5E+06 (b)
Freon-114	0.03	NA	1.1E+07 (b)
Vinyl chloride	0.03	260 (c)	7.1E+04 (d)
1,3-butadiene	0.03	4.4 (c)	6.7E+05 (e)
Methyl bromide	0.03	19 (c)	NA
Ethyl chloride	0.03	26,000 (c)	2.3E+05 (b)
1,1-dichloroethene (vinylidene chloride)	0.06	NA	7.4E+05 (b)
Carbon disulfide	0.02	2,200 (c)	2.0E+03 (d)
trans-1,2-dichloroethene (trans-1,2-dichloroethylene)	0.07	240 (a)	2.8E+05 (e)
1,1-dichloroethane	0.02	NA	7.4E+05 (b)
Methyl tert-butyl ether	0.01	11,000 (c)	5.0E+04 (e)
Vinyl acetate	0.03	700 (c)	6.7E+03 (e)
cis-1,2-dichloroethene (cis-1,2-dichloroethylene)	0.07	7.9 (a)	1.4E+05 (e)
Chloroform	0.02	97 (f)	3.1E+01 (d)
Tetrahydrofuran	0.02	NA	NA
1,2-dichloroethane	0.02	2,400 (f)	5.0E+04 (g)
1,1,1-trichloroethane (methyl chloroform)	0.05	27,000 (c)	1.2E+04 (d)
Cyclohexane	0.03	NA	NA
1,2-dichloropropane	0.02	18 (c)	2.2E+05 (b)
Bromodichloromethane	0.02	130 (a)	NA
Trichloroethene (trichloroethylene)	0.07	54 (a)	1.3E+05 (e)
1,4-dioxane	0.06	3,600 (f)	8.3E+02 (d)
cis-1,3-dichloropropene	0.03	91 (c)	1.3E+02 (b)
trans-1,3-dichloropropene	0.02	91 (c)	1.7E+04 (b)
1,1,2-trichloroethane	0.03	1.1 (a)	9.2E+04 (b)
Dibromochloromethane	0.02	170 (a)	NA
1,2-dibromoethane	0.02	69 (c)	NA
Tetrachloroethene	0.02	270 (f)	3.0E+03 (d)
Chlorobenzene	0.03	92 (a)	1.0E+04 (e)
Bromoform	0.05	210 (a)	NA
Styrene	0.03	4,300 (c)	4.9E+03 (d)
1,1,1,2-tetrachloroethane	0.05	NA	2.9E+03 (b)
4-ethyl toluene	0.03	NA	1.0E+05 (b)
Benzyl chloride	0.05	NA	NA
1,3-dichlorobenzene	0.05	NA	4.2E+03 (b)
1,2-dichlorobenzene	0.06	1,200 (a)	5.0E+04 (b)
1,2,4-trichlorobenzene	0.14	15 (a)	6.8E+02 (b)
Hexachlorobutadiene	0.07	NA	1.0E+03 (g)
Methanol	NA	NA	NA
Isoprene	0.01	NA	NA
Methyl methacrylate	0.02	2,900 (c)	1.7E+04 (e)
2-butoxyethanol	NA	NA	NA
Vinyl Bromide	NA	19 (c)	NA

a: U.S. EPA Region 9 Regional Screening Levels.

b: U.S. Department of Energy 15-Minute Temporary Emergency Exposure Limits (TEELs)

c: U.S. EPA Integrated Risk Information System (IRIS).

d: California EPA 1-hour Reference Exposure Limit (REL)

e: U.S. EPA 1-hour Acute Exposure Guideline Levels (AEGL-1)

f: Agency for Toxic Substances and Disease Registry (ASTDR) Chronic Minimal Risk Level (MRL)

g: American Industrial Hygiene Association (AIHA) 1-hour Emergency Response Planning Guidelines (ERPG)

Table 26. Summary of VOC Measurements at Residence

Compound	Concentration (ppb)							R _f C _i (ppb)	Accute Toxicity Level (ppb)
	MDL	Field Blank	2/14/12	2/18/12	2/19/12 (Non-Blasting)	2/21/12	2/23/12		
Freon-12	0.04	ND	< 0.83	< 0.82	< 1.22	< 0.88	< 1.03	4.9E+02(a)	3.0E+06(b)
Methyl chloride	0.04	ND	< 0.83	< 0.82	< 1.22	< 0.88	< 1.03	1.9E+02(c)	9.7E+04(b)
Acrolein	0.07	ND	ND	< 1.65	< 2.43	< 1.76	< 2.06	0.0E+00(c)	1.1E+00(d)
Acetone	0.76	19.0	< 8.32	18.0	29.3	13.0	29.9	3.1E+04(f)	2.0E+05(e)
Freon-11	0.02	ND	< 0.83	< 0.82	< 1.22	< 0.88	< 1.03	3.9E+03(a)	8.9E+05(b)
Isopropyl alcohol	0.15	< 5	< 8.32	< 8.23	< 12.17	< 8.79	< 10.32	NA	NA
Methylene chloride	0.02	< 0.5	< 0.83	< 0.82	< 1.22	< 0.88	< 1.03	1.0E+03(f)	4.0E+03(d)
Freon-113	0.02	ND	ND	< 0.82	< 1.22	< 0.88	ND	2.3E+05(a)	1.3E+06(b)
2-butanone	0.11	10.0	ND	5.1	8.7	1.8	11.9	1.5E+04(c)	4.4E+03(d)
Ethyl acetate	0.03	ND	ND	ND	ND	ND	ND	NA	4.2E+05(b)
Hexane	0.01	< 0.5	1.2	1.0	< 1.22	< 0.88	< 1.03	2.5E+03(c)	4.3E+05(b)
Benzene	0.06	ND	< 1.66	< 1.65	< 2.43	< 1.76	< 2.06	9.6E+01(c)	4.1E+02(d)
Carbon tetrachloride	0.03	ND	< 0.83	< 0.82	< 1.22	< 0.88	< 1.03	6.3E+02(c)	3.0E+02(d)
Heptane	0.02	ND	ND	ND	ND	ND	ND	NA	3.7E+05(b)
Methyl isobutyl ketone	0.06	ND	ND	ND	ND	ND	< 1.03	1.2E+04(c)	7.3E+04(b)
Toluene	0.02	< 0.5	< 0.83	< 0.82	< 1.22	< 0.88	< 1.03	1.9E+04(c)	9.8E+03(d)
2-hexanone	0.02	< 0.5	ND	ND	ND	ND	< 1.03	8.8E+01(c)	9.8E+03(b)
Ethylbenzene	0.02	< 0.5	< 0.83	< 0.82	< 1.22	< 0.88	< 1.03	4.3E+03(c)	3.3E+04(e)
m&p-xylene	0.12	< 1	< 1.66	< 1.65	< 2.43	< 1.76	< 2.06	4.3E+02(c)	5.1E+03(d)
o-xylene	0.06	< 1	< 1.66	< 1.65	< 2.43	< 1.76	< 2.06	4.3E+02(c)	5.1E+03(d)
1,3,5-trimethylbenzene	0.03	ND	ND	< 0.82	< 1.22	< 0.88	ND	NA	1.4E+05(e)
1,2,4-trimethylbenzene	0.03	ND	ND	ND	ND	ND	ND	3.4E+01(a)	1.4E+05(e)
1,4-dichlorobenzene	0.05	ND	ND	ND	ND	ND	ND	4.8E+03(c)	1.0E+04(b)
Ethanol	0.64	< 5	< 8.32	< 8.23	< 12.17	< 8.79	47.3	NA	NA
Naphthalene	0.03	< 0.5	< 0.83	< 0.82	< 1.22	< 0.88	< 1.03	1.6E+01(c)	1.4E+04(b)

MDL = Method detection limit.

ND = Not detected.

a: U.S. EPA Region 9 Regional Screening Levels. Available at www.epa.gov/region9/superfund/prg/

b: U.S. Department of Energy 15-Minute Temporary Emergency Exposure Limits (TEELs)

c: U.S. EPA Integrated Risk Information System (IRIS).

d: California EPA 1-hour Reference Exposure Limit (REL)

e: U.S. EPA 1-hour Acute Exposure Guideline Levels (AEGL-1)

f: Agency for Toxic Substances and Disease Registry (ASTDR) Chronic Minimal Risk Level (MRL)

g: American Industrial Hygiene Association (AIHA) 1-hour Emergency Response Planning Guidelines (ERPG)

Table 27. Summary of VOC Measurements at School

Compound	Concentration (ppb)							R _f C _i (ppb)	Accute Toxicity Level (ppb)
	MDL	Field Blank	2/14/12	2/18/12	2/19/12 (Non-Blasting)	2/21/12	2/23/12		
Freon-12	0.04	ND	< 1.08	< 0.95	< 1.19	< 1.29	< 1.13	4.9E+02(a)	3.0E+06(b)
Methyl chloride	0.04	ND	< 1.08	< 0.95	< 1.19	< 1.29	< 1.13	1.9E+02(c)	9.7E+04(b)
Acrolein	0.07	ND	< 2.15	< 1.91	ND	< 2.58	ND	0.0E+00(c)	1.1E+00(d)
Acetone	0.76	19.0	23.4	20.8	29.3	26.1	29.0	3.1E+04(f)	2.0E+05(e)
Freon-11	0.02	ND	< 1.08	< 0.95	< 1.19	< 1.29	< 1.13	3.9E+03(a)	8.9E+05(b)
Isopropyl alcohol	0.15	< 5	< 10.76	< 9.54	< 11.93	< 12.88	< 11.34	NA	NA
Methylene chloride	0.02	< 0.5	< 1.08	< 0.95	< 1.19	< 1.29	< 1.13	1.0E+03(f)	4.0E+03(d)
Freon-113	0.02	ND	< 1.08	< 0.95	< 1.19	< 1.29	ND	2.3E+05(a)	1.3E+06(b)
2-butanone	0.11	10.0	8.8	7.9	12.6	6.2	18.0	1.5E+04(c)	4.4E+03(d)
Ethyl acetate	0.03	ND	< 1.08	1.8	ND	ND	ND	NA	4.2E+05(b)
Hexane	0.01	< 0.5	< 1.08	2.0	< 1.19	< 1.29	< 1.13	2.5E+03(c)	4.3E+05(b)
Benzene	0.06	ND	< 2.15	< 1.91	< 2.39	< 2.58	< 2.27	9.6E+01(c)	4.1E+02(d)
Carbon tetrachloride	0.03	ND	< 1.08	< 0.95	< 1.19	< 1.29	< 1.13	6.3E+02(c)	3.0E+02(d)
Heptane	0.02	ND	< 1.08	< 0.95	ND	ND	ND	NA	3.7E+05(b)
Methyl isobutyl ketone	0.06	ND	ND	ND	ND	ND	ND	1.2E+04(c)	7.3E+04(b)
Toluene	0.02	< 0.5	< 1.08	1.7	< 1.19	< 1.29	< 1.13	1.9E+04(c)	9.8E+03(d)
2-hexanone	0.02	< 0.5	ND	ND	ND	ND	< 1.13	8.8E+01(c)	9.8E+03(b)
Ethylbenzene	0.02	< 0.5	< 1.08	< 0.95	< 1.19	< 1.29	< 1.13	4.3E+03(c)	3.3E+04(e)
m&p-xylene	0.12	< 1	< 2.15	< 1.91	< 2.39	< 2.58	< 2.27	4.3E+02(c)	5.1E+03(d)
o-xylene	0.06	< 1	< 2.15	< 1.91	< 2.39	< 2.58	< 2.27	4.3E+02(c)	5.1E+03(d)
1,3,5-trimethylbenzene	0.03	ND	< 1.08	ND	ND	< 1.29	ND	NA	1.4E+05(e)
1,2,4-trimethylbenzene	0.03	ND	ND	< 0.95	ND	ND	ND	3.4E+01(a)	1.4E+05(e)
1,4-dichlorobenzene	0.05	ND	ND	< 0.95	ND	ND	ND	4.8E+03(c)	1.0E+04(b)
Ethanol	0.64	< 5	< 10.76	< 9.54	< 11.93	< 12.88	< 11.34	NA	NA
Naphthalene	0.03	< 0.5	< 1.08	< 0.95	< 1.19	< 1.29	< 1.13	1.6E+01(c)	1.4E+04(b)

MDL = Method detection limit.

ND = Not detected.

a: U.S. EPA Region 9 Regional Screening Levels.

b: U.S. Department of Energy 15-Minute Temporary Emergency Exposure Limits (TEELs)

c: U.S. EPA Integrated Risk Information System (IRIS).

d: California EPA 1-hour Reference Exposure Limit (REL)

e: U.S. EPA 1-hour Acute Exposure Guideline Levels (AEGL-1)

f: Agency for Toxic Substances and Disease Registry (ASTDR) Chronic Minimal Risk Level (MRL)

g: American Industrial Hygiene Association (AIHA) 1-hour Emergency Response Planning Guidelines (ERPG)

Tables 26 and 27 show that the concentrations of toxic VOCs, which included chlorinated hydrocarbons such as methylene chloride, aromatic compounds such as benzene, and polar compounds such as acrolein, were uniformly low at both sampling sites. Almost all measured concentrations of these VOCs were less than 1 ppb, and showed no dependence on the sampling site or the occurrence of blasting events. In many cases, the measured concentrations of these toxic VOCs at the two sampling sites were similar to the corresponding concentrations measured in the field blank. Relatively innocuous polar VOCs such as isopropyl alcohol and ethanol were also found in all samples and in the VOC field blank at concentrations of several ppb. The presence of those VOCs is believed to be due to contamination during humidification in preparing the sampling canisters, and the data do not indicate VOC concentrations in ambient air. Also, all the measured concentrations were well below the chronic and acute toxicity levels.

3.8 Microscopy/Chemical Analysis of Particles

Several of the passive substrates used to collect deposited particles were analyzed by microscopy to characterize individual particles. Generally, the particle loading (in terms of particles per unit substrate area) on the substrates was very light. The three panels in Figure 23 show three different images of separate regions of a substrate collected on one of the background days. These images each show a variety of particles that range in size up to ~50 μm in size. Chemical analysis was performed on a subset of the larger particles using energy dispersive X-ray (EDX) analysis to identify potential sources. Many of the particles showed strong signatures for one or more of the crustal elements including Al, Si, Ca, K, and Fe. Additionally, strong signatures for Cl or S were observed in a number of the particles analyzed. All of the particles showed a strong carbon and oxygen signature; however, since the substrate is carbonaceous the observed signatures may include stray results from the substrate. For each of the particles analyzed, the noteworthy element(s) identified in the EDX signature are identified on the images. Of the particles, with crustal signatures, Ca tended to be the most abundant species in the signatures for the background sample.

Figure 24 and Figure 25 show images of particles collected at the residence sampling site on February 22 during the morning and the afternoon, respectively. Overall, there were fewer particles on these substrates than on the background substrates. However, the particles on these substrates that had signatures of crustal elements tended to have a higher silicon signature than the particles analyzed on the background sample, which tended to have a higher calcium signature.

3.9 Investigation of Individual Case Studies

The preceding summaries of the ambient monitoring data do not show elevated levels of any of the measured air pollutants that appear to be correlated with the occurrence of blasting events, or that are out of the ordinary for locations similar to the sampling sites. However, the blasting events are very short in duration, and air quality impacts of such events may be overlooked if only average data are considered. Consequently, a more focused investigation has been conducted to see if air quality impact of individual blasting events can be detected in the monitoring data.

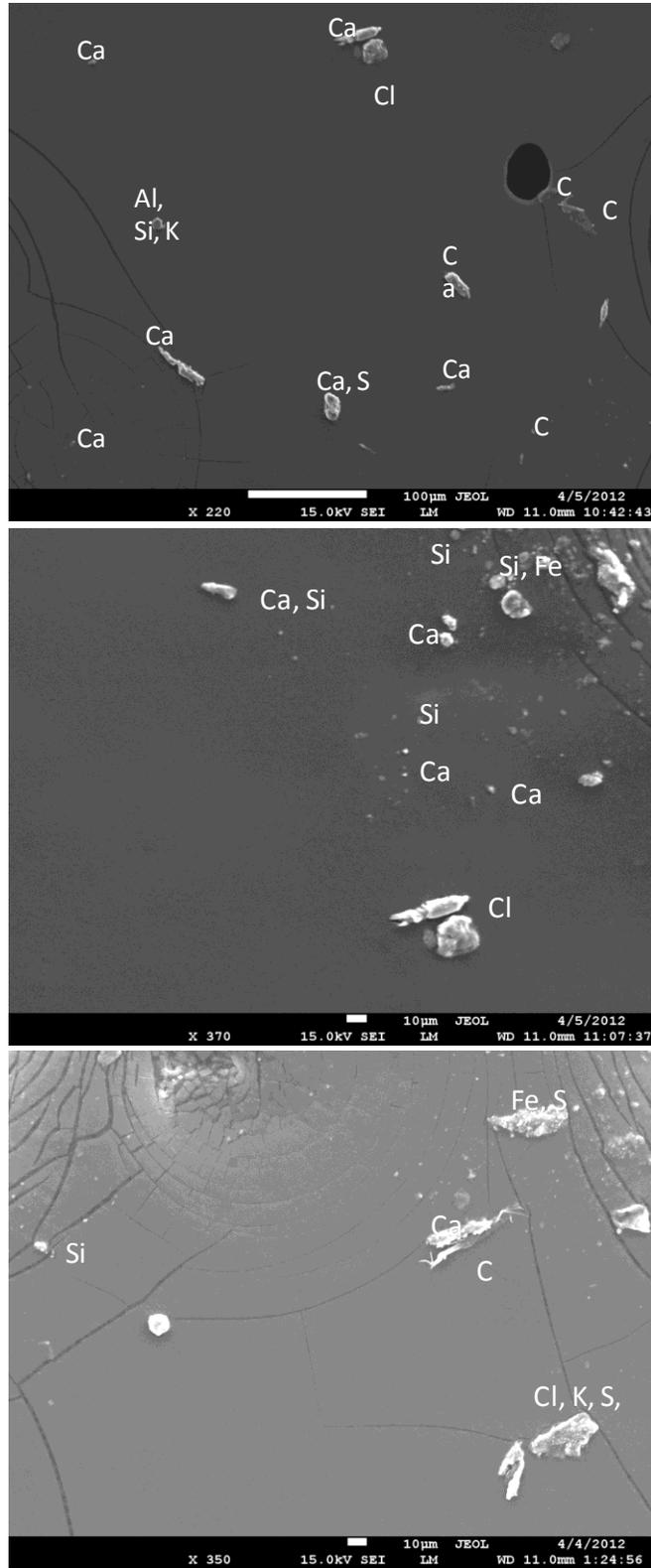


Figure 23. Microscopic images of particles collected on a substrate collected on a non-blasting day.

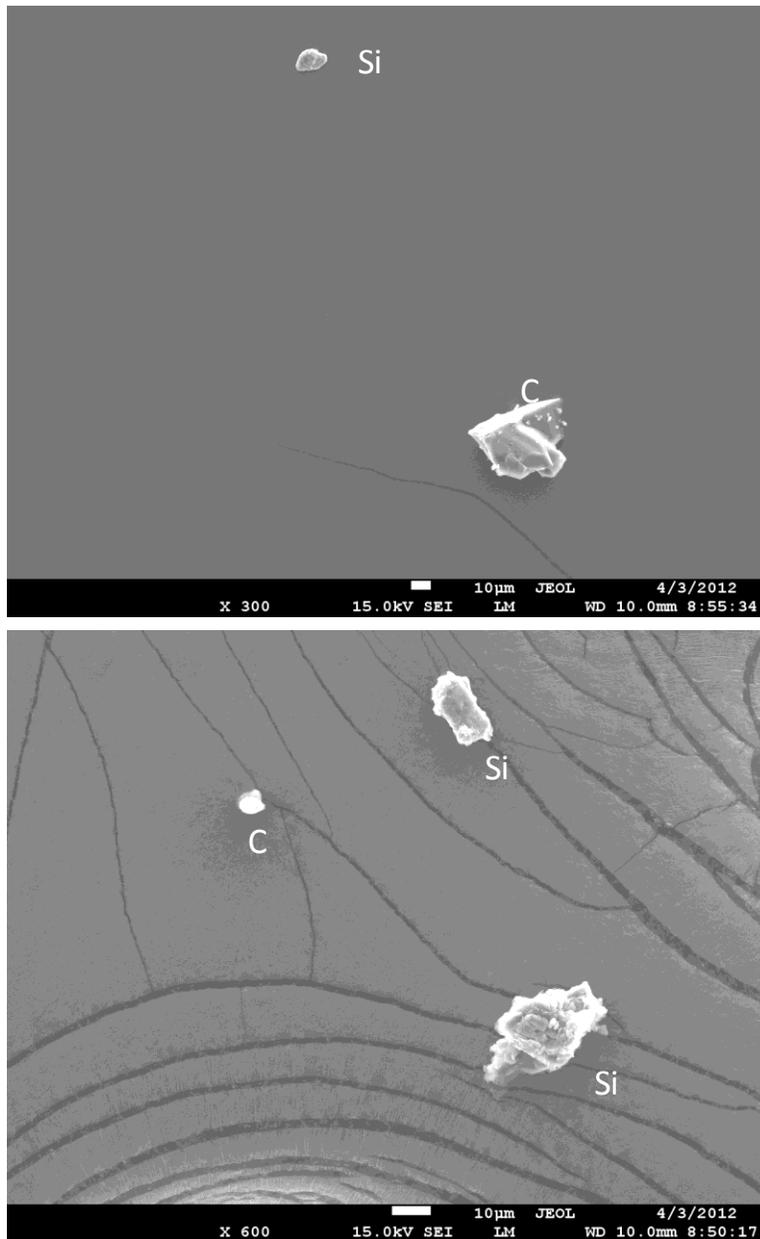


Figure 24. Images of particles on substrate collected at the residence sampling site during the morning of 2/22/12.

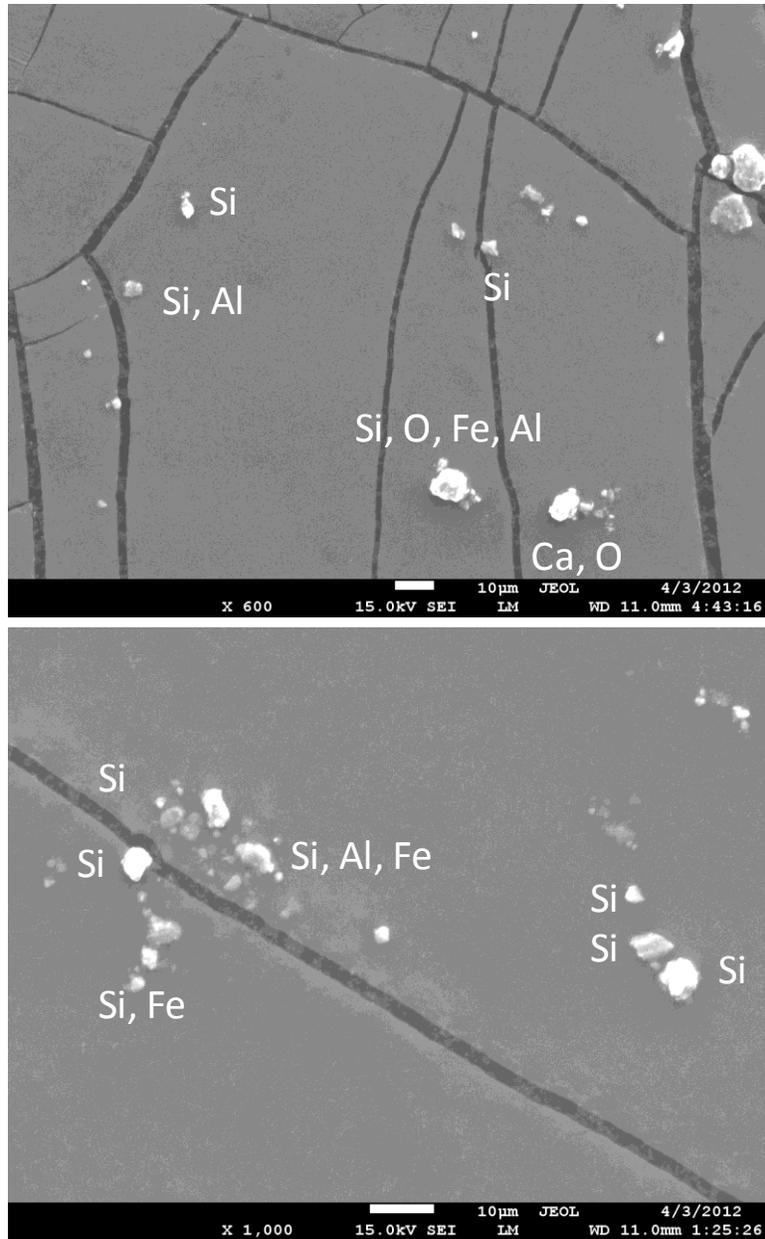


Figure 25. Images of particles on substrate collected at the residence sampling site during the afternoon of 2/22/12.

The light and variable winds at the two sampling sites and the mine site, and the difference in elevation of the mine site relative to the other sites, make it difficult to identify conclusively when a blast plume may have impacted one of the sampling sites. The wind roses in Appendix A suggest that winds would potentially allow for transport of blast emissions to the residence sampling site on February 13, 14, 16, and 18, and that winds were generally favorable for transport of blast emissions to the school site on February 13 and 18. Of those dates, February 14 is the only date on which 3-hour sampling for nitrate, ammonium, and VOCs bracketed the time of a blast event. On that day a blast occurred at 11:29, and at the residence site a 3-hour

nitrate/ammonium sample was collected from 10:45 to 14:02 and a 3-hour canister was collected from 10:37 to 14:02. Inspection of the data shows no apparent impact of blast emissions on any of the target pollutants. For example, the 3-hour nitrate was $< 0.3 \mu\text{g}/\text{m}^3$ (Table 13), the 3-hour ammonium was among the lowest ammonium measurements at $1.6 \mu\text{g}/\text{m}^3$ (Table 15), and the VOC canister results (Table 20) were among the lowest observed. Similarly, inspection of the hourly data files for February 14 for TEOM PM fractions, soot/UVPM, CO, and NO/NO₂/NO_x at the residence site (see Figures 8, 12, 13, and 15, respectively) do not show any change in ambient levels of these species after the blast relative to before the blast. Inspection of the raw data files for these species recorded at 1-minute or 5-minute intervals leads to the same conclusion.

Data from February 16 and February 18 were also reviewed as case studies, because on both of these days multiple blasting events occurred almost simultaneously, maximizing the potential for impact at the sampling sites. On February 16 two blasts occurred at 9:43 and 9:44, respectively, and on February 18 three blasts occurred at 13:17, 13:18, and 13:18, respectively. Regarding the February 16 data, a review showed that the daily sample values of TSP, PM₁₀, PM_{2.5}, and soot/UVPM at the residence site were not noticeably different from the values on the other test days (see Tables 7, 8, 9, and 10). Inspection of the continuous data at hourly and 1- or 5-minute time resolution similarly showed no changes in ambient levels associated with the time of the blasts.

Regarding the February 18 data, the data from both the residence site and the school were reviewed as described above. Again the daily average values of the various air pollutants were not noticeably different from the values on other days, and inspection of the continuous data at hourly, 1-minute, or 5-minute time resolution showed no changes in ambient levels that could be associated with the time of the blasts.

The overall outcome of these case study investigations is that any impact of blast emissions at the two sampling sites must have been minimal, as any such impact is not discernible in the continuous or integrated data obtained at the sites. This outcome applies even when meteorological conditions appear to have been indicative of potential transport of blast emissions in the direction of one or both sampling sites, and when the occurrence of multiple blasts nearly simultaneously would be expected to maximize any such impacts.

4 SUMMARY AND CONCLUSIONS

An air quality assessment study was performed in the vicinity of surface mining operations in Clear Fork, West Virginia. The study was conducted over a two week period from February 9 to 23rd, 2012 and included monitoring of local meteorological conditions as well as the characterization of different size fractions of airborne PM and of a variety of gaseous air pollutants throughout the study period. Integrated measurements of TSP, PM₁₀, and PM_{2.5} were made at two sites in the community (a residential site and the local elementary school) to characterize the daily average PM concentrations at the sites during the study period. At the residential site, continuous measurements of PM₁₀ and PM_{2.5} were also made using a TEOM, and continuous measurements of soot were made using an Aethalometer. Integrated samples for determination of total nitrate, total ammonia/ammonium, and VOCs were also collected at both sites, and passive samplers for ammonia and NO₂ were deployed at both of those sites and at four other locations in the community. Results for pollutants monitored are summarized below:

- In general, the daily TSP concentrations measured at the residence sampling site were greater than those measured at the school. Daily average concentrations for TSP at the two sites ranged from 10.5 to 33.7 $\mu\text{g}/\text{m}^3$ at the residence and from 5.8 to 30.8 $\mu\text{g}/\text{m}^3$ at the school. The TSP concentrations measured on the two non-blasting days (i.e., sampling periods ending on February 12 and 19) were among the lowest measured concentrations, but were not the lowest. The relatively low concentrations on those days may indicate the absence of specific sources on those days, but does not conclusively point to individual sources. Currently there is no NAAQS for TSP, but the TSP concentrations in this study were much lower than the former TSP NAAQS of 260 $\mu\text{g}/\text{m}^3$.
- The daily average PM₁₀ concentrations ranged from approximately 5 to 18 $\mu\text{g}/\text{m}^3$ at the two sampling sites with average concentrations of 12.2 and 10.2 $\mu\text{g}/\text{m}^3$ at the residence and school sites, respectively. These results are well below the daily PM₁₀ NAAQS of 150 $\mu\text{g}/\text{m}^3$ and are substantially below the annual average PM₁₀ concentration of 18.9 $\mu\text{g}/\text{m}^3$ measured in Charleston, West Virginia during 2010. In general, the PM₁₀ measurements at the residence and school sites agreed reasonably closely on each sampling day. Furthermore, the results from the integrated PM₁₀ measurements at the residence site compared favorably with the averaged results from the continuous PM₁₀ measurements conducted at that site.
- The daily average PM_{2.5} concentrations measured at the residence and school sites ranged from 5.5 to 10.2 $\mu\text{g}/\text{m}^3$ during the study period. Additional PM_{2.5} measurements were made by the WV DEP at an air monitoring station in Beckley, approximately 20 miles to the south of the study area. Those measurements typically agreed with the measurements at the residence and school sites within 2 $\mu\text{g}/\text{m}^3$. The average PM_{2.5} concentrations at the residence and school sites were 7.3 and 7.1 $\mu\text{g}/\text{m}^3$, respectively, and the average concentration at the Beckley site was 7.0 $\mu\text{g}/\text{m}^3$. These results are all below the annual average of 10.3 $\mu\text{g}/\text{m}^3$ measured in Beckley during 2010, and well below the PM_{2.5} NAAQS annual limit of 15 $\mu\text{g}/\text{m}^3$ and the 24-hour limit of 35 $\mu\text{g}/\text{m}^3$. Continuous measurements showed occasional brief periods of relatively higher concentrations of PM₁₀ and PM_{2.5}. Those periods did not appear to coincide with blasting events.

- Continuous CO, NO/NO₂/NO_x, and soot measurements showed predominantly low ambient concentrations with occasional brief periods of higher concentrations. The observed concentrations did not approach any health-based air quality standards, and the occasional periods of higher concentrations were not associated with blasting events. Integrated measurements of total nitrate and total ammonia/ammonium at the two sampling sites similarly showed low concentrations, minimal differences between sites, and no clear indication of higher concentrations on days on which blasting occurred.
- Passive sampling for NO₂ in four areas of the community resulted in average NO₂ concentrations that agreed closely with those determined by the continuous NO/NO₂/NO_x monitors located at the residence and school sampling sites. Passive sampling for NH₃ rarely showed detectable levels, perhaps due to the relatively low ambient temperatures in the February field period.
- The concentrations of toxic VOCs, which included chlorinated hydrocarbons such as methylene chloride, aromatic compounds such as benzene, and polar compounds such as acrolein, were uniformly low at both sampling sites. Almost all measured concentrations of these VOCs were less than 1 ppb, and showed no dependence on the sampling site or the occurrence of blasting events. Relatively innocuous polar VOCs such as isopropyl alcohol were found at concentrations of several ppb in all samples and in the VOC blank. The presence of those VOCs however may be due to contamination, and the data do not indicate their concentrations in ambient air.
- The metals composition of PM₁₀ particles and the crustal elemental composition of passively deposited large particles were also determined, but did not show significant temporal or site-to-site differences or association with the occurrence of blasting events. Concentrations of toxic metals (e.g., lead, manganese, chromium) in PM₁₀ were very low, i.e., less than 5 ng/m³ above the corresponding blank level.

Detailed inspection of the integrated and continuous data was conducted to investigate whether any air quality impacts of blasting events could be discerned in the data. That inspection included review of meteorological and continuous monitoring data at the highest time resolution recorded (1-minute or 5-minute data). The data were also inspected during periods when multiple blasts occurred simultaneously. None of these efforts revealed any conclusive evidence of impact of blast emissions on air quality at the two sampling sites.

The overall finding of this study thus is that the local air quality is well within applicable health-based standards and does not appear to be affected by emissions from nearby blasting events in surface coal mining. The lack of such impact may be due to the difference in elevation of the mine and the sampling sites, causing blast emissions to be dispersed before reaching the valley sampling sites.

5 RECOMMENDATIONS

The overall finding is limited to the two-week study conditions reported here. Additional monitoring to evaluate air quality under different meteorological conditions, other seasons, or in a study of longer duration is recommended. In addition, direct sampling of the explosion plume produced by blasting would be helpful to characterize pollutants in the emissions. Finally, use of a tracer to indicate the presence of blast emissions at sampling sites could be a useful approach to consider in any future study.

6 REFERENCES

1. U.S. EPA, Compendium Method IO-3.1: Selection, Preparation and Extraction of Filter Material, U.S. Environmental Protection Agency, Office of Research and Development, EPA/625/R-96/010a, June 1999.
2. U.S. EPA, Compendium Method IO-3.5: Determination of Metals in Ambient Particulate Matter using Inductively Coupled Plasma Mass Spectrometry (ICP/MS), U.S. Environmental Protection Agency, Office of Research and Development, EPA/625/R-96/010a, June 1999.
3. U.S. EPA, Compendium Method TO-15: Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS), U.S. Environmental Protection Agency, Office of Research and Development, EPA/625/R-96/010b, January 1999.
4. U.S. EPA, Method 300.0, Determination of Inorganic Anions by Ion Chromatography, U.S. Environmental Protection Agency, Office of Research and Development, August 1993
5. U.S. EPA, Method 350.1, Determination of Ammonia Nitrogen by Semi-Automated Colorimetry, U.S. Environmental Protection Agency, Office of Research and Development, August 1993.

APPENDIX A
SITE PHOTOGRAPHS



Figure 26. Photograph of equipment shelter at residence.



Figure 27. Photograph of equipment shelter at school.



Figure 28. Photograph of particle sampling and meteorological monitoring equipment at residence.



Figure 29. PM₁₀ sampler at school.



Figure 30. $PM_{2.5}$ sampler at school.



Figure 31. Meteorological monitoring equipment at mine site.



Figure 32. Continuous gas analyzers with calibrator and datalogger.

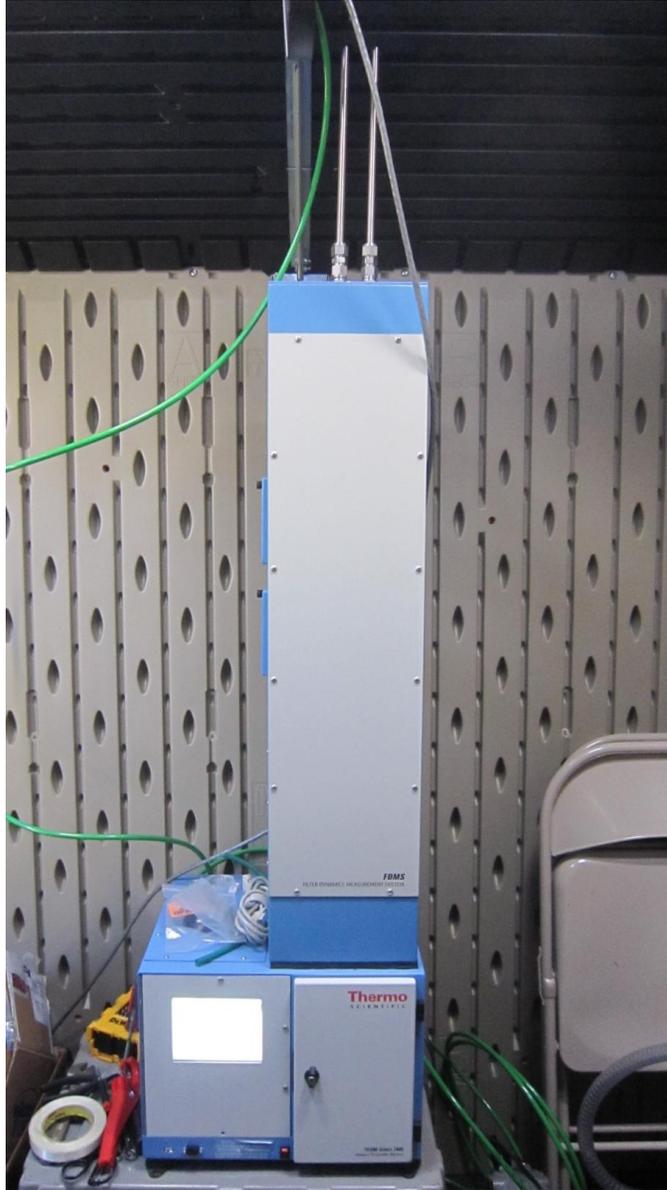


Figure 33. TEOM used to continuously measure PM_{10} and $PM_{2.5}$ at residence.

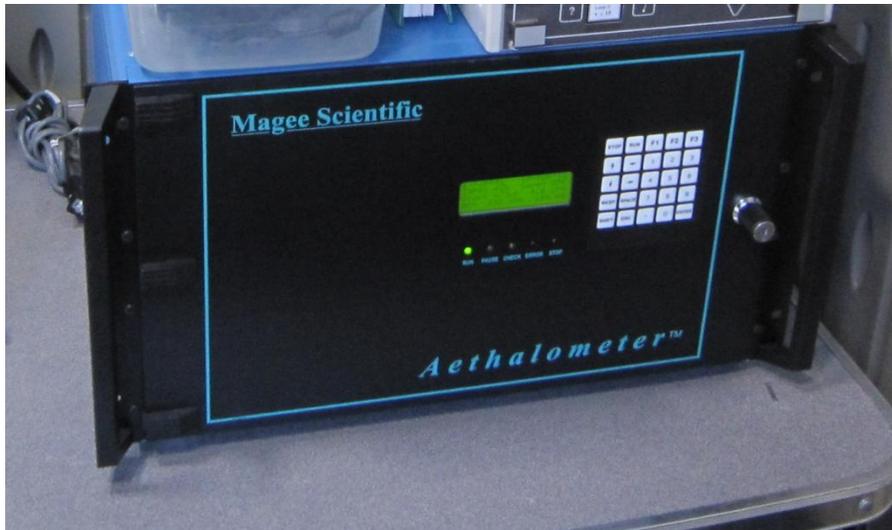


Figure 34. Aethalometer used to continuously measure soot concentrations at residence.

APPENDIX B
DAILY WIND ROSES

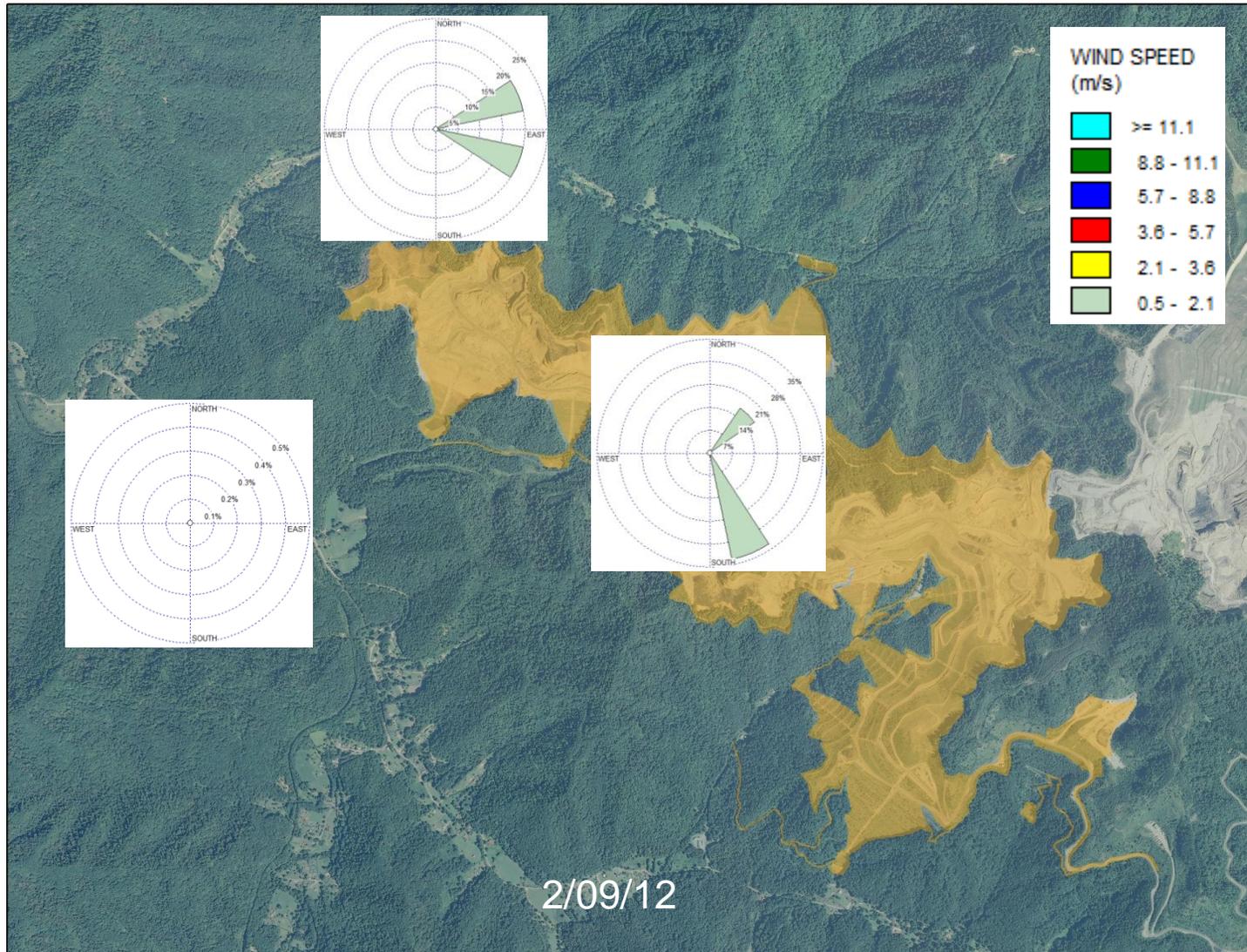


Figure 35. Wind roses for 2/09/12. (Only calm conditions were observed at the school so no wind data available).

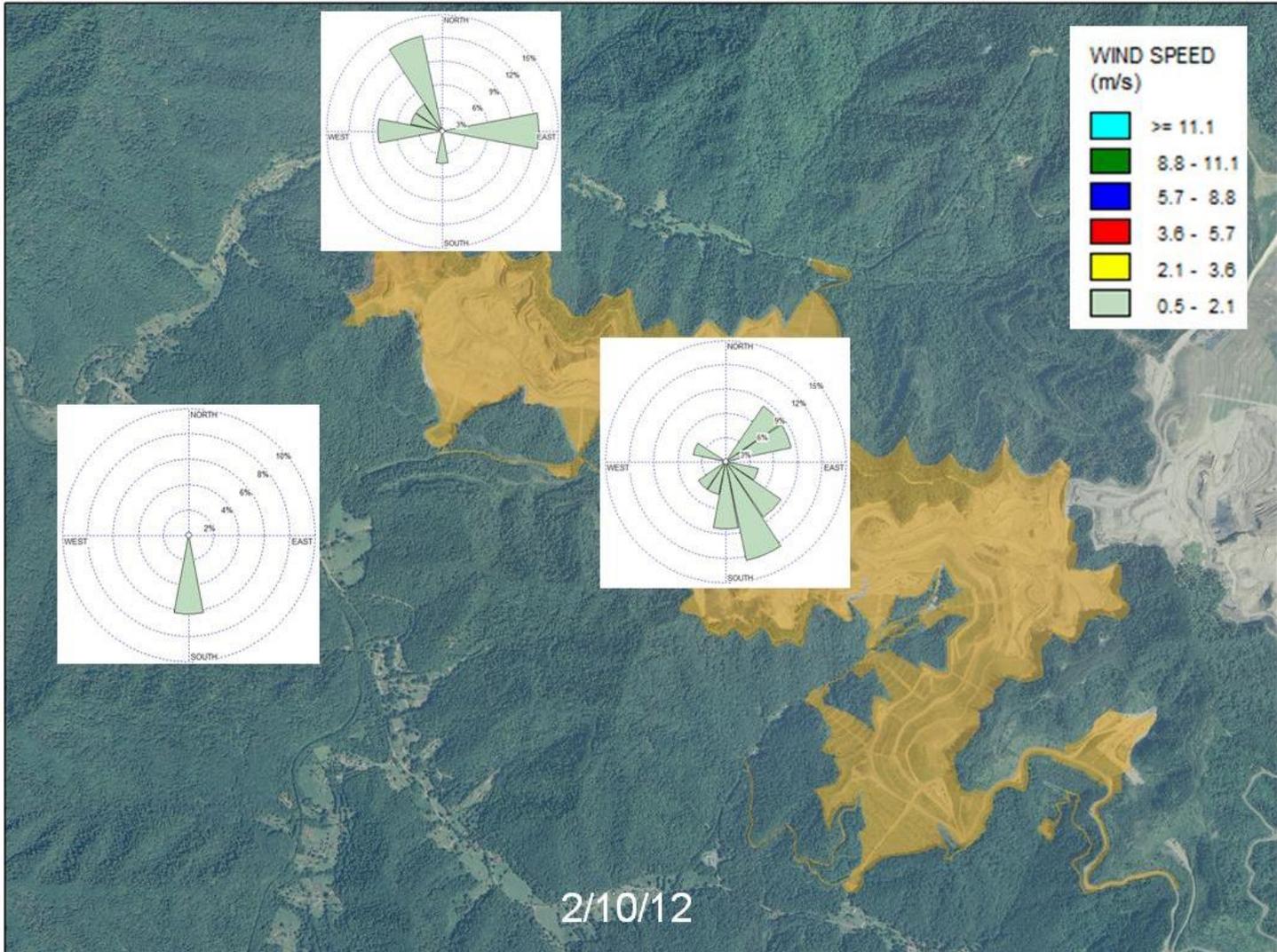


Figure 36. Wind roses for 2/10/12.

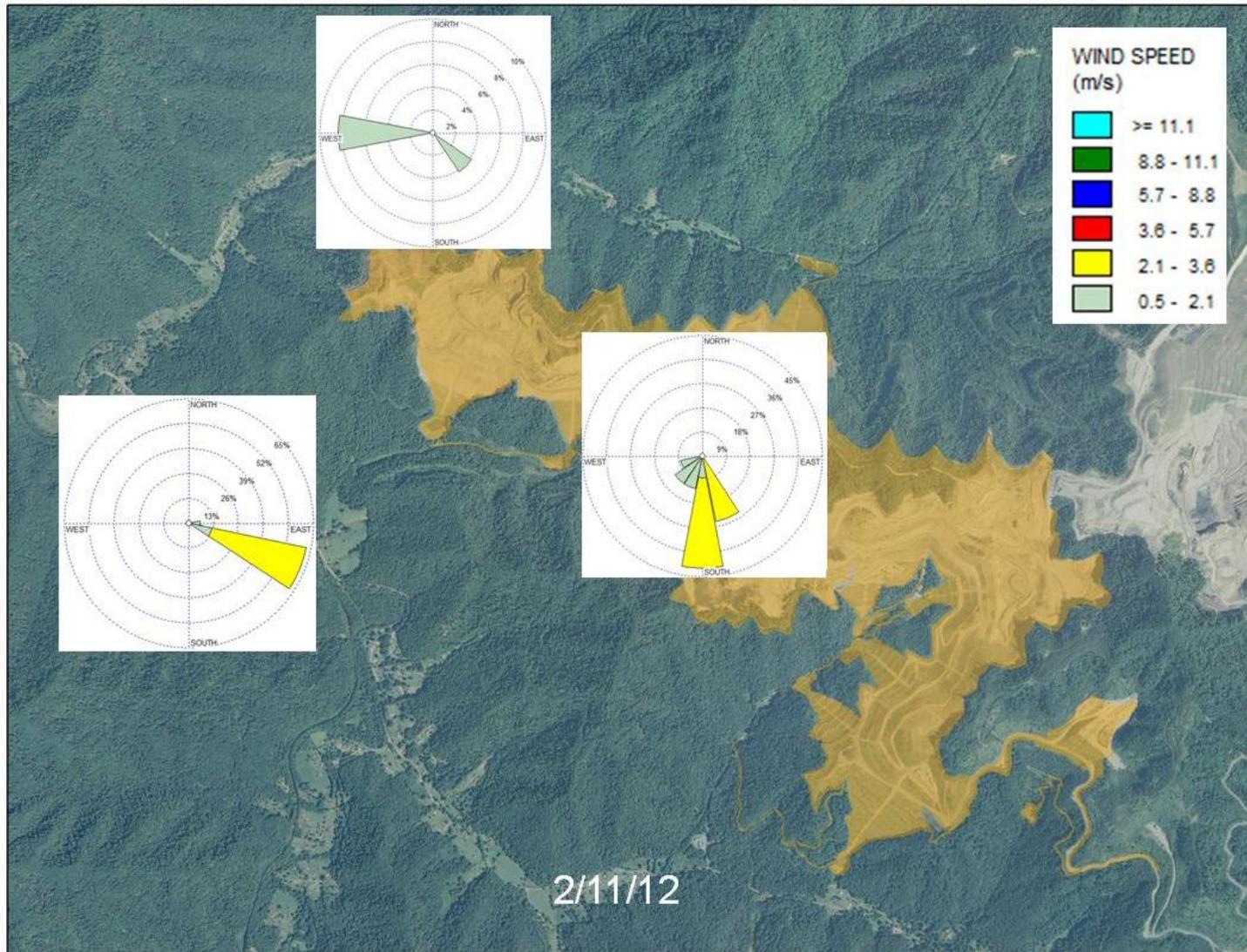


Figure 37. Wind roses for 2/11/12.

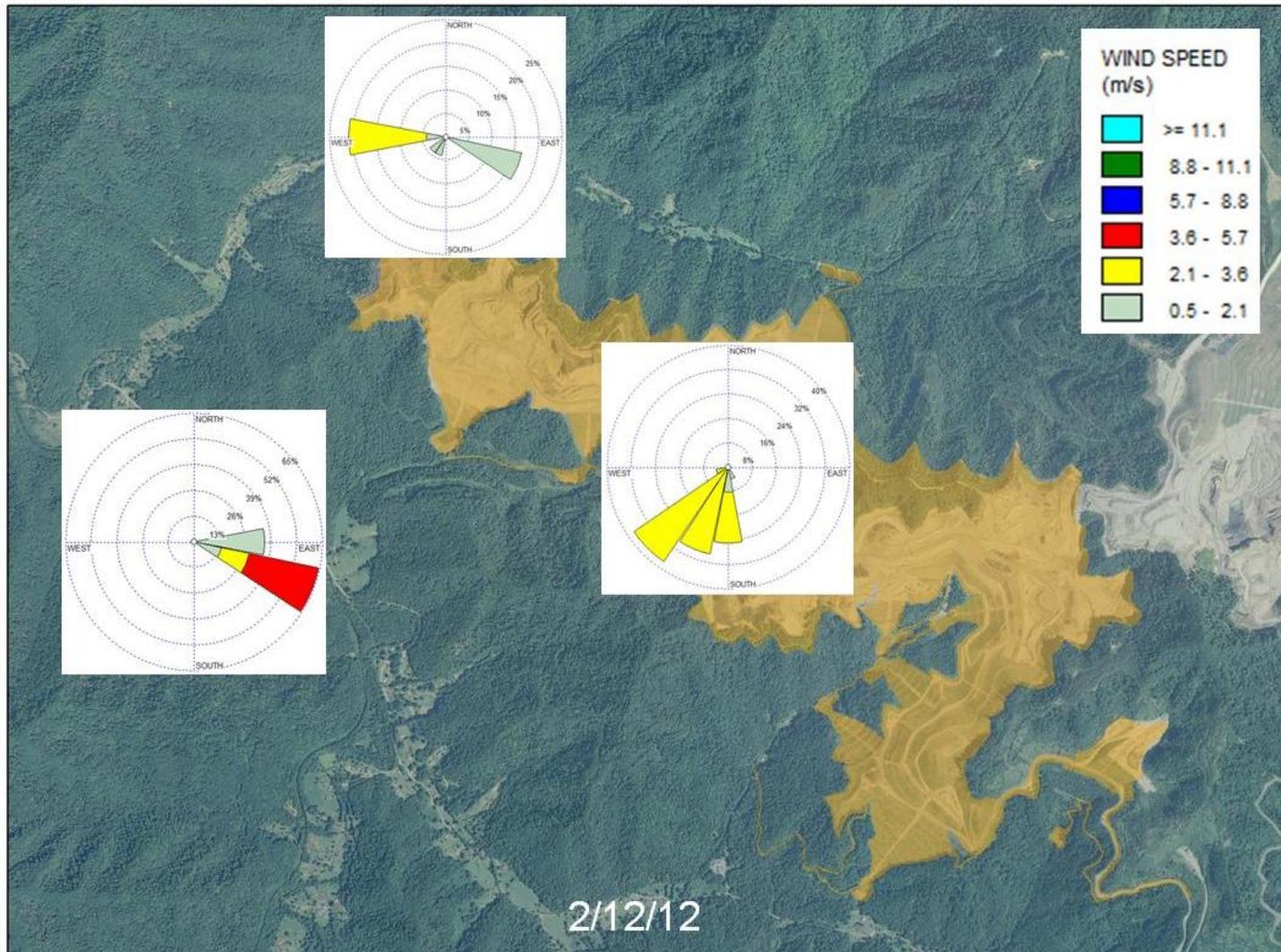


Figure 38. Wind roses for 2/12/12.

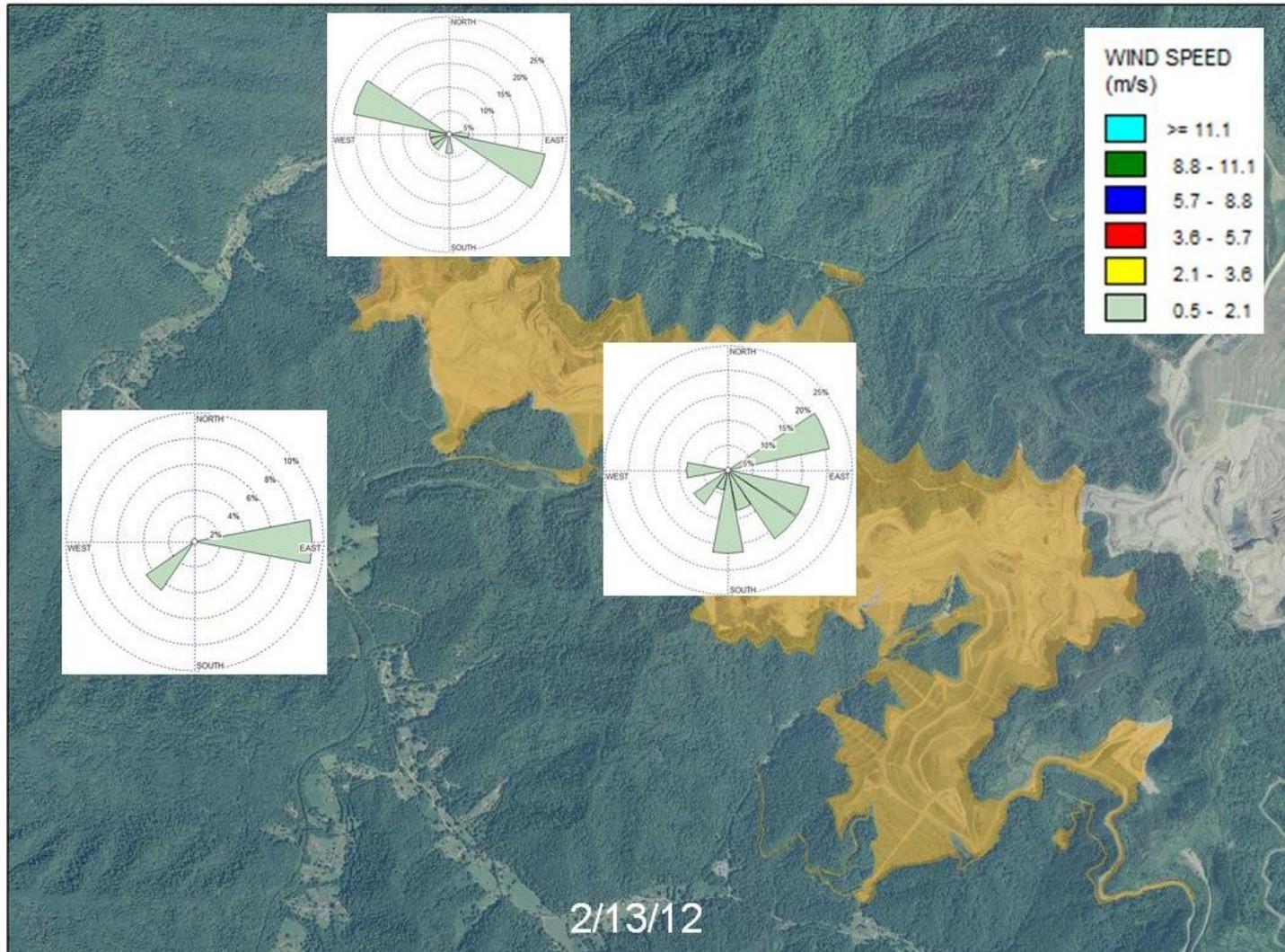


Figure 39. Wind roses for 2/13/12.

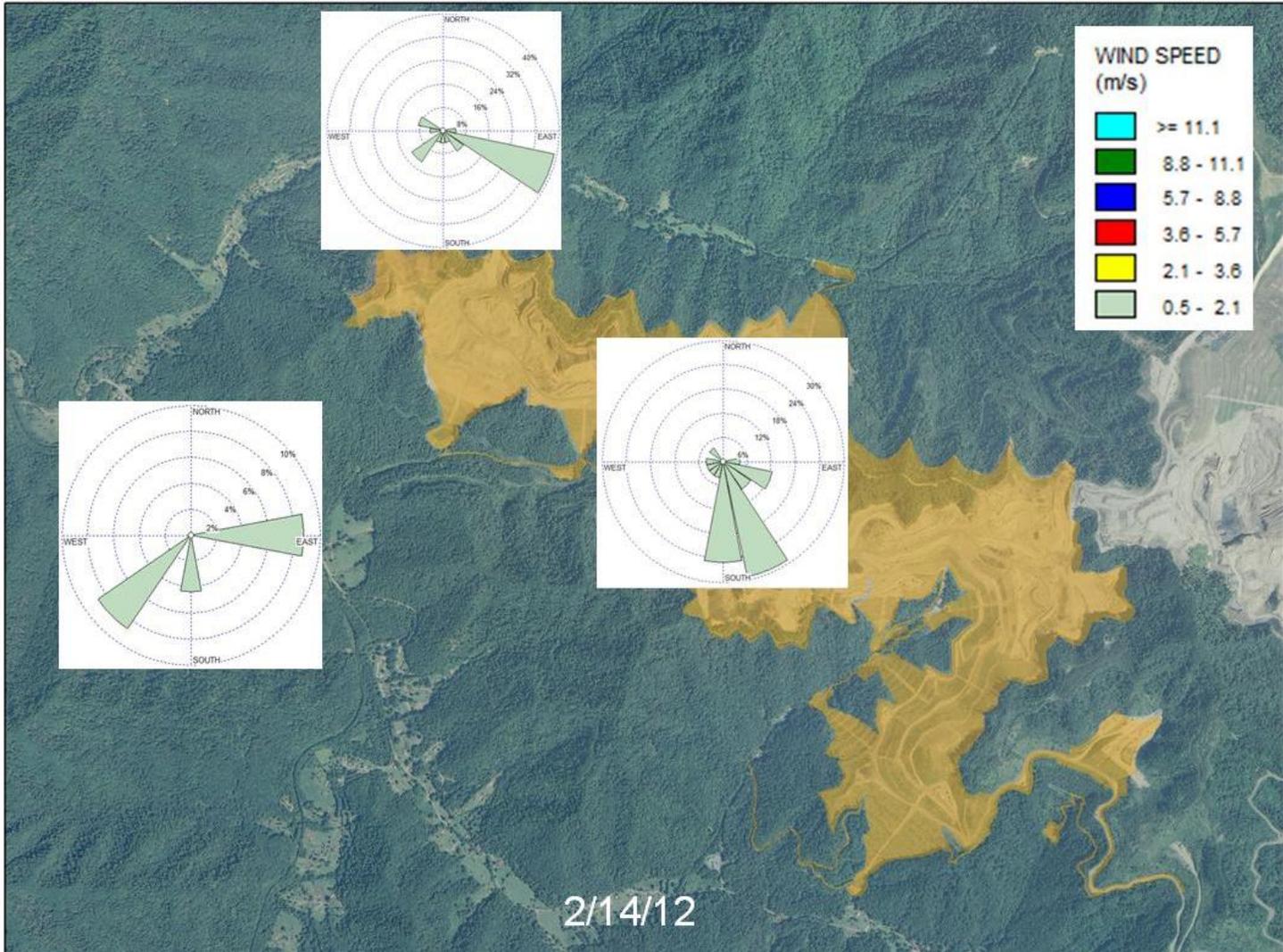


Figure 40. Wind roses for 2/14/12.

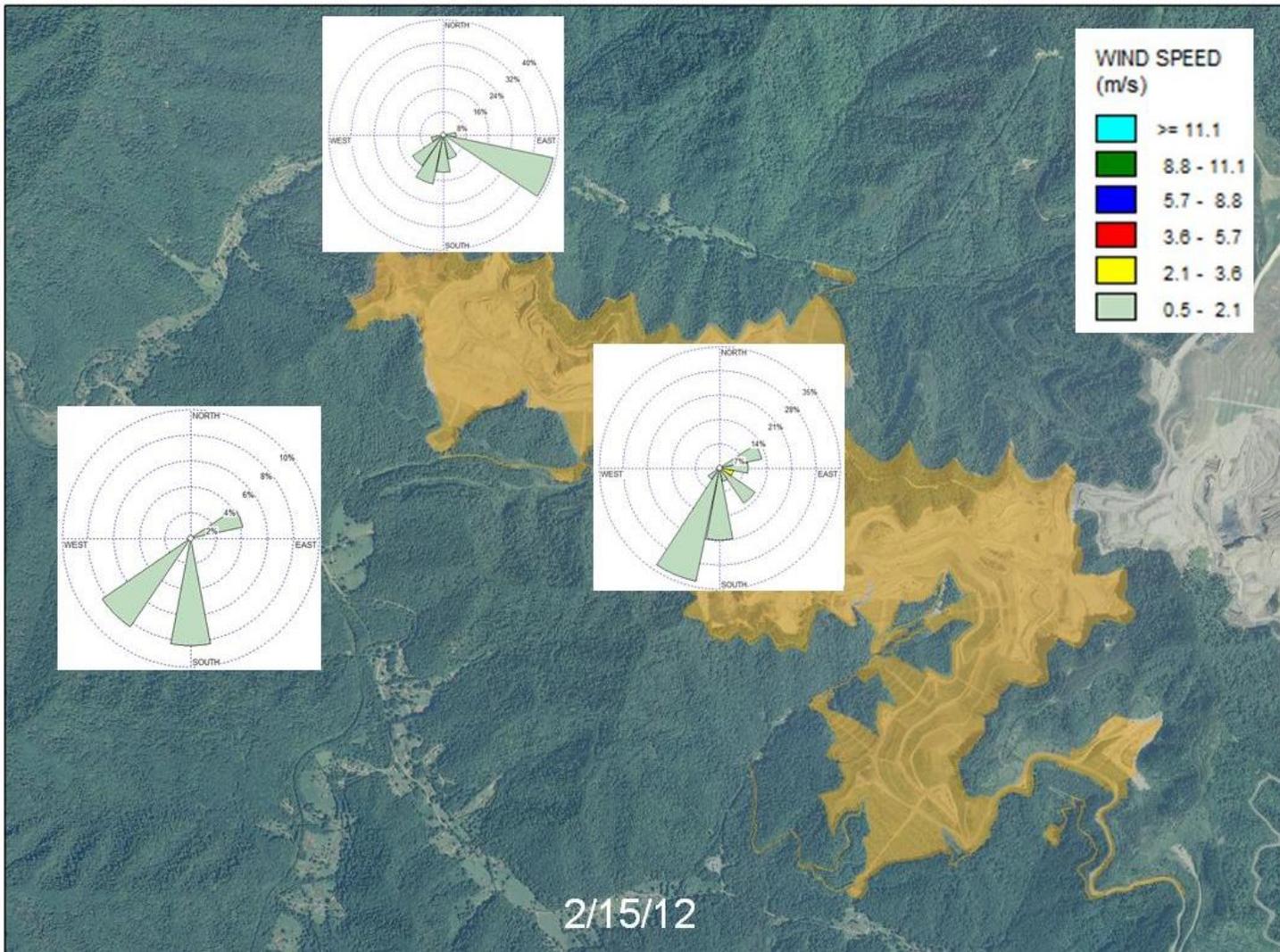


Figure 41. Wind roses for 2/15/12.

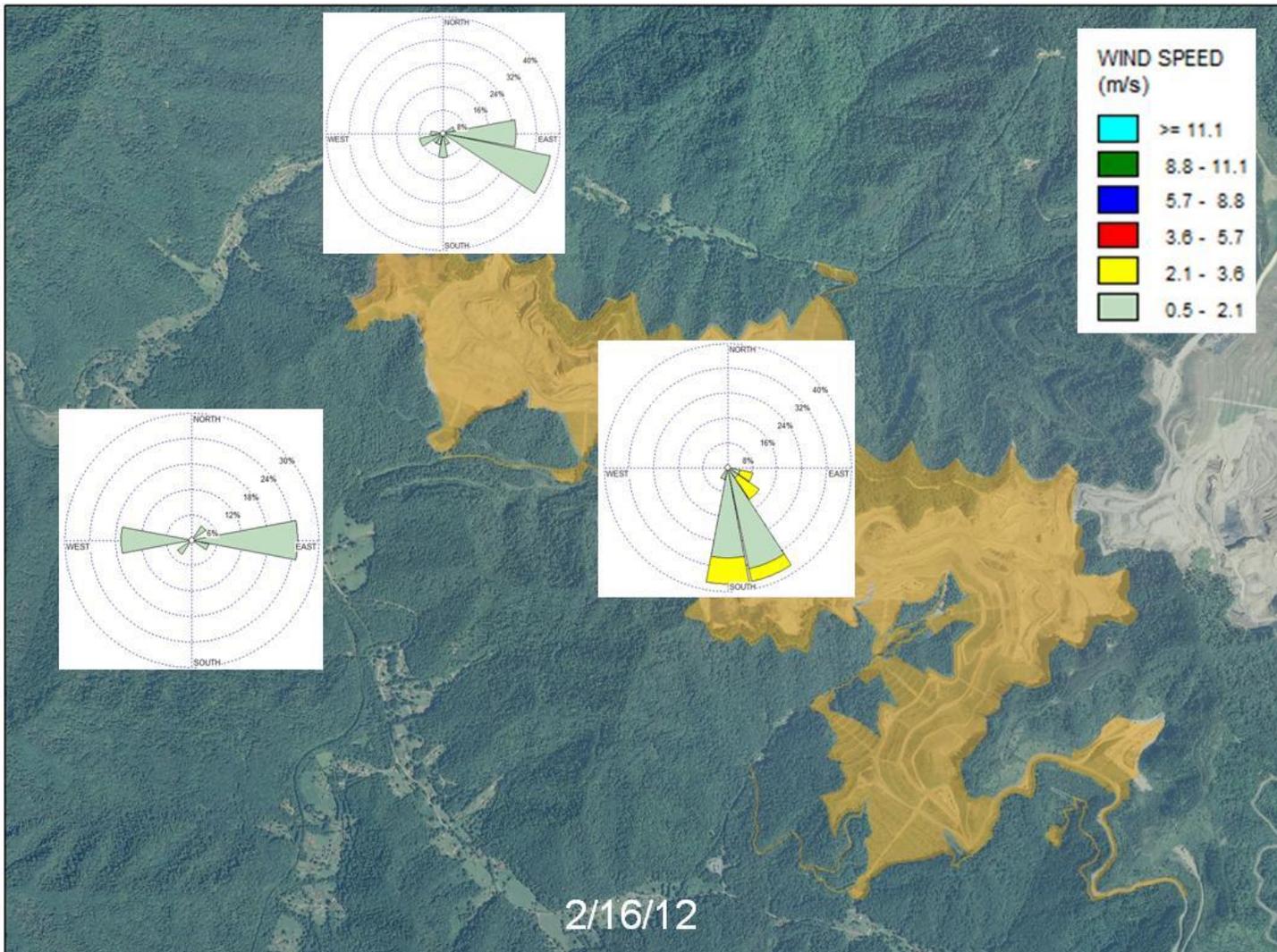


Figure 42. Wind roses for 2/16/12.

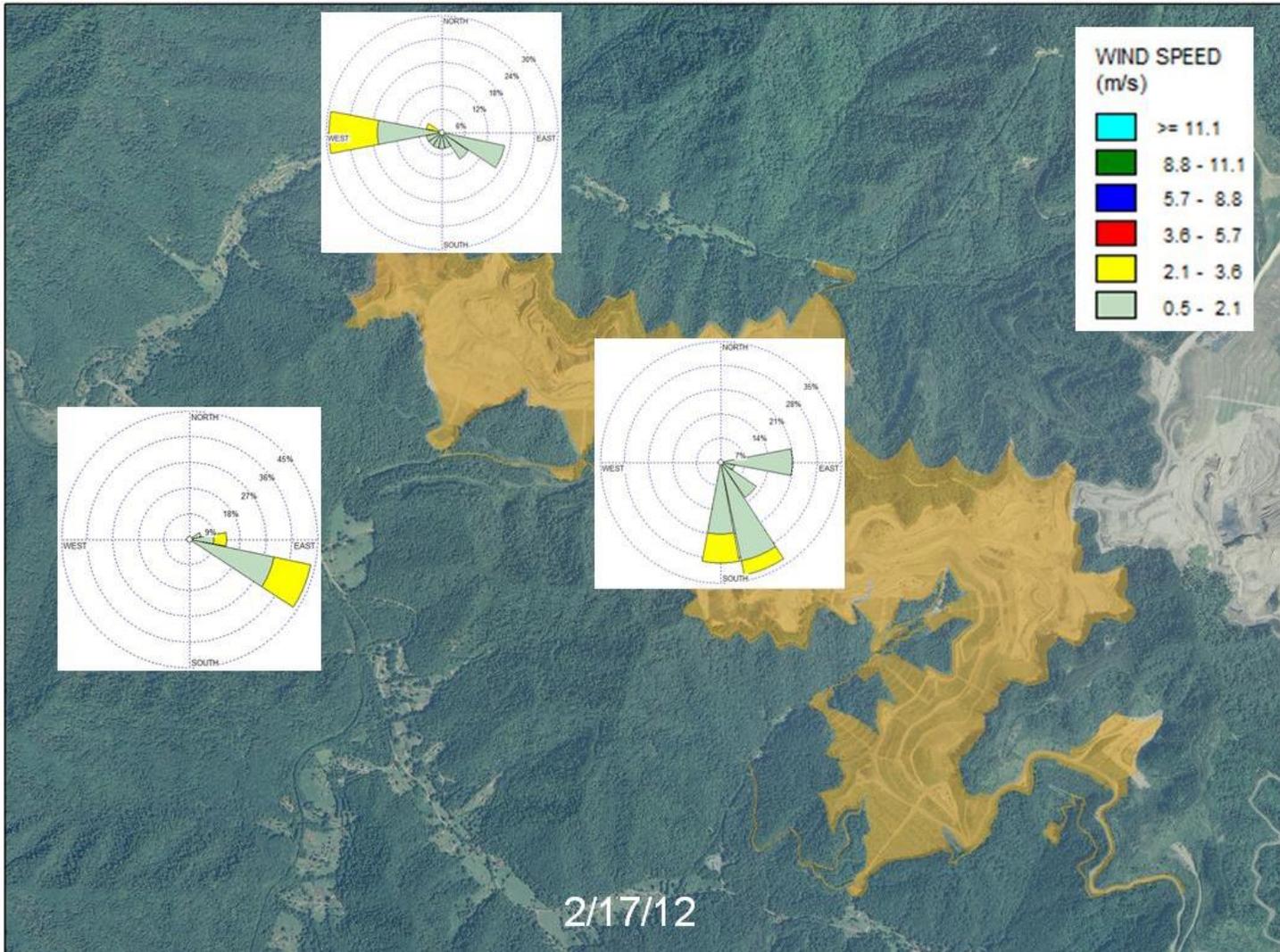


Figure 43. Wind roses for 2/17/12.

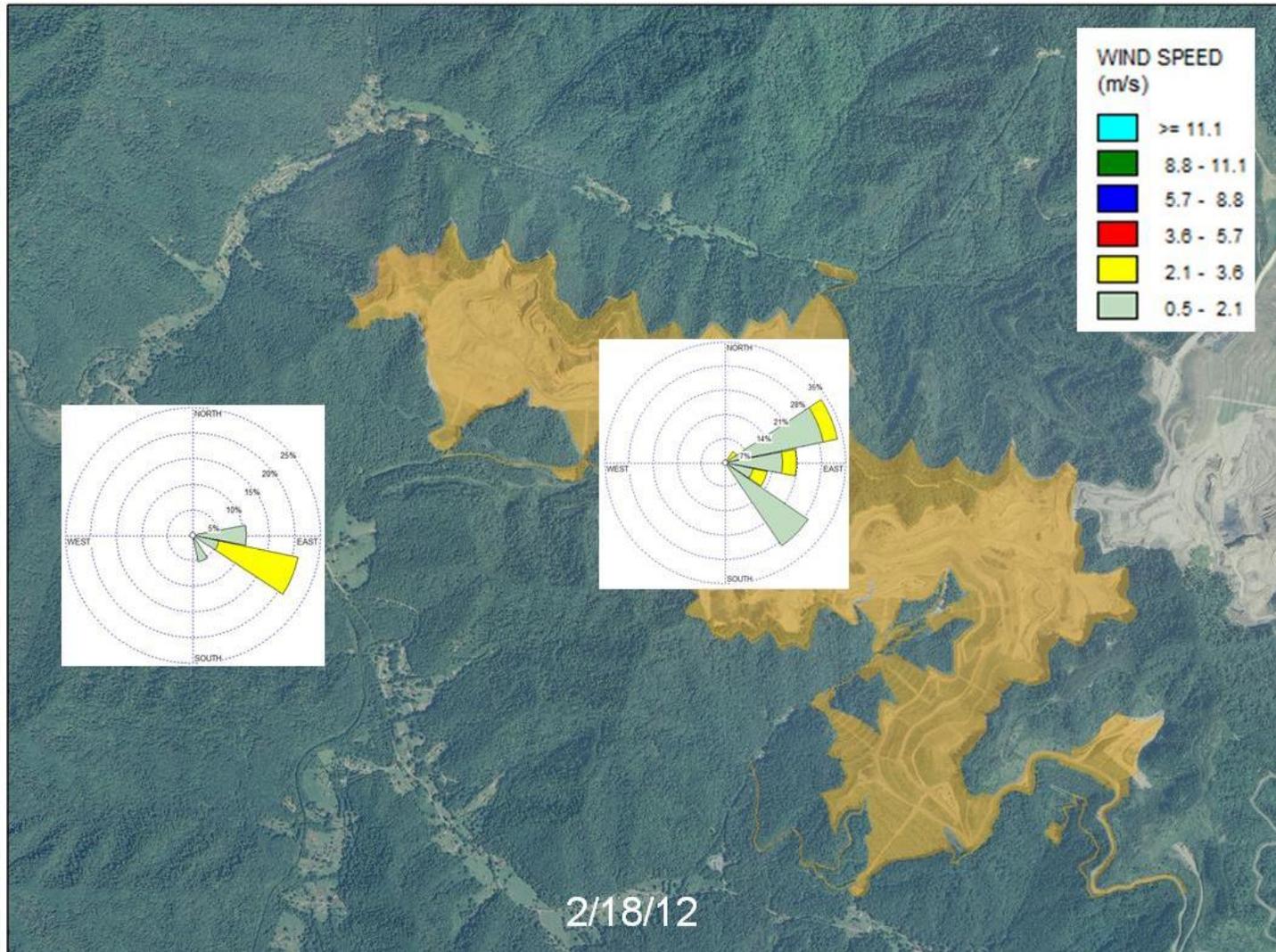


Figure 44. Wind roses for 2/18/12. (No readings available from residence).

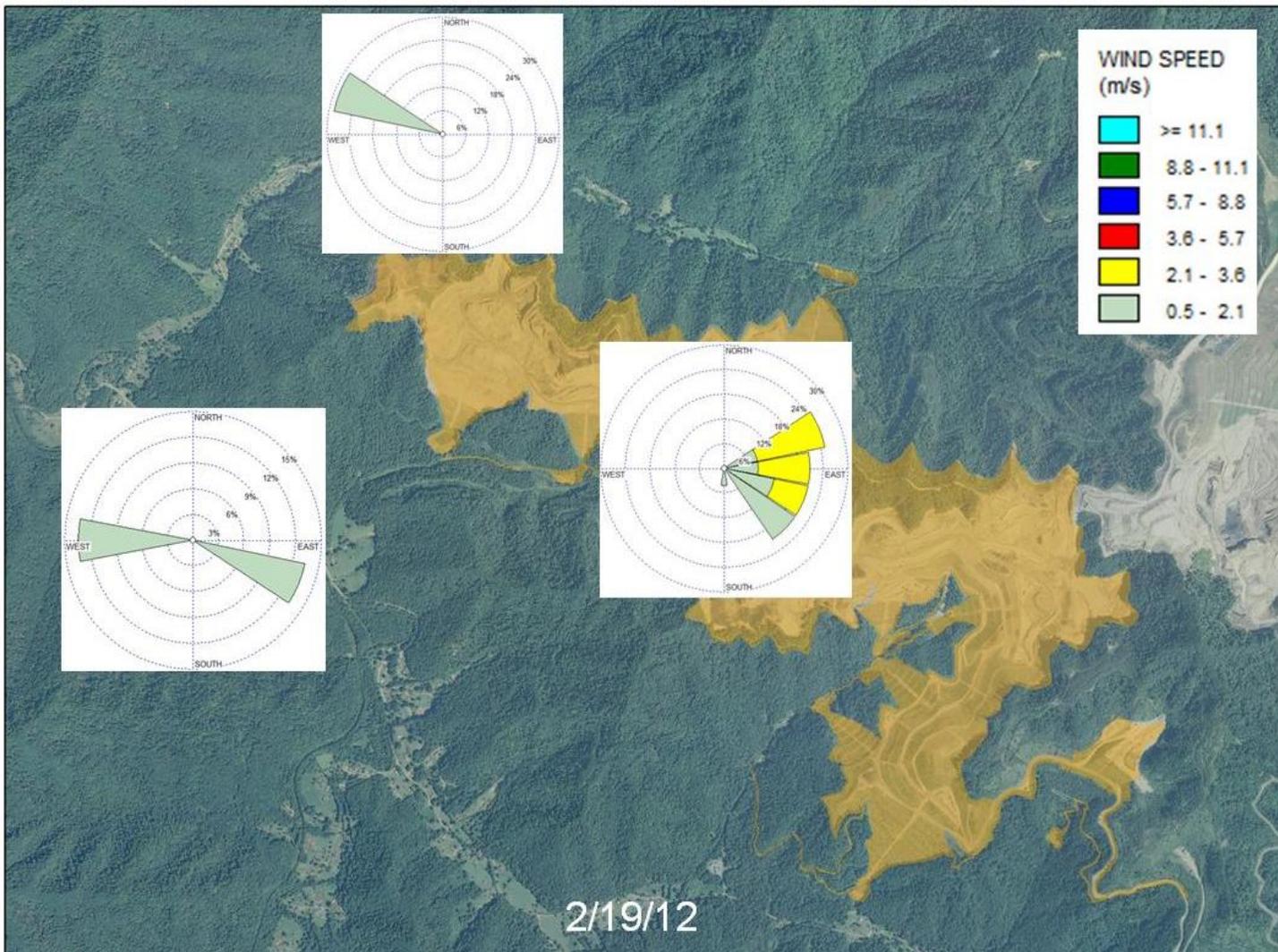


Figure 45. Wind roses for 2/19/12.

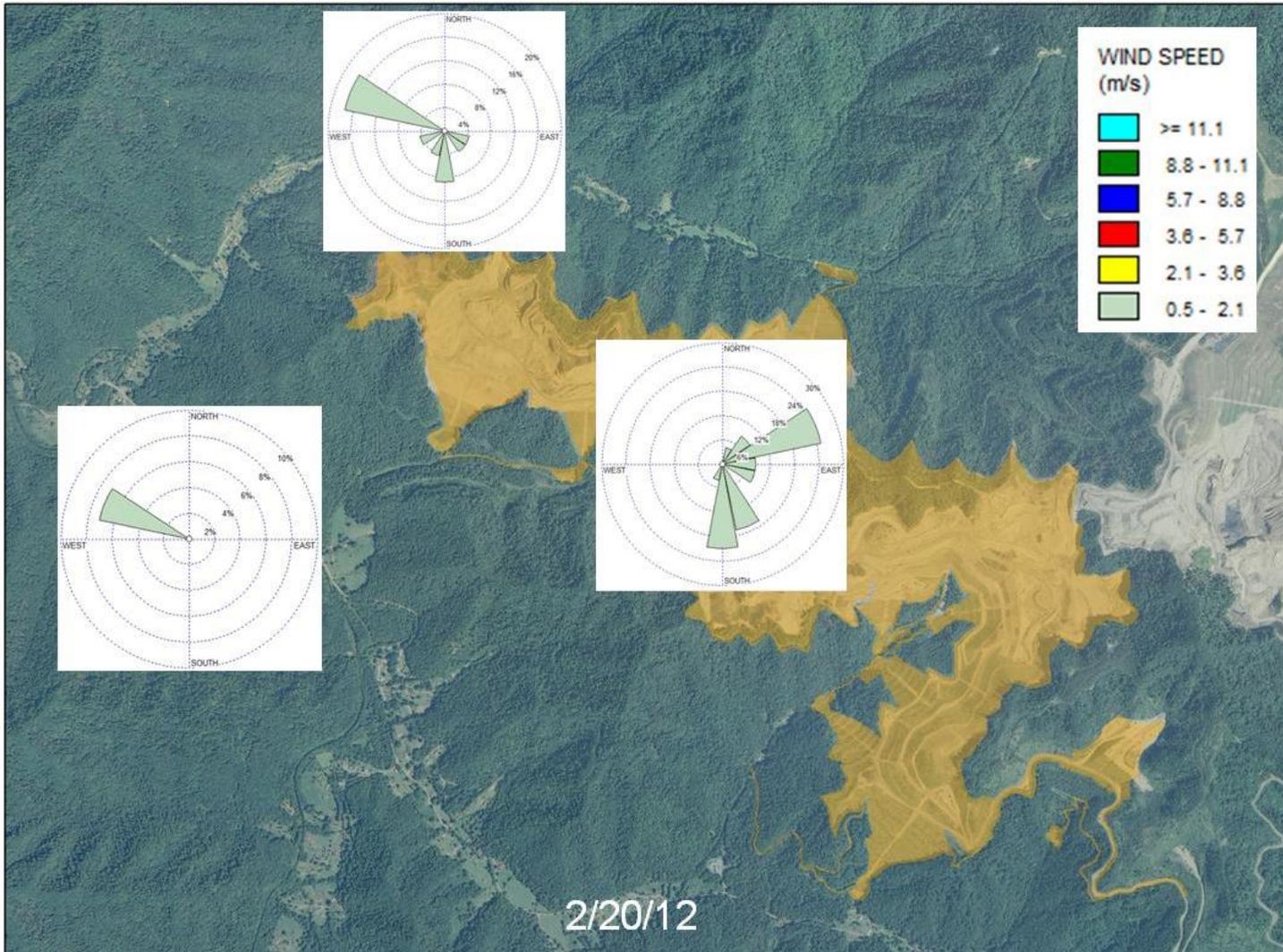


Figure 46. Wind roses for 2/20/12.

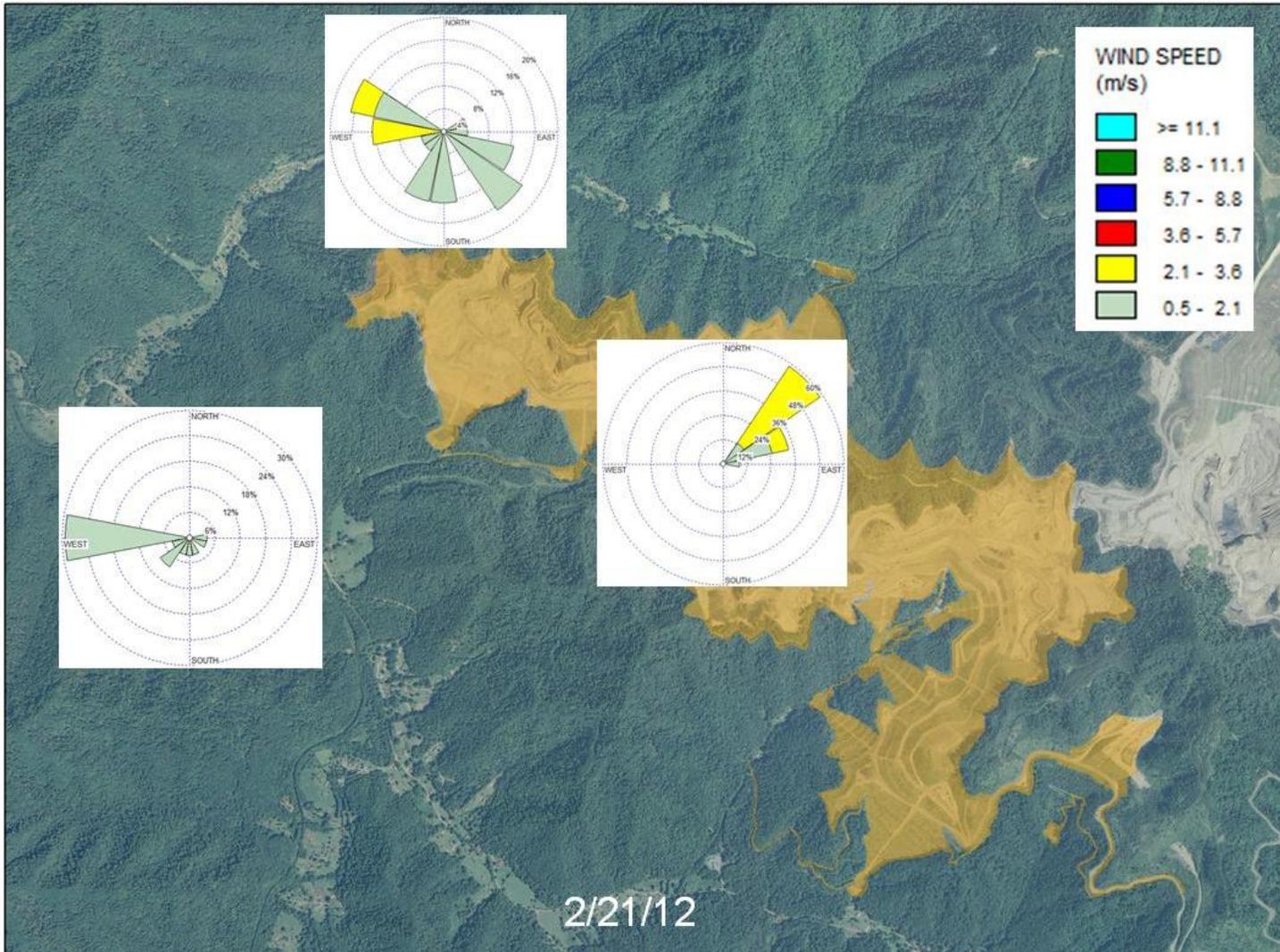


Figure 47. Wind roses for 2/21/12.

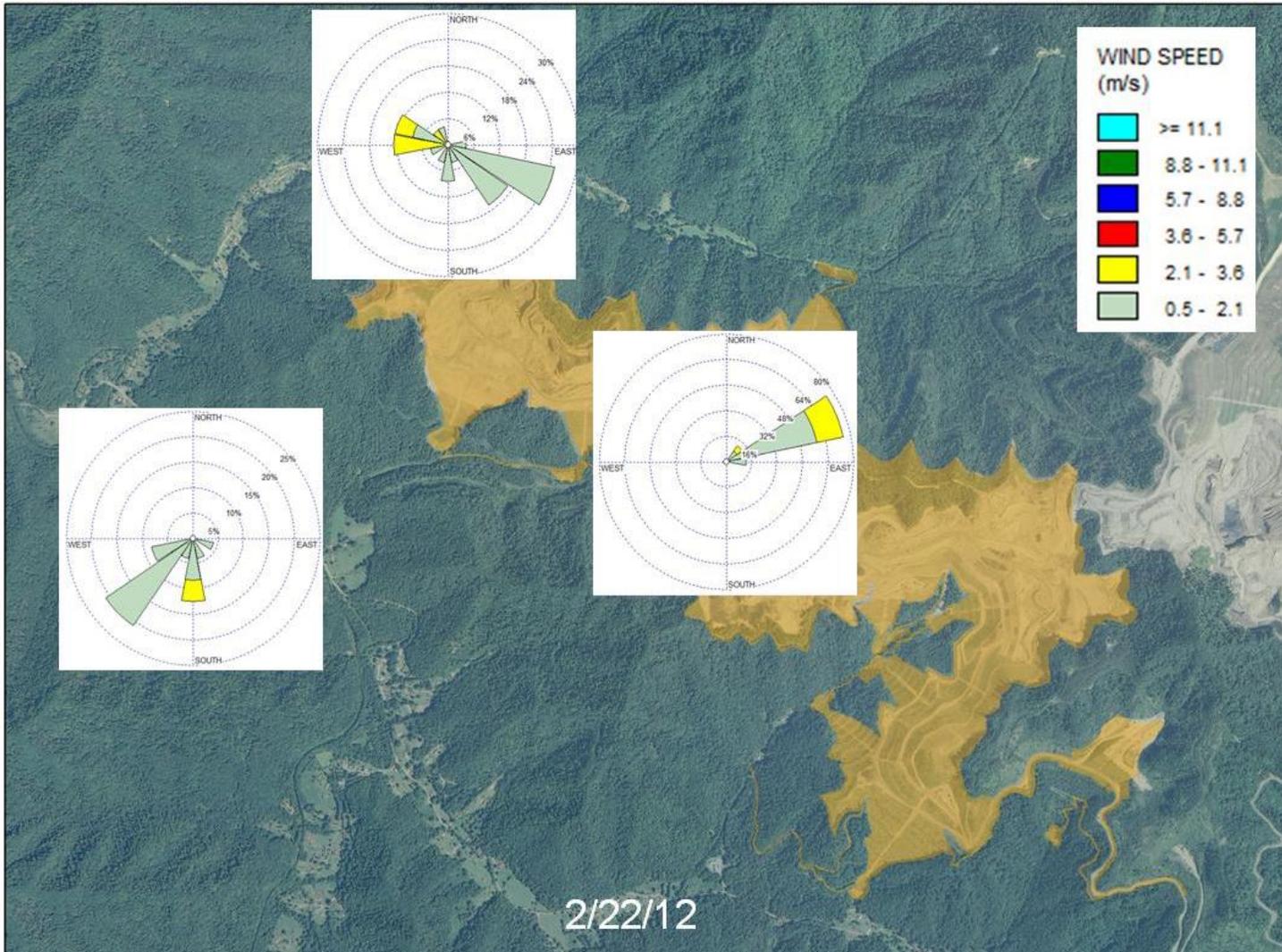


Figure 48. Wind roses for 2/22/12.

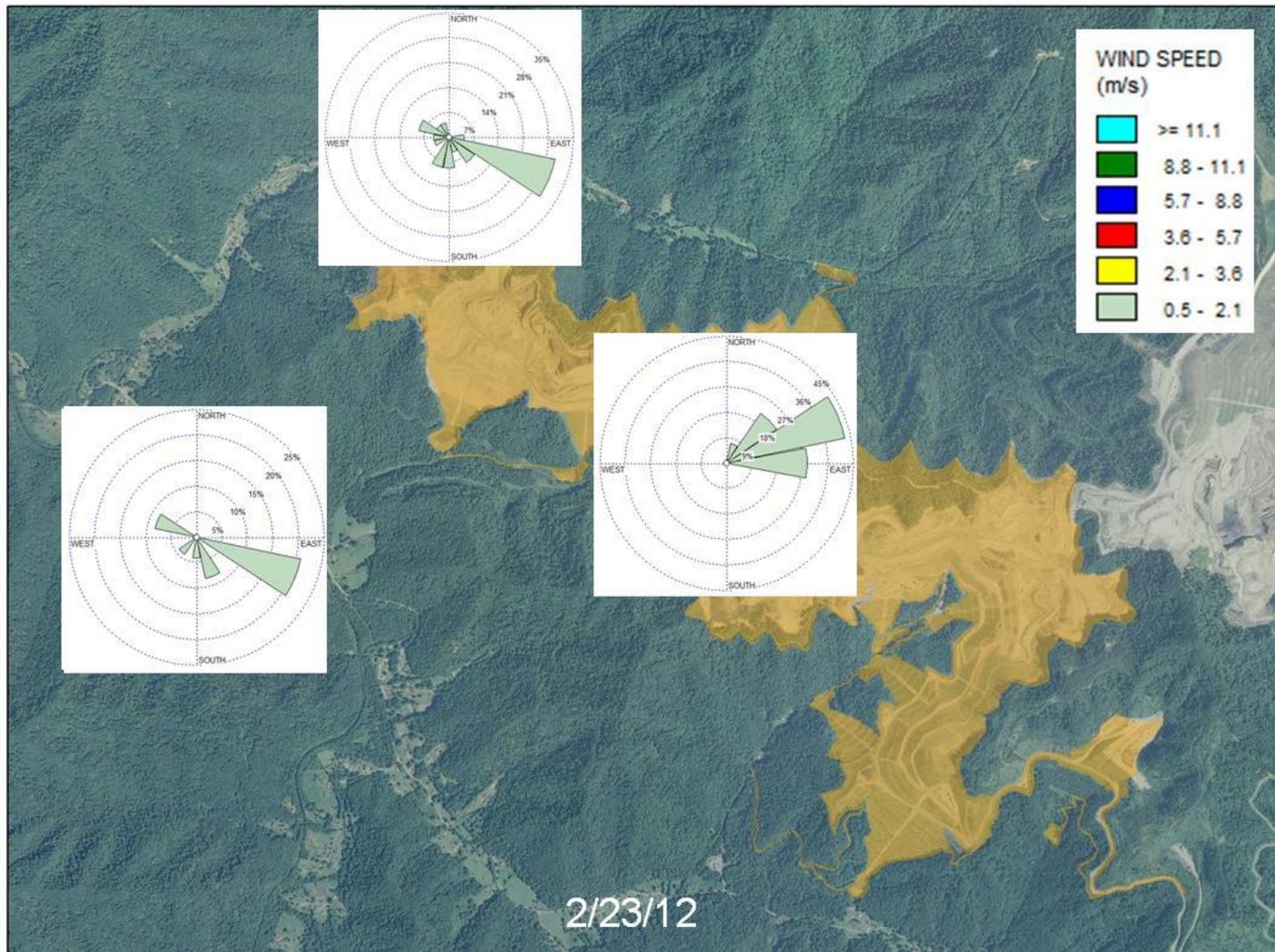


Figure 49. Wind roses for 2/23/12.