GARFIELD COUNTY
2010 AIR QUALITY MONITORING SUMMARY

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EXECUTIVE SUMMARY

This report summarizes air quality monitoring data collected during 2010 in Garfield County, Colorado. The monitoring stations include the Parachute, Rifle, Bell-Melton, Rulison, and Battlement Mesa sites, which are all in close proximity to oil and gas development in the county. Parameters monitored include organic compounds (VOCs), and meteorology at all sites, where VOCs monitored include speciated non-methane hydrocarbons (SNMOC) and carbonyl compounds. Additionally, particulate matter ≤ 10 micrometers in diameter (PM_{10}) is monitored at the Parachute site, and PM_{10}, particulate matter ≤ 2.5 micrometers in diameter ($PM_{2.5}$) and ozone (O_3) are monitored at Rifle site.

Criteria pollutants are pollutants subject to the National Ambient Air Quality Standards (NAAQS). Criteria pollutants monitored in 2010 included PM_{10} at the Parachute and Rifle sites, and $PM_{2.5}$ and O_3 at the Rifle site. At present, air quality measurements in Garfield County do not violate air quality standards for O_3, PM_{10}, or $PM_{2.5}$.

Highest concentrations of $PM_{2.5}$ and SNMOCs were observed during the colder winter months, and highest PM_{10} concentrations were observed during both the winter and spring. High PM measurements in the winter are affected by temperature inversions in the Colorado River Basin. During an inversion, air pollutants can build up due to limited atmospheric mixing. High SNMOCs measurements can also be affected by inversions, but are also generally higher in the winter because these compounds become more reactive and deplete faster during warm summer months. Springtime concentrations of PM_{10} coincided with high wind events, which likely entrained large dust particles in the air.

Light alkanes, which are SNMOC compounds with fewer than five carbon atoms, made up between 77 and 87% of the total SNMOC compounds measured. Natural gas production activities are likely the largest contributing source of light alkanes (ethane, propane, iso/n-butane and iso/n-pentane) in the area. These compounds are some of the least reactive in terms of ground level ozone formation, but the large quantities of these compounds increase the potential for ozone formation. Light alkanes are not considered hazardous air pollutants (HAPs), so they are of lesser concern with respect to health effects.

Some of the less abundant SNMOCs - including the heavy alkane methylcyclohexane; the aromatics toluene and m/p-xylene; and the alkenes isobutene, ethylene, and propylene - indicated high ozone formation potential. These compounds were measured in much lower quantities than the light alkanes, but can more readily contribute to ozone formation due to higher reactivity. Sources for these compounds include gasoline, diesel, fire sources, and oil and gas production.

1.0 INTRODUCTION

Oil and gas exploration and production within the Piceance Basin in Colorado, and elsewhere in the Rocky Mountain region, has undergone rapid growth over the last decade. In response to this growth, concerns have grown regarding air quality across Garfield County. Additionally, industrial growth has contributed to an overall growth in population resulting in a greater number of air quality sources in Garfield County.

The Garfield County Public Health Department (GCPHD) is committed to protecting the health and welfare of its citizens. In 2005, in response to citizen concerns, the GCPHD enhanced air quality monitoring efforts to evaluate levels of particulate matter < 10 micrometers in diameter (PM_{10}) and volatile organic compounds (VOCs) in the area. In 2008, the monitoring network was modified to encompass speciated non-methane hydrocarbons (SNMOC) and carbonyl compounds and the regulatory monitoring network expanded from PM_{10} to include particulate matter < 2.5 micrometers in diameter ($PM_{2.5}$) and ozone (O_3). These changes were designed to serve a wide range of purposes, including monitoring of criteria pollutant levels, ozone formation potential, toxics assessments, and source attribution.

The 2010 monitoring network in Garfield County consisted of five (5) monitoring locations, with four (4) stations operating concurrently. Characteristics of the monitoring locations are described below.

- Parachute (PACO): Parachute is a small urban center of approximately 1,300 people within very close proximity to oil and development and production activities. The town is located along Interstate 70 and is the transportation hub for heavily traveled roads which service the surrounding canyons.
- Rifle (RICO): Rifle is a rapidly growing urban center on the Interstate 70 corridor with estimated population of about 9,200 people. Rifle is in close proximity to oil and gas development activities, and is also central to industrial support for the oil and gas industry.
- Bell-Melton (BRCO): The Bell-Melton site is a rural homestead approximately four miles south of the town of Silt, in close proximity to moderate oil and gas development and heavy natural gas production.
- Rulison (RUCO): Rulison is a rural community located about nine miles northeast of Parachute and five miles southwest of Rifle along Interstate 70. This site began operation in January 2009 amid substantial natural gas development and production activities. Equipment at this site was relocated to the Battlement Mesa location in September 2010.
- Battlement Mesa (BMCO): Battlement Mesa is a rural community located about 1.5 miles southeast of Parachute. This site began operation in September 2010 in response to a proposed large natural gas development within to community, and to begin developing baseline data in advance of the project.

Figure 1-1 is a map of the monitoring sites in Garfield County and Table 1-1 lists the parameters monitored. The Garfield County Public Health Department (GCPHD) monitors pollutants and meteorology at these stations with technical support from several agencies. Filter based PM_{10} monitors in Rifle and Parachute are operated by the GCPHD, with filter analysis

supported by the Colorado Department of Public Health and Environment (CDPHE). SNMOC and carbonyl compounds are sampled at all sites and analyzed by the Eastern Research Group, Inc. (ERG). The GCPHD monitors meteorology at the Bell-Melton sites, Rulison and Battlement Mesa sites. Air Resource Specialists, Inc. (ARS) supports monitoring, data collection and data validation for continuous PM_{10} and $PM_{2.5}$, O_3, and meteorology at the Rifle site, and meteorology at the Parachute site. GCPHD also operates a digital Web camera at the Rifle site. Camera images are collected every 15-minutes and displayed on the Garfield County Air Quality Monitoring Web site (http://www.garfieldcountyaq.net), along with associated data.

Figure 1-1. Map of Garfield County Monitoring Sites.

Table 1-1

Garfield County
Parameters Monitored by Site

Component	Method	Sampling Frequency	Supporting Agency
Rifle, Colorado			
SNMOC	TO-12	24-hour (1/6 day)	ERG
Carbonyls	TO-11A	24-hour (1/12 day)	ERG
PM_{10}	FRM	24-hour (1/3 day)	CDPHE
PM_{10}	TEOM	Hourly	ARS
$PM_{2.5}$	TEOM	Hourly	ARS
Ozone	42C	Hourly	ARS
Meteorology	Various	Hourly	ARS
Visibility Web Camera	Digital	15-min	ARS
Parachute, Colorado			
SNMOC	TO-12	24-hour (1/6 day)	ERG
Carbonyls	TO-11A	24-hour (1/12 day)	ERG
PM_{10}	FRM	24-hour (1/3 day)	CDPHE
Meteorology	Various	Hourly	GCPHD
Bell-Melton, Colorado			
SNMOC	TO-12	24-hour (1/6 day)	ERG
Carbonyls	TO-11A	24-hour (1/12 day)	ERG
Meteorology	Various	Hourly	GCPHD
Rulison, Colorado (discontinued 9/12/2010)			
SNMOC	TO-12	24-hour (1/6 day)	ERG
Carbonyls	TO-11A	24-hour (1/12 day)	ERG
Meteorology	Various	Hourly	GCPHD
Battlement Mesa, Colorado (began monitoring 9/18/2010)			
SNMOC	TO-12	24-hour (1/6 day)	ERG
Carbonyls	TO-11A	24-hour (1/12 day)	ERG
Meteorology	Various	Hourly	GCPHD

2.0 METEOROLOGICAL SUMMARIES

Meteorological data collected along with air quality parameters are used to better understand the local conditions and transport of air pollutants. Meteorological data collected at all sites include wind speed, wind direction, temperature, relative humidity, and precipitation.

Quarterly time series plots for all parameters collected during 2010 are presented in Appendix A. Equipment failure affected collection of meteorological data at the Bell-Melton site, with data collection temporarily discontinued in November 2010 due to power issues. Equipment at the Parachute site was upgraded in March 2010, and Garfield County is in the process of updating the meteorology network at the other stations to improve data collection.

Figures 2-1 through 2-5 present wind roses showing the frequency of hourly wind speed and direction for the Garfield County monitoring sites in 2010. The direction of the bar signifies the direction the wind is coming from, the length of the bars indicate the cumulative frequency for each direction, and the colors indicate wind speed.

Winds at the Garfield County sites are influenced by flow along the Colorado River Basin, where Interstate 70 crosses through the county. Also, local flow is influenced by various drainage flow through valleys along various Colorado River tributaries. General wind pattern observations for each site are as follows:

- Winds at the Parachute site were most frequently from the southwest and north-northeast/northeast and northwest, corresponding to flows up and down the Colorado River Valley, and also drainage flow along Parachute Creek.
- Winds at the Rifle site were scattered, with highest frequency out of the north, along Rifle Creek, and from the west-southwest up the Colorado River Valley.
- The Bell-Melton site is located south of Interstate 25, and predominant winds at the site measured from the southeast along CR331/Dry Hollow Creek.
- Winds at the Rulison site were also up and down the Colorado River Valley, with winds predominantly from the south-southwest and north-northeast.
- Winds at the Battlement Mesa site also roughly corresponded to the Colorado River Valley, with winds predominantly from the south-southwest and northeast.

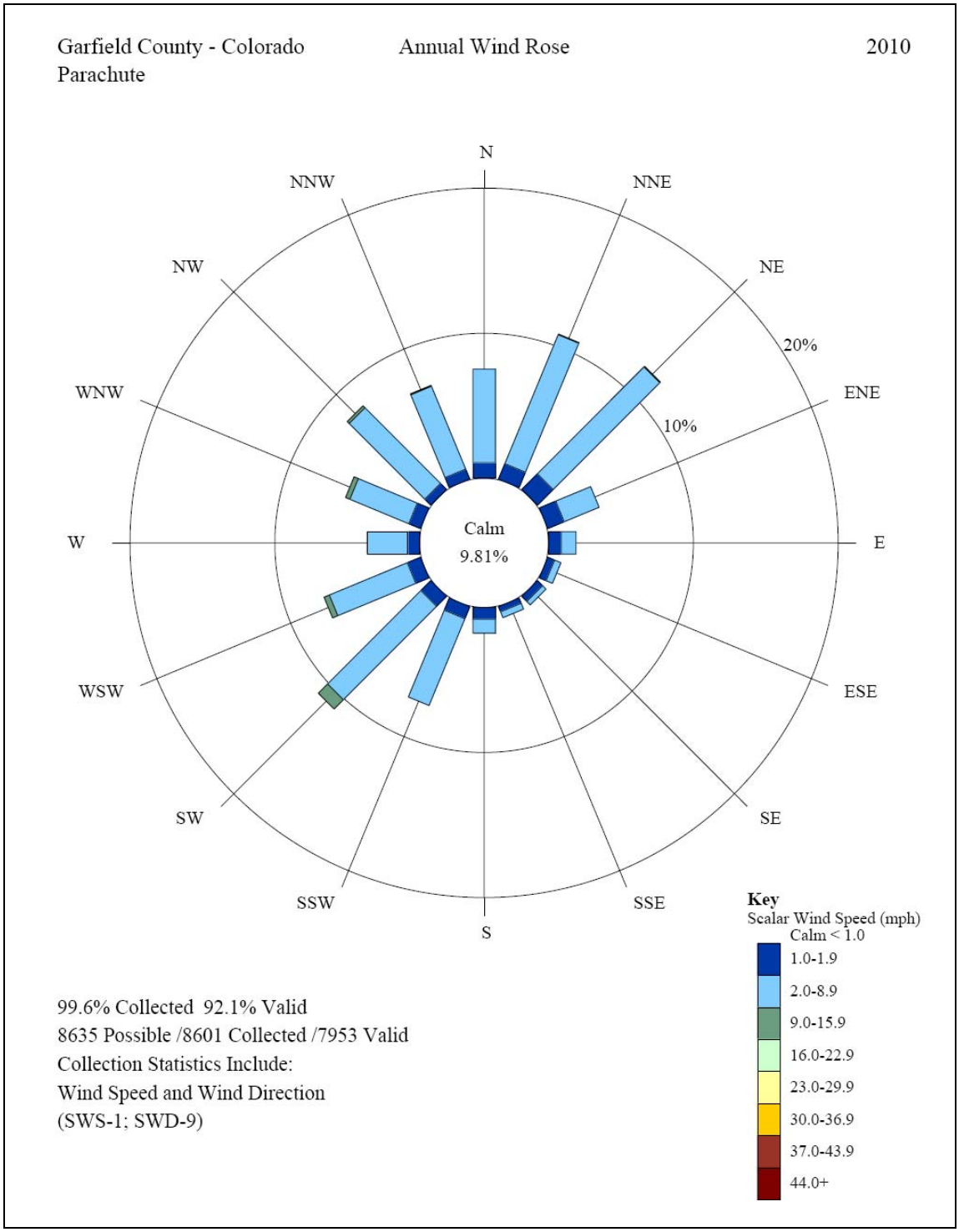

Figure 2-1. 2010 Wind Rose for the Parachute Monitoring Site.

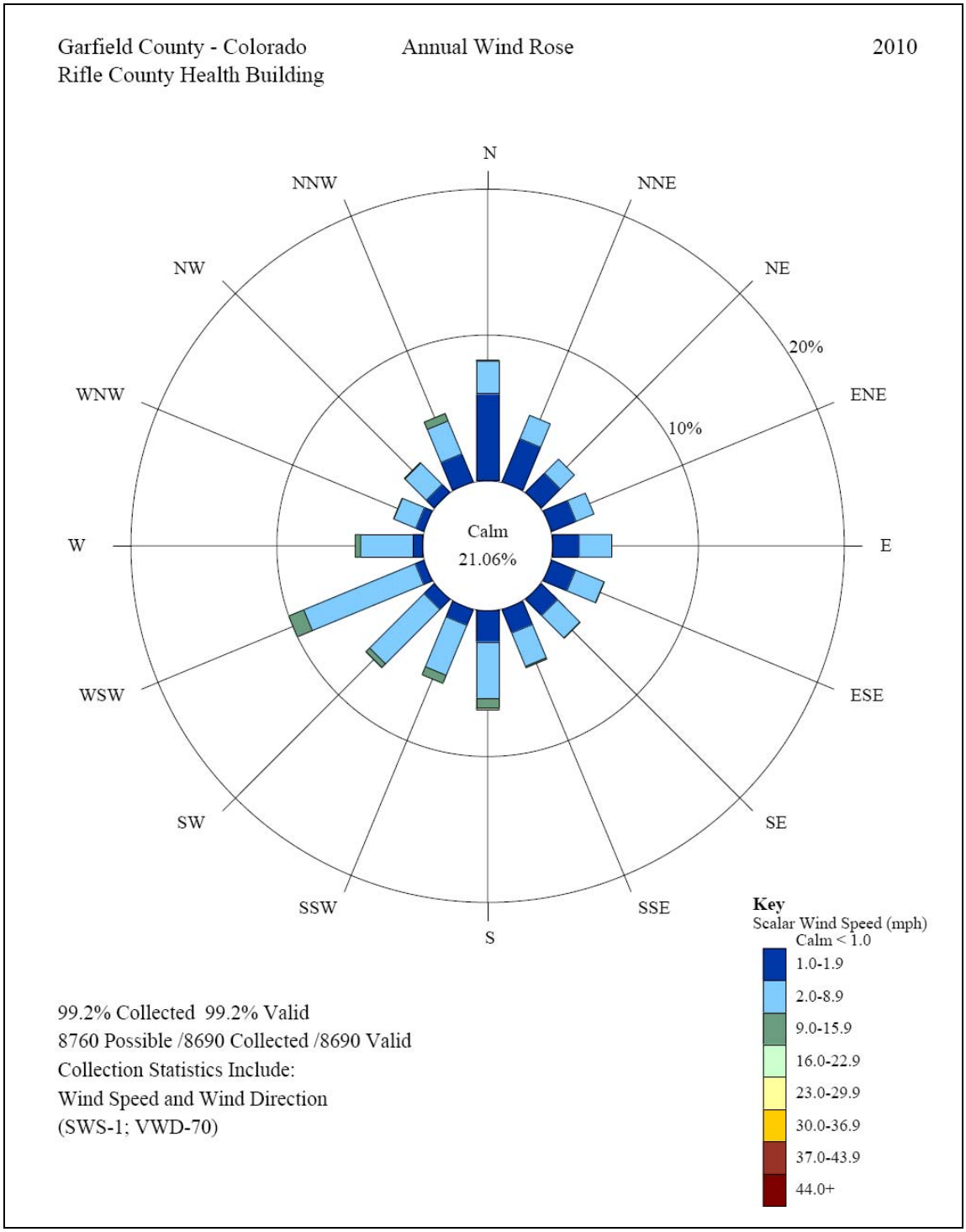

Figure 2-2. 2010 Wind Rose for the Rifle Monitoring Site.

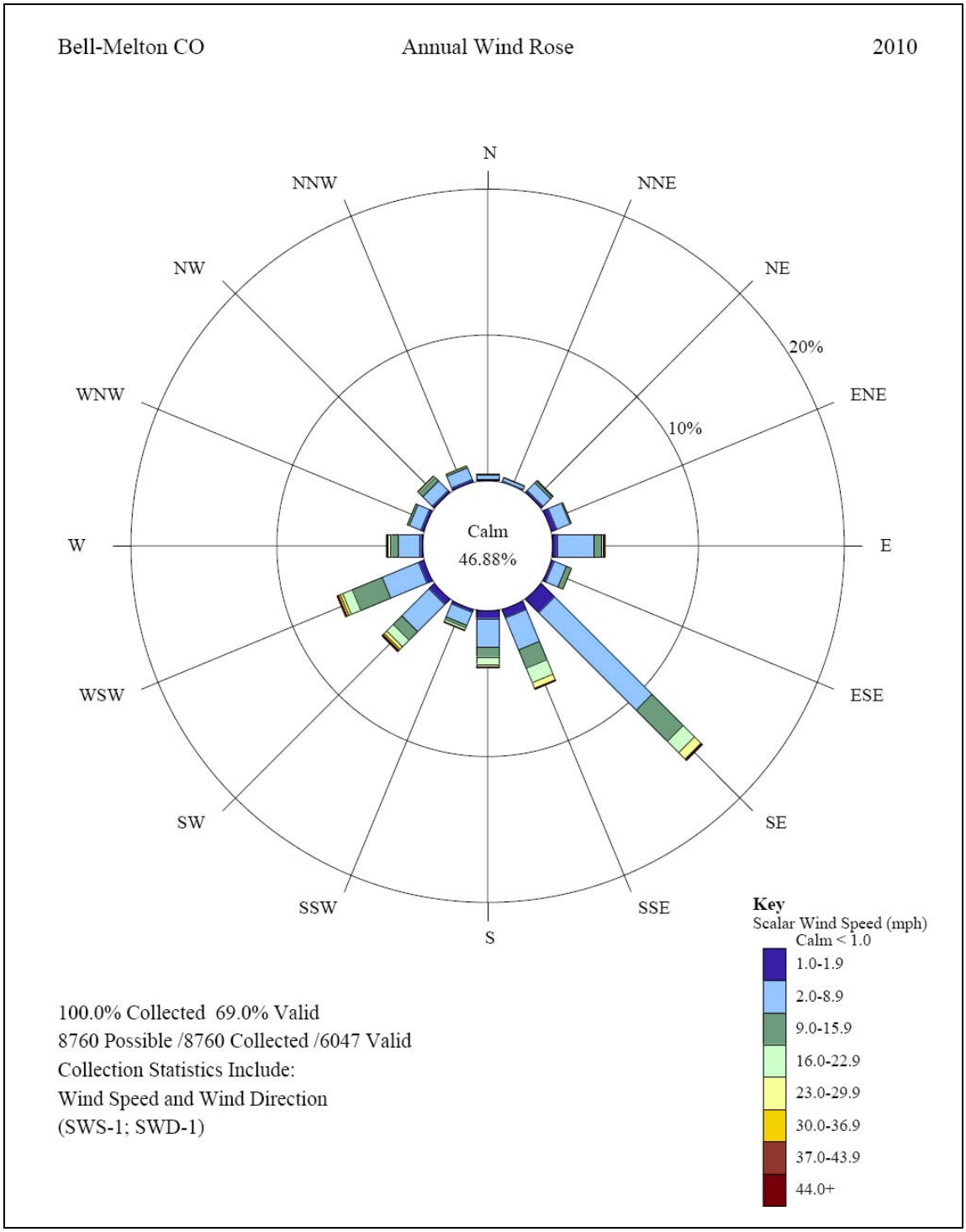

Figure 2-3. 2010 Wind Rose for the Bell-Melton Monitoring Site.

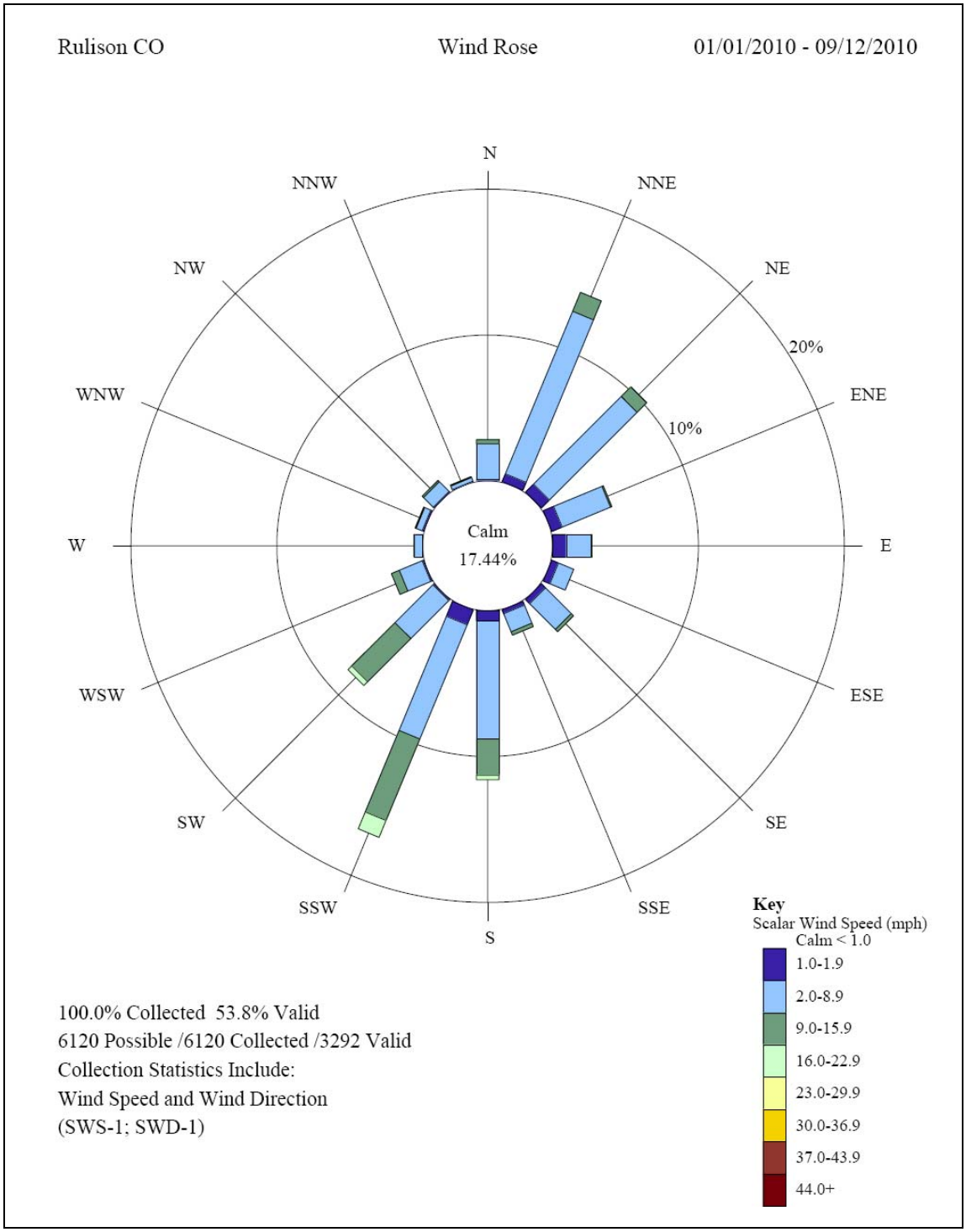

Figure 2-4. 2010 Wind Rose for the Rulison Monitoring Site.

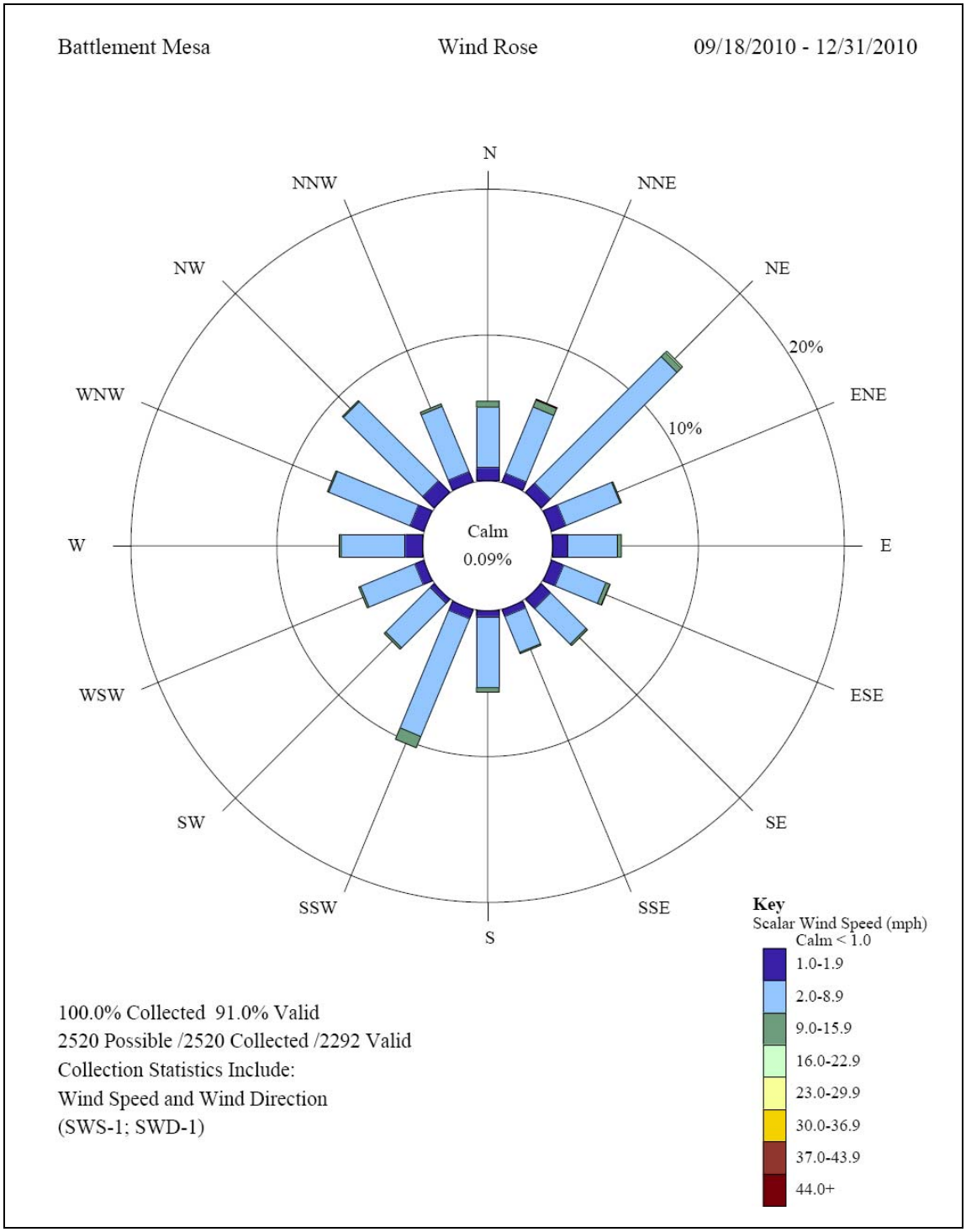

Figure 2-5. 2010 Wind Rose for the Battlement Mesa Monitoring Site.

2.1 RESIDENCE TIME MAPS

Some pollutants affecting air quality are emitted locally, while others may be transported from other regions. Fires on the West Coast can affect air quality in Garfield County, and regional dust can be transported from semi-arid regions in the southwest. Some air toxics can also persist in the atmosphere long enough to be transported from other regions. Atmospheric lifetimes are characterized for some VOC compounds, and are highly variable depending on the reactivity of the compound and other removal pathways. Benzene, for example, can have a lifetime of up to 84 hours in the atmosphere before oxidizing; formaldehyde for up to 26 hours; and 1,3-butadiene for about 2.8 hours (http://www.scorecard/chemical-profiles/).

Meteorological back trajectories ending at the Rifle site were generated to identify the geographic areas that may influence long range transport of pollutants. Back trajectory analyses use interpolated measured or modeled meteorological fields to estimate the most likely central path over geographical areas that provided air to a receptor at a given time. The method essentially follows a parcel of air backward in hourly steps for a specified length of time. Back trajectories account for the impact of wind direction and wind speed on delivery of emissions to the receptor but do not account for chemical transformation, dispersion, and deposition of emissions.

Trajectories were generated using the Hybrid-Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model developed by the National Oceanic and Atmospheric Administration's (NOAA) Air Resources Laboratory (ARL). Detailed information regarding the trajectory model and these data sets can be found on NOAA's Web site (http://www.arl.noaa.gov/ready/hysplit4.html). Four back trajectories were generated per day, with end times of 0000, 0600, 1200, and 1800 MST, with end heights of 500 meters. Each hourly point along 72-hour back trajectory paths were binned and summed into 1/4 degree horizontal grid cells of latitude and longitude, and plotted as a residence time where different colors indicate the percent of total back trajectories that traversed each longitude latitude grid cell.

Figure 2-6 presents a map of the 2010 residence time for the Rifle site in Garfield County. One general path of influence comes from the northwest, through Utah and Idaho. Another more pronounced path is from the south-southwest through Utah and Arizona. Figure 2-7 presents quarterly residence time maps, which follow the same general pattern as the annual map, with the Utah-Idaho path more prominent during summer months, and the Arizona-Utah path more prominent during the winter months. Very few back trajectories originate east of Rifle, with the largest eastern influence occurring during the third quarter. Because back trajectories only account for wind speed and wind direction, they contain only information on possible atmospheric transport paths, but no information on location of sources or atmospheric lifetime of pollutants.

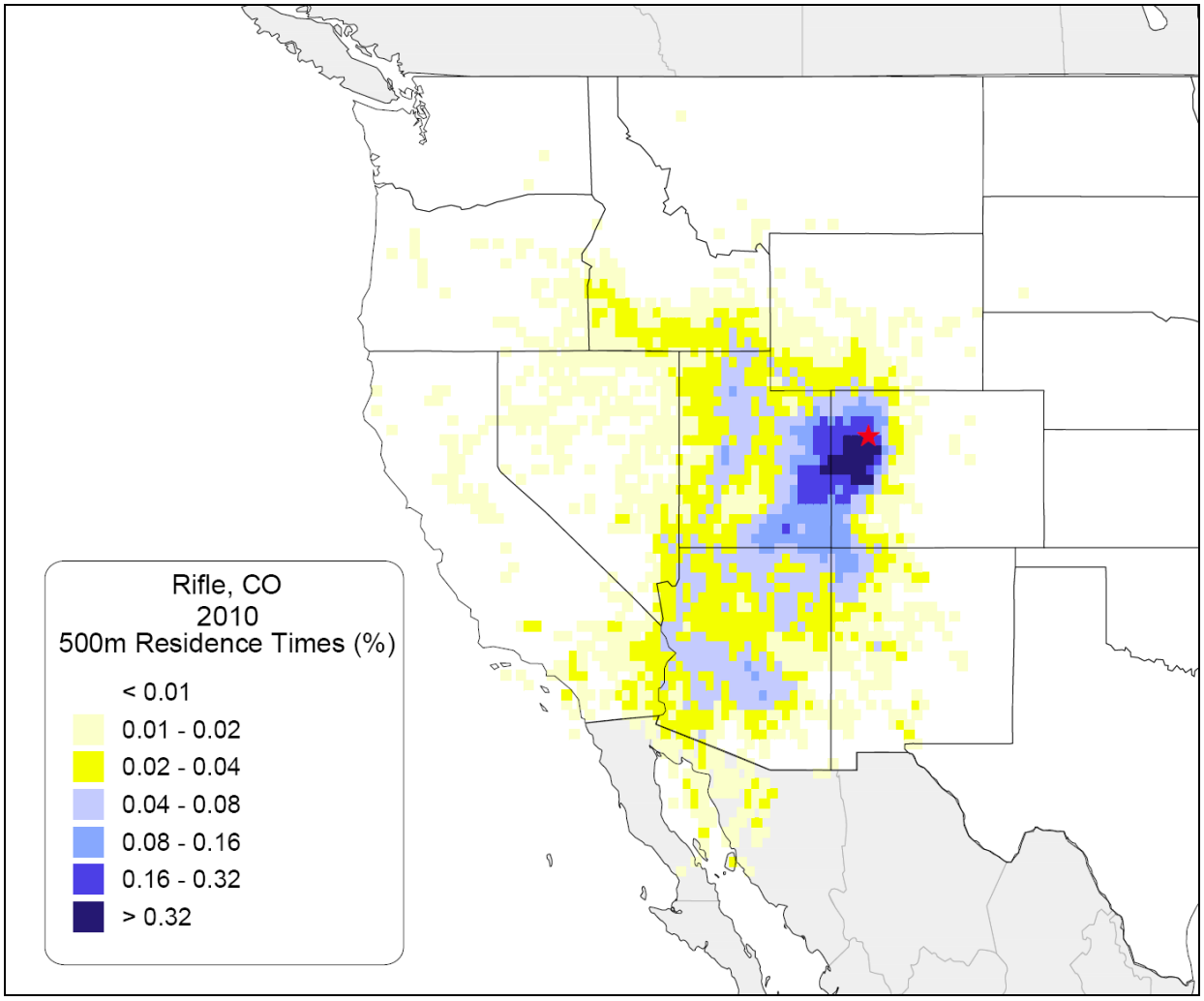

Figure 2-6. 2010 Residence Time Map for Rifle Monitoring Site in Garfield County.

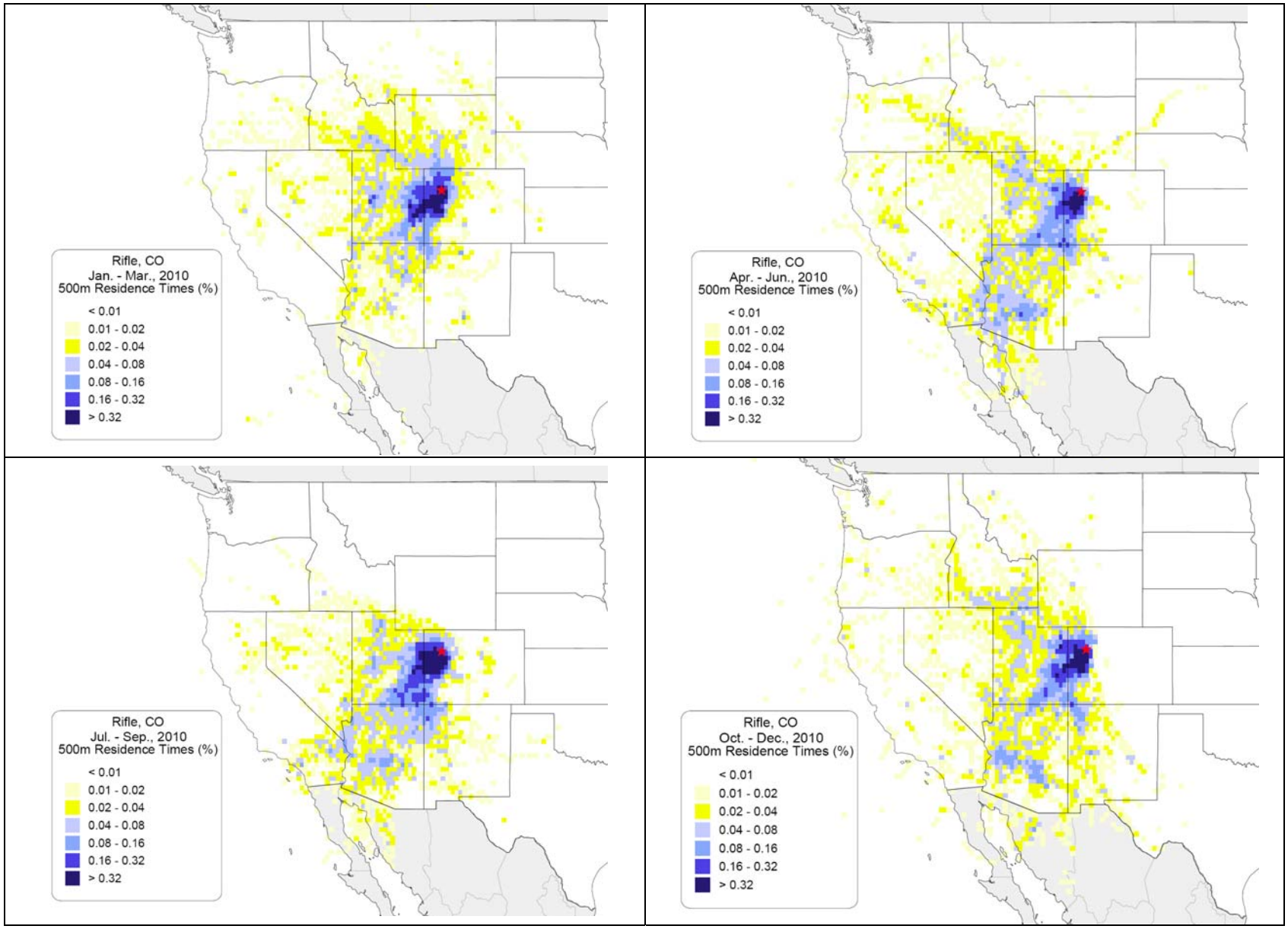

Figure 2-7. 2010 Quarterly Residence Time Maps for Rifle Monitoring Site in Garfield County.

3.0 CRITERIA POLLUTANT SUMMARIES

The Clean Air Act requires EPA to set two types of NAAQS for ground-level O_3, particle pollution ($PM_{2.5}$ and PM_{10}), lead, NO_2, carbon monoxide (CO), and sulfur dioxide (SO_2). The types of standards are as follows:

- Primary Standards: These standards are designed to protect public health with an adequate margin of safety, including the health of sensitive populations such as asthmatics, children, and the elderly.

- Secondary Standards: These standards are designed to protect public welfare from adverse effects, including visibility impairment and effects on the environment (e.g., vegetation, soils, water, and wildlife).

Filter-based PM_{10} measurements have been made every third day at the Parachute and Rifle sites for several years. Garfield County began monitoring continuous $PM_{2.5}$ and PM_{10} at the Rifle site in September 2008. The level of the national primary and secondary ambient air quality standards for PM_{10} is a 24-hour average concentration of 150 micrograms per cubic meter ($\mu g/m^3$). A violation of the standard would occur if the number of days with a 24-hour average concentration above 150 $\mu g/m^3$ over a 3-year period is equal to or greater than one. The standards for $PM_{2.5}$ are an annual arithmetic mean of 15 $\mu g/m^3$ and a 24-hour average of 35 $\mu g/m^3$. A violation of the $PM_{2.5}$ standard occurs when the 3-year average of the weighted annual mean exceeds that annual standard, or the 3-year average of the 98th percentile 24-hour average value exceeds the 24-hour standard.

O_3 monitoring began at the Rifle site in June 2008. The current NAAQS for O_3 is 0.075 ppm (75 ppb) over an 8-hour period. An exceedance of the standard occurs when an 8-hour average O_3 concentration is greater than or equal to 76 ppb. A violation of the standard occurs when the 3-year average of the fourth highest daily maximum 8-hour average ozone concentration equals or exceeds 76 ppb.

Values measured for O_3, $PM_{2.5}$, and PM_{10} in 2010 at the Rifle site are presented with corresponding NAAQS in Table 3-1. PM_{10} measured at the Parachute site is presented in Table 3-2. At present, air quality measurements in Garfield County do not violate air quality standards for these criteria pollutants.

Table 3-1

2010 Standards Summary for the Rifle Site

Parameter	NAAQS		Measured		
	Averaging Time	Standard	Measured Value		Date(s)
Ozone (O_3)	Rolling 8-hour	0.075 ppm/ 75 ppb*	Highest Daily Max.:	69 ppb	5/29
			4th Highest Daily Max.:	66 ppb	4/14, 4/15, 6/23
Particulate Matter ≤2.5µm ($PM_{2.5}$)	Annual	15 µg/m^3	Arithmetic Mean:	8.7 µg/m^3	1/1-12/31
	24-hour	35 µg/m^3	Highest Max 24-hr:	29.0 µg/m^3	1/3
			98th percentile 24-hr:	24.5 µg/m^3	1/2
Particulate Matter ≤10µm (PM_{10})	24-hour	150 µg/m^3**	Highest Daily Max 24-hr:	59 µg/m^3	5/29
			2nd Highest Daily Max. 24-hr:	55 µg/m^3	6/16

*To attain the O_3 standard, the 3-year average of the fourth-highest daily maximum 8-hour average O_3 concentrations must not exceed the standard.

**To attain the PM_{10} standard, the average cannot exceed the standard more than once per year on average over 3 years.

Table 3-2

2010 Standards Summary for the Parachute Site

Parameter	NAAQS		Measured		
	Averaging Time	Standard	Measured Value		Date(s)
Particulate Matter ≤10µm (PM_{10})	24-hour	150 µg/m^3	Highest Daily Max. 24-hr:	125 µg/m^3	5/23
			2nd Highest Daily Max. 24-hr:	55 µg/m^3	11/19

3.1 OZONE (O_3)

Ozone is a secondary pollutant, meaning it is not emitted directly from sources, but is formed from photochemical interactions of VOCs and oxides of nitrogen (NO_X) in the presence of sunlight. The basic formation and depletion equations for O_3 are presented below:

NO_2 + sunlight → NO + O

O + O_2 + M → O_3 + M (where M is a non-reactive molecule required for this process)

NO + O_3 → NO_2 + O_2

Without the presence of VOCs, the diurnal cycle is a balanced reaction, with equal production and depletion of O_3. When VOCs are present, they can react with nitric oxide (NO) to produce NO_2, as follows:

NO + RO → NO_2 + RO_2 (where R represents a reactive VOC)

This effectively creates competition for NO, allowing O_3 to build up instead of being depleted by NO. Also, when NO reacts with hydrocarbons, additional NO_2 is produced without consuming O_3. The produced NO_2 can further react to produce more O_3.

It was previously thought that, due to the nature of ozone formation, elevated levels of ozone were only possible during hot summer months. Recently, high-ozone readings have been recorded during the wintertime in the Green River Basin in Wyoming, and the Uintah Basin in Utah. Wintertime ozone formation requires, along with VOC and NO_2 emissions, distinct meteorological conditions. The meteorological conditions associated with wintertime ozone include strong temperature inversions, low winds, snow cover, and bright sunlight.

Ozone measurements began in June 2008 at the Rifle site. Figures 3-1, 3-2, and 3-2 present daily maximum 8-hour averages of O_3 monitored at the site in 2008, 2009, and 2010, respectively, along with the NAAQS. Ozone measurements at the Rifle site are highest in the summer, and Rifle has not seen the wintertime ozone highs that have been observed in Wyoming and Utah.

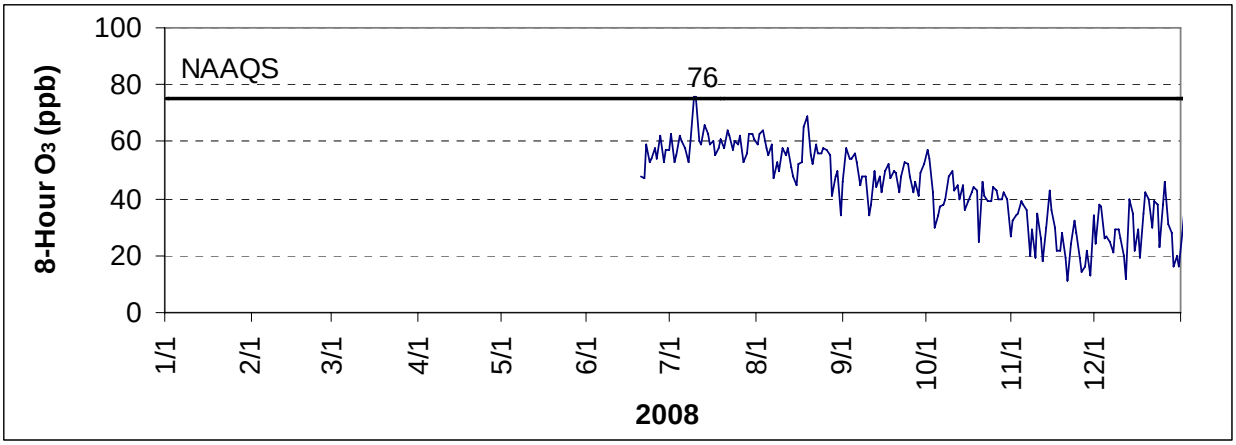

Figure 3-1. Daily Maximum 8-Hour Averages of Ozone Monitored at the Rifle Site in 2008.

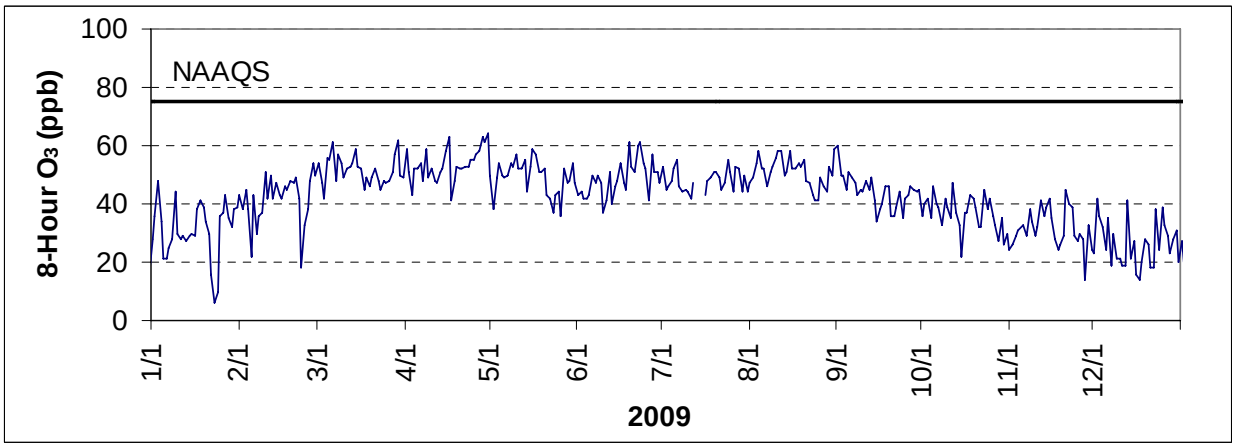

Figure 3-2. Daily Maximum 8-Hour Averages of Ozone Monitored at the Rifle Site in 2009.

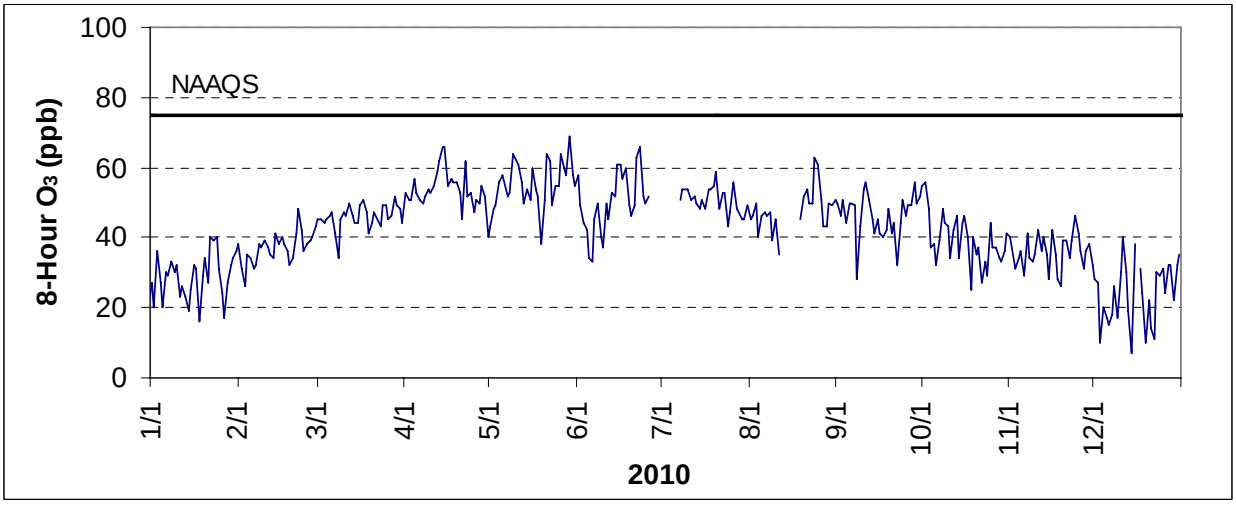

Figure 3-3. Daily Maximum 8-Hour Averages of Ozone Monitored at the Rifle Site in 2010.

Table 3-3 presents the highest daily maximum O_3 measurements in 2010. No exceedances were recorded in 2010. A violation of the standard does not occur unless the 3-year average of the 4th highest daily maximum values is greater than 75 ppb.

Table 3-3

Rifle Site
Ten Highest Daily Maximum 8-Hour Ozone Averages in 2010

Level	Date	Daily Maximum 8-Hour Ozone (ppb)
1	5/29/2010	69
2	4/14/2010	66
3	4/15/2010	66
4*	6/23/2010	**66**
5	5/9/2010	64
6	5/21/2010	64
7	5/26/2010	64
8	6/22/2010	63
9	4/13/2010	62
10	4/22/2010	62

* The 3-year average of the 4th highest daily maximum is used to determine attainment status.

Figure 3-4 presents a pollutant rose for the Rifle site for O_3 measured in 2010. A pollutant rose shows the frequency of wind direction and uses different shading to represent O_3 values. The wind rose indicates that highest concentrations of O_3 were measured when winds were between the west-southwest and south.

Figure 3-5 presents the diurnal cycle of measured hourly O_3 at the Rifle station. The cycle shows lowest concentrations in the early morning hours and maximum concentrations in the late afternoon. This pattern results from daytime photochemical production from NO_X ($NO + NO_2$) and VOC precursors, and ozone loss by dry deposition and reaction with NO at night.

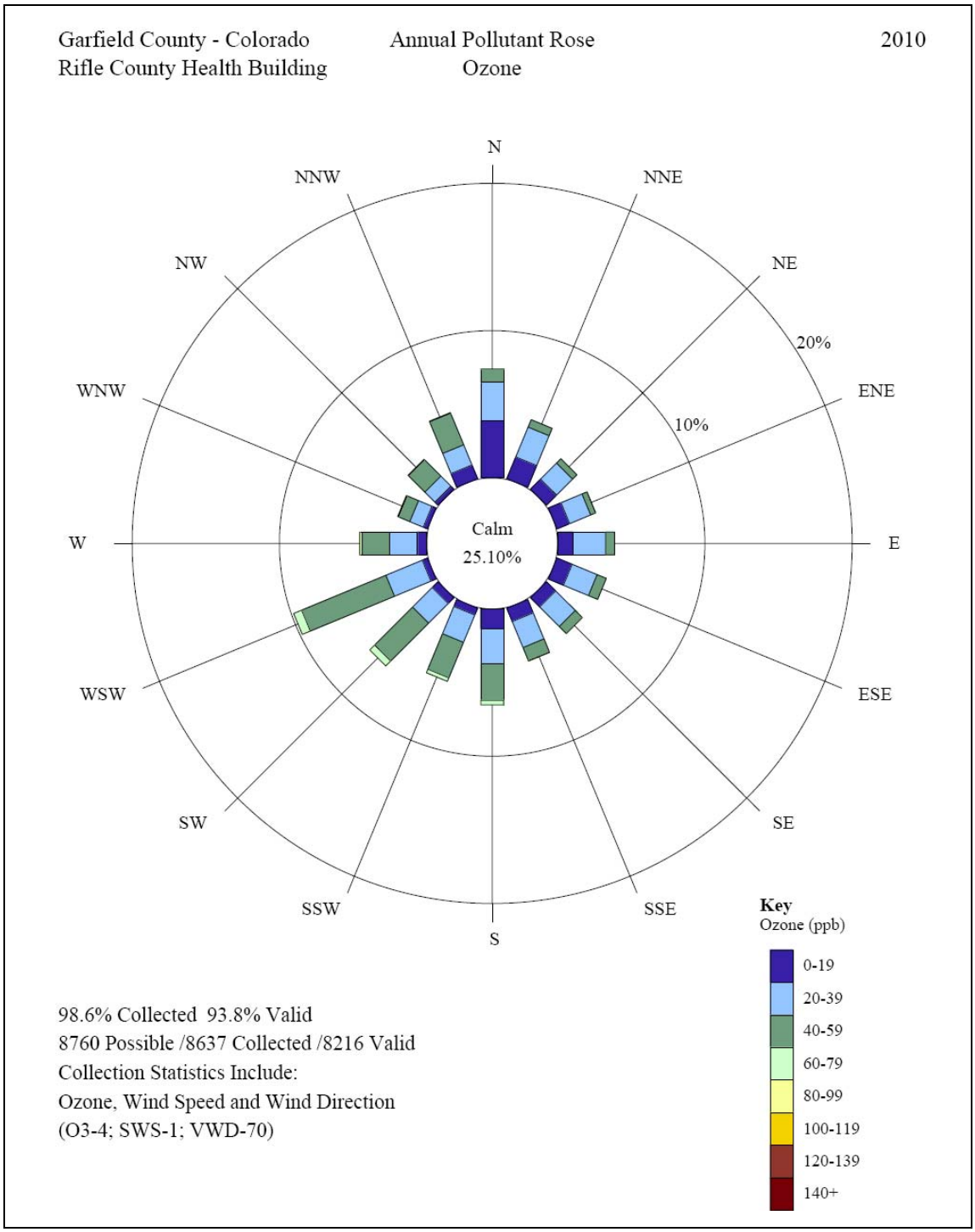

Figure 3-4. 2010 Pollutant Rose for Ozone Measurements at the Rifle Monitoring Site.

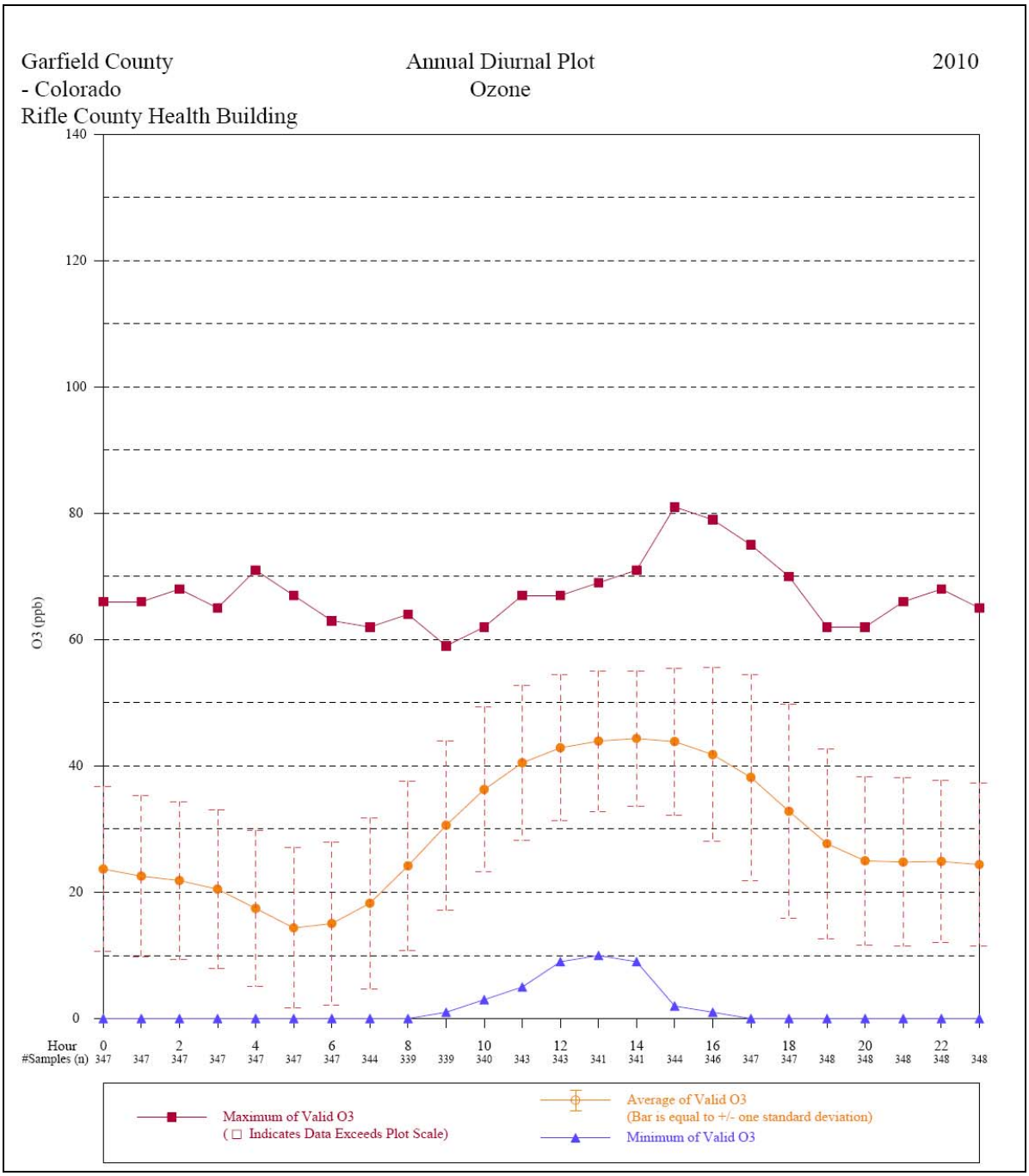

Figure 3-5. 2010 Diurnal Plot Showing Average Concentrations of Ozone at the Rifle Site.

3.2 PARTICULATE MATTER (PM_{10} AND $PM_{2.5}$)

The Parachute and Rifle sites monitor 24-hour PM_{10}. Continuous PM_{10} and $PM_{2.5}$ monitoring began at the Rifle site in September 2008.

3.2.1 Filter Based PM_{10} Measurements

Figure 3-6 presents the annual average PM_{10} measured at the Parachute site since 2000, and Figure 3-7 presents annual average PM_{10} measured at the Rifle site since 2005. At both the Rifle and Parachute sites, the highest average recorded PM_{10} was recorded in 2008, but measurements at this site have dropped since 2009.

Figures 3-8 and 3-9 present the highest and second highest 24-hour average values measured at the Parachute and Rifle sites, respectively. The NAAQS for PM_{10} is a 24-hour average of 150 ppb (shown on chart), which was exceeded at the Parachute site in 2008. No exceedances have been recorded at the Rifle site. An exceedance of the standard does not constitute a violation unless the average number of annual exceedances over a 3-year period is greater than or equal to 1.

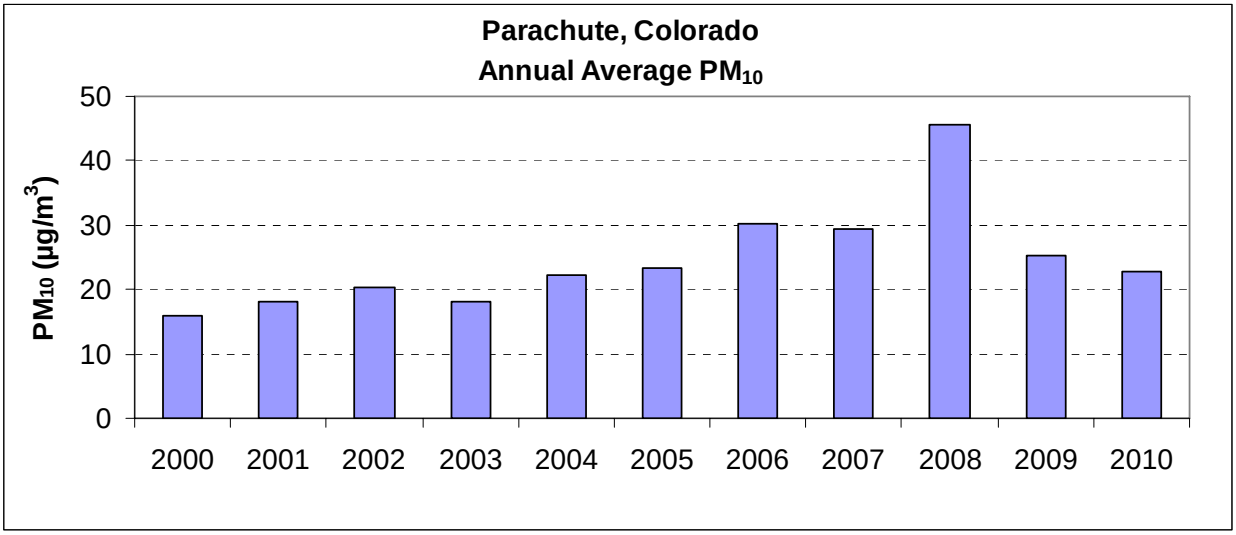

Figure 3-6. Annual Average PM_{10} Measured at the Parachute Site.

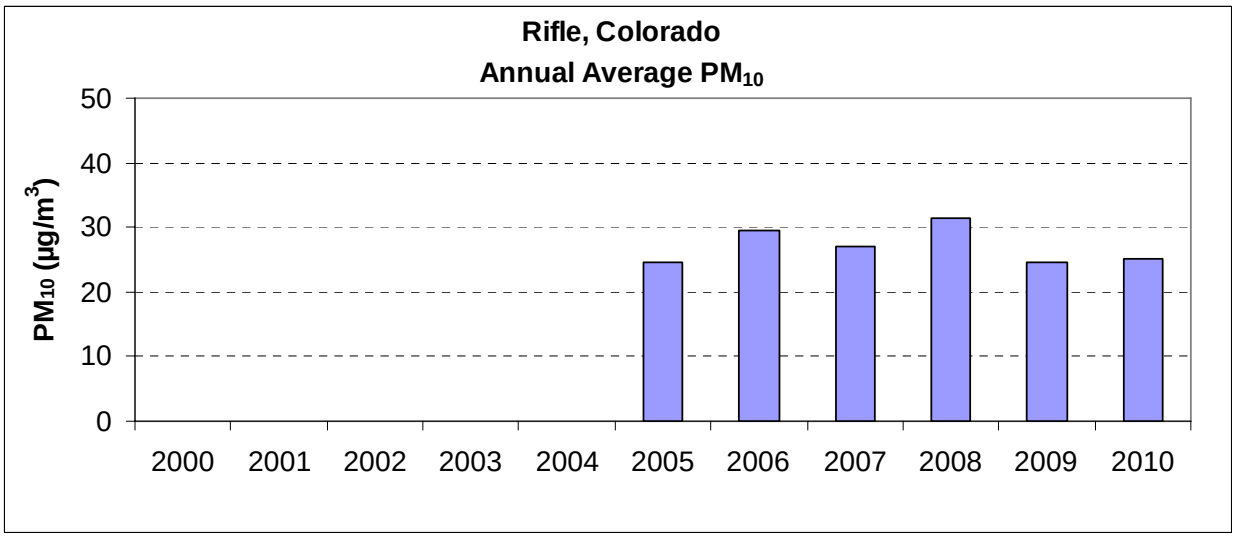

Figure 3-7. Annual Average PM_{10} Measured at the Rifle Site.

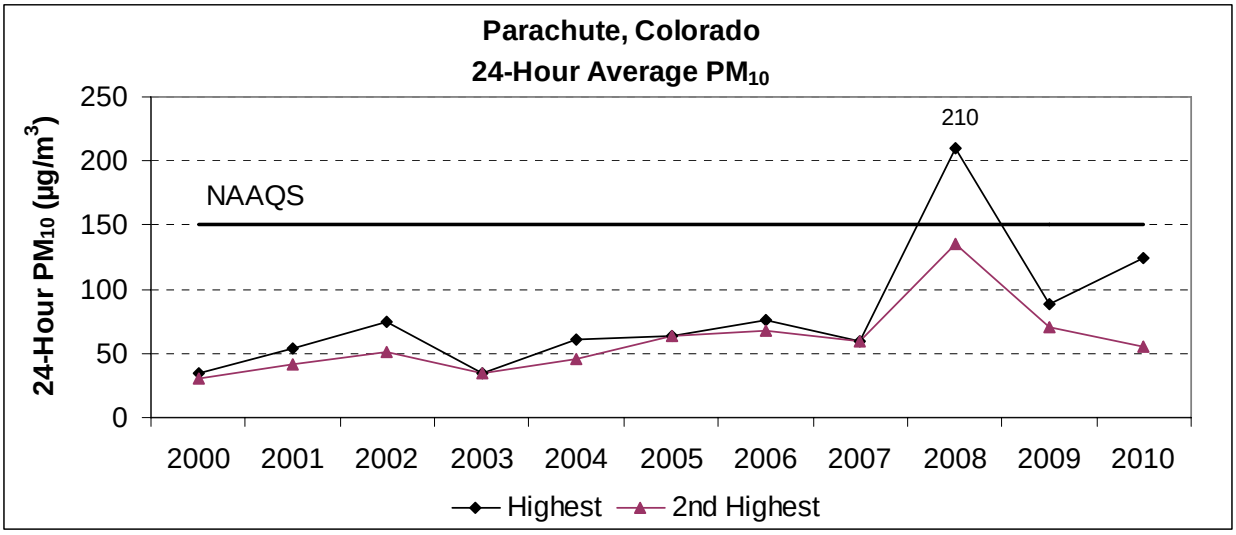

Figure 3-8. Highest and Second Highest 24-Hour Average PM_{10} Measured at the Parachute Site.

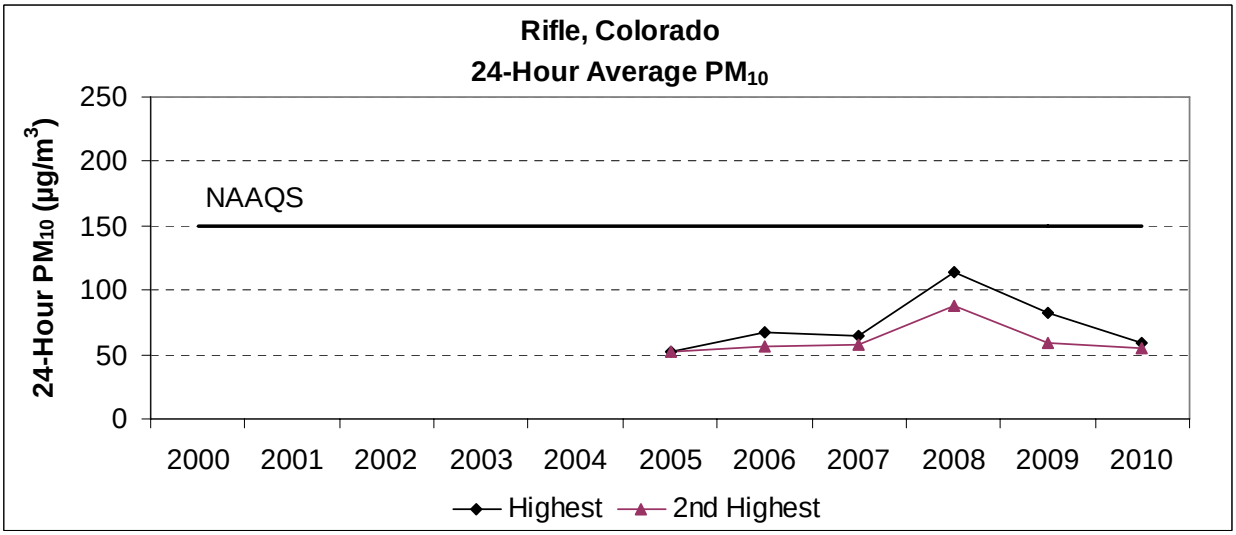

Figure 3-9. Highest and Second Highest 24-Hour Average PM_{10} Measured at the Rifle Site.

3.2.2 Collocated PM_{10} Measurements

Continuous PM_{10} is collocated with the filter based PM_{10} measurements at the Rifle site. Figure 3-10 presents a correlation plot comparing 24-hour averages from both methods showing correlation between the collocated methods, which is good (R^2=0.51), but lower than previous years because of the effect of a few outliers. The FRM data is useful for comparison to NAAQS, but is only available every third day in 24-hour averages. Continuous data are useful to assess particulate pollution because they are available on an hourly basis, and are available in real-time.

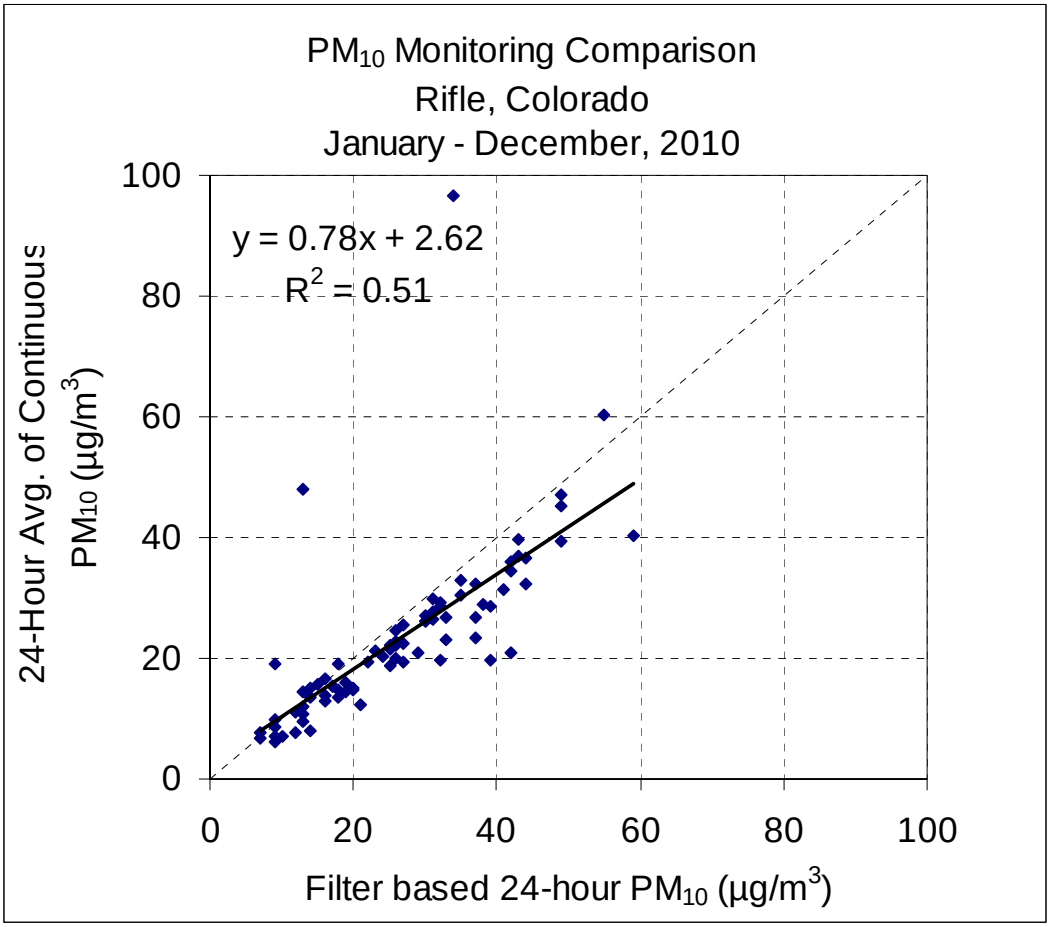

Figure 3-10. Correlation between Continuous and Filter Based Measurements at the Rifle Monitoring Site in 2010.

3.2.3 Continuous PM Measurements

Continuous PM_{10} and $PM_{2.5}$ are monitored at the Rifle site. Figure 3-11 is a pollutant rose showing wind direction and associated PM_{10} concentration measured, and Figure 3-12 is a pollutant rose for $PM_{2.5}$. The pollutant roses indicate that highest PM_{10} and $PM_{2.5}$ measurements occurred most frequently when winds were out of the north and south.

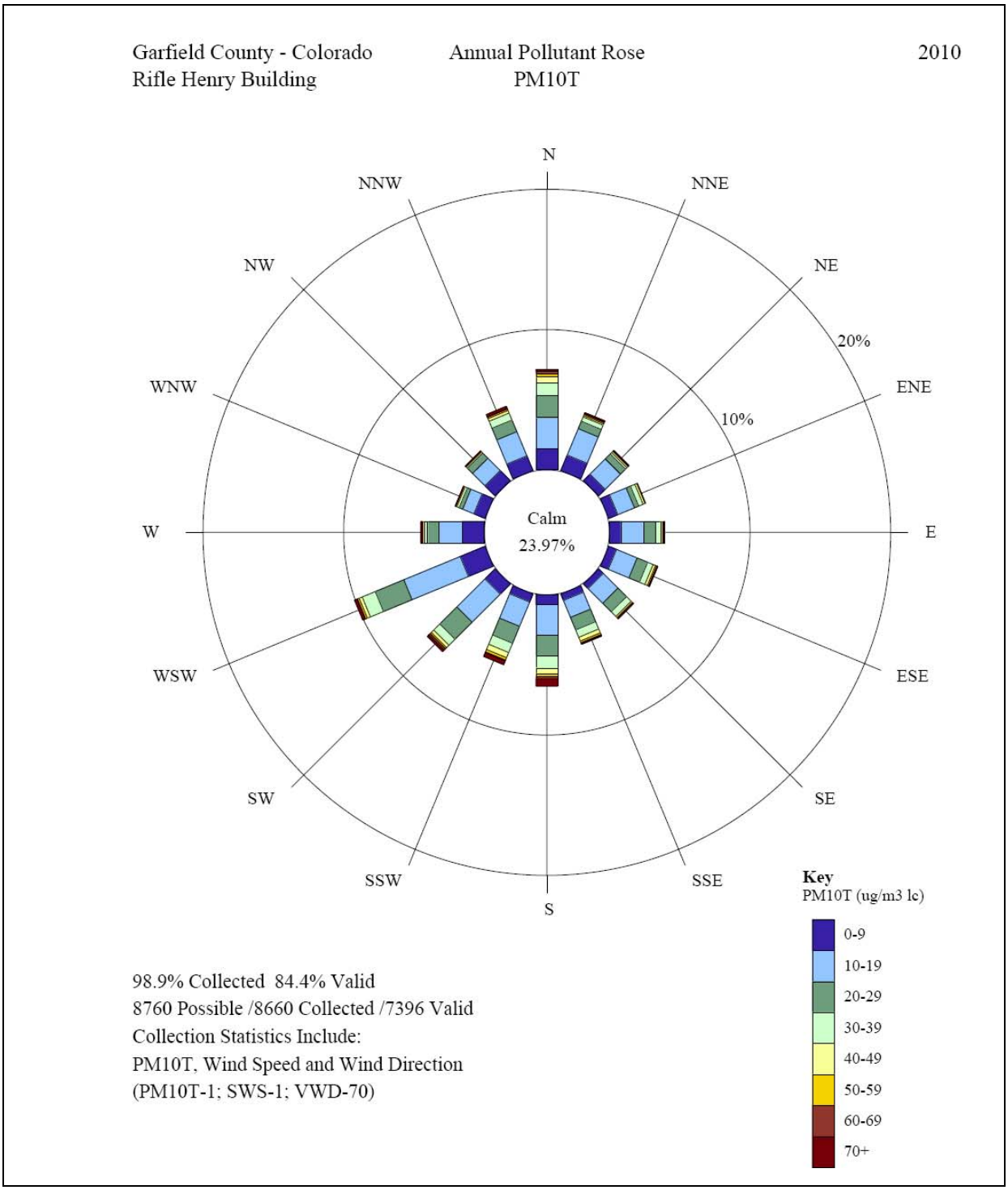

Figure 3-11. 2010 Pollutant Rose for PM_{10} Measurements at the Rifle Monitoring Site.

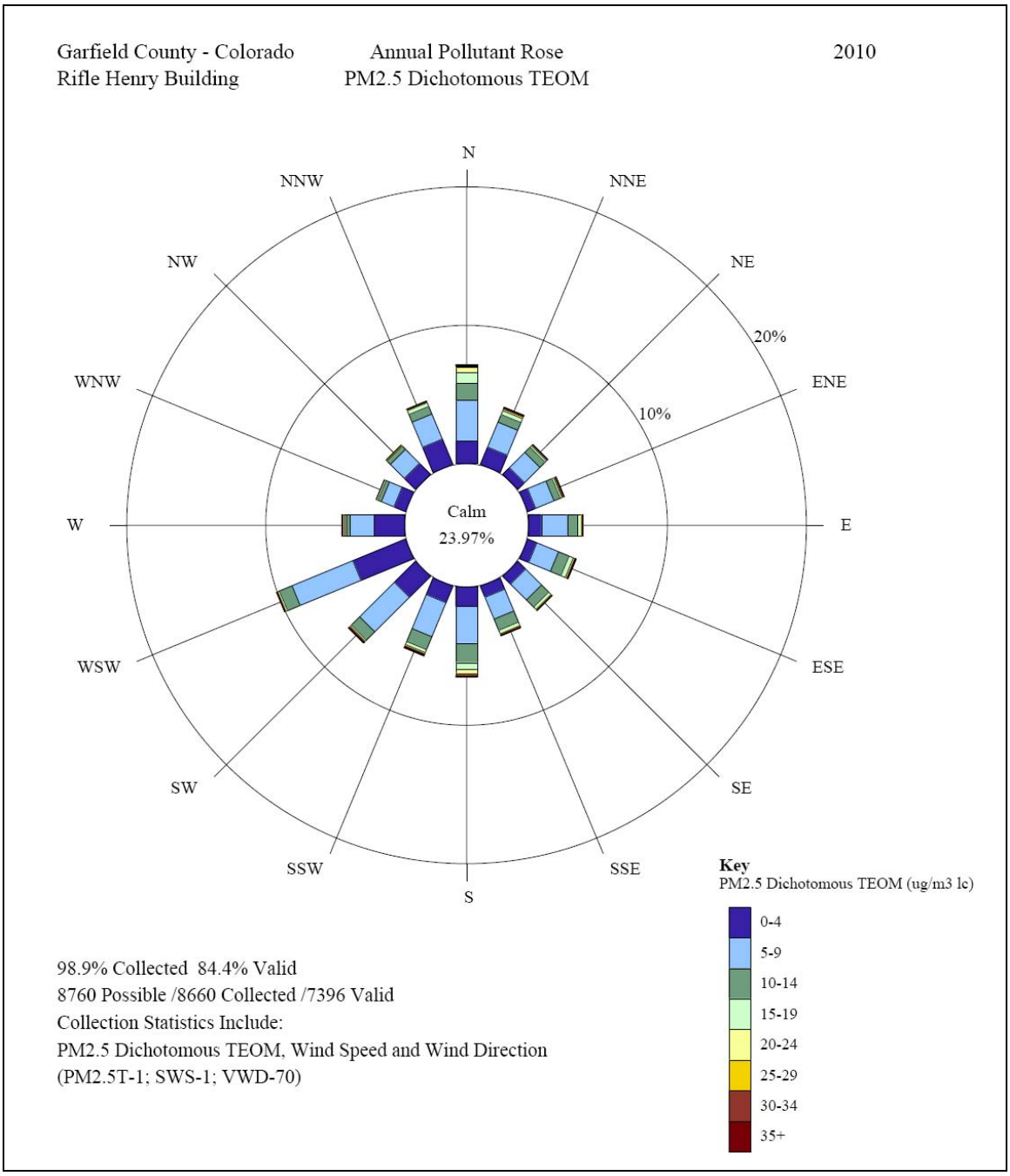

Figure 3-12. 2010 Pollutant Rose for $PM_{2.5}$ Measurements at the Rifle Monitoring Site.

Figure 3-13 presents a monthly average plot. Monthly averages of $PM_{2.5}$ were higher during the winter months, and PM_{10} was high in the winter and the spring. High PM measurements in the winter are affected by temperature inversions in the Colorado River Basin. These occur when snow cover and low winds promote the development of an inversion, where cold air is trapped under a layer of warmer air. Air pollutants can build up during inversions because of the limited atmospheric mixing. The passage of a storm front and the associated strong winds can break up the inversion and disperse pollutants. High PM_{10} measured during the spring were often affected by high winds which can entrain dust into the air.

Figure 3-14 presents an example of a temperature inversion in Garfield County which led to high particulate concentrations. The figure shows the 1-hour PM_{10} and $PM_{2.5}$ and 24-hour $PM_{2.5}$ measurements and several meteorological parameters measured between November 16 and November 26, 2010. The 24-hour NAAQS is also plotted. During this event, PM_{10} and $PM_{2.5}$ values were elevated between November 17 and 20, and winds were low. On November 21, the winds increased and broke up the inversion causing PM levels to drop.

Figure 3-15 presents an example of high springtime PM_{10} measured at the Rifle site in April 2010. During this period, PM_{10} was elevated on April 12 and 13 when wind speeds were high. After this period, winds calmed down, PM_{10} levels dropped and O_3 increased. The 8-hour O_3 averages measured during the more stagnant period between April 14 and 15 were the second highest 8-hour average recorded at the Rifle site in 2010, but still lower than the standard (75 ppb) at 66 ppb. VOC levels, which are generally highest in the winter, also were high on April 15, as shown in SNMOC summaries in Section 4, Figure 4-1.

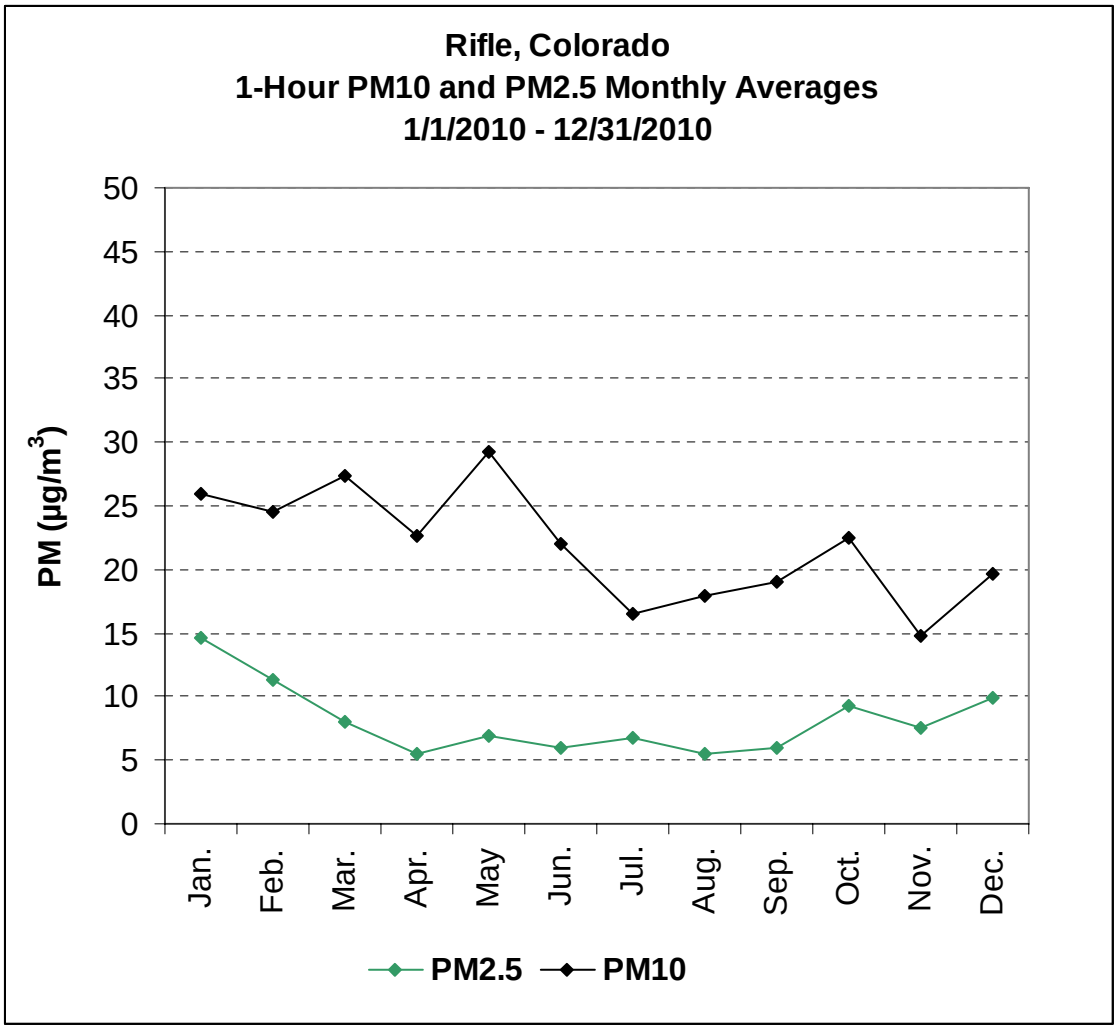

Figure 3-13. Monthly Average of Continuous Particulate Matter Measurements at the Rifle Monitoring Site in 2010.

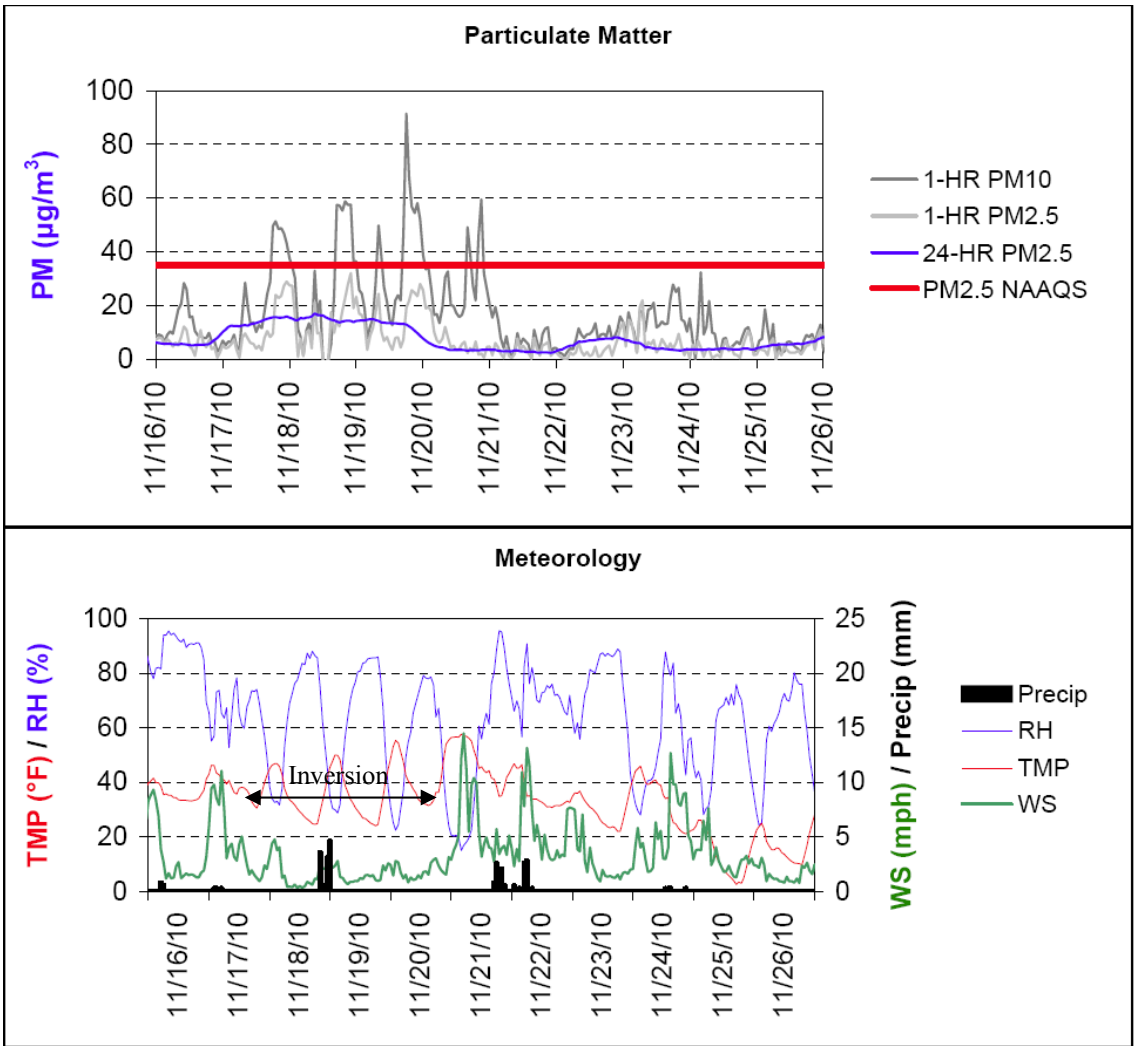

Figure 3-14. Hourly Particulate and Meteorological Measurements at the Rifle Monitoring Site between November 16, 2010 and November 26, 2010.

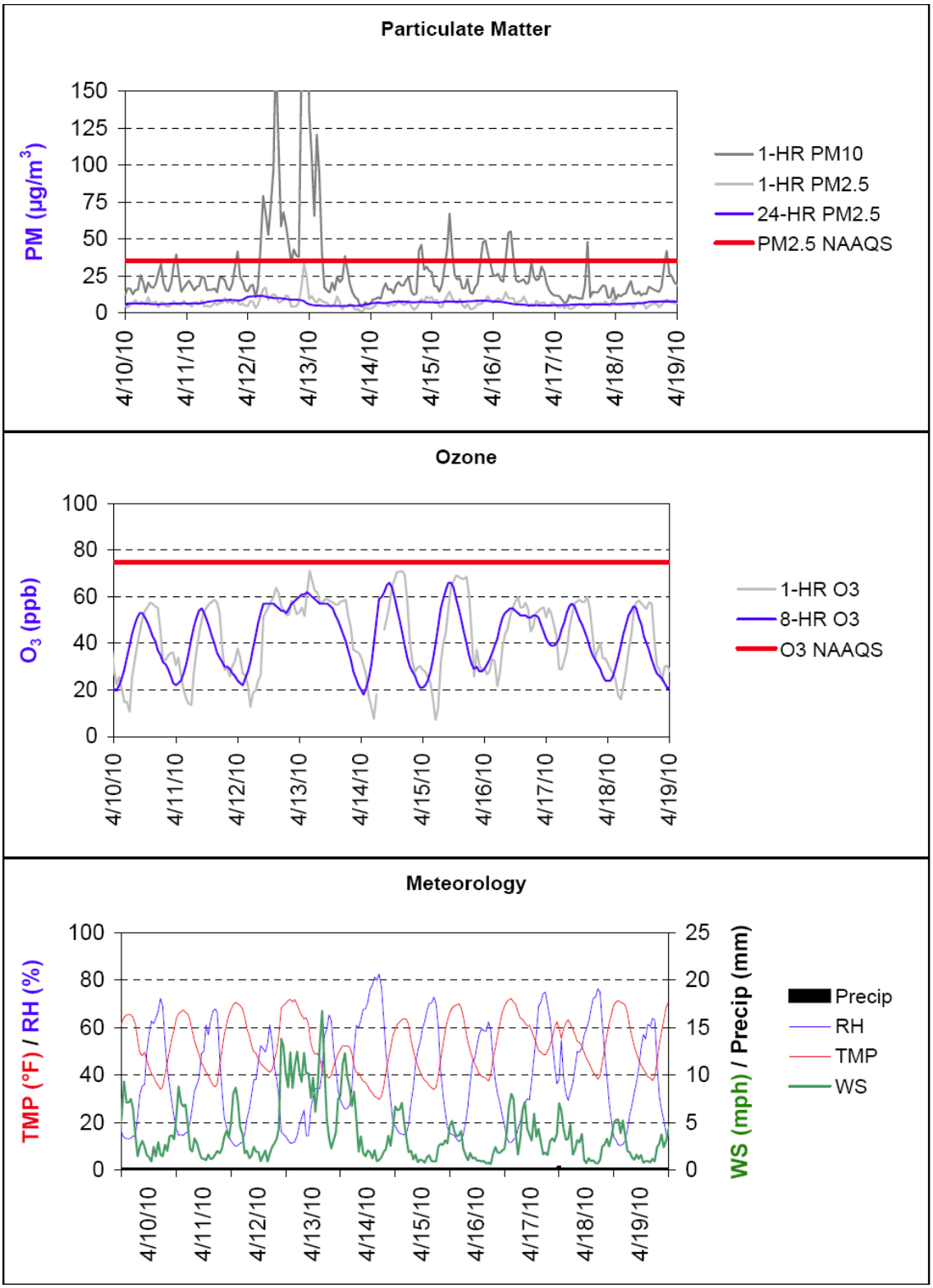

Figure 3-15. Hourly Particulate, Ozone and Meteorological Measurements at the Rifle Monitoring Site between April 10, 2010 and April 19, 2010.

4.0 SPECIATED NON-METHANE HYDROCARBONS (SNMOC) AND CARBONYL SUMMARIES

In 2010, SNMOCs and carbonyl compounds were monitored at all sites in Garfield County, with monitoring at the Battlement Mesa site beginning in September 2010, when equipment was relocated from the Rulison site. SNMOCs and carbonyl compounds are subsets of VOCs. VOCs are generally carbon- and hydrogen-based chemicals that exist in the gas phase or can evaporate from liquids. VOCs can react in the atmosphere to form O_3 and $PM_{2.5}$. HAPs are a subset of VOC compounds, and include compounds that are known or believed to cause human health effects at low doses. Summaries of SNMOCs, carbonyls, and HAPs levels measured in 2010 are presented in this section.

4.1 SPECIATED NON-METHANE HYDROCARBONS (SNMOC)

SNMOC compounds were collected and analyzed according to EPA Compendium Method TO-12, with 24-hour samples collected at all sites on a 1-in-6 day schedule. This method includes analyses for 81 different compounds. Appendix B lists minimum, maximum, and average concentrations of all detected SNMOC compounds by site.

SNMOC compounds can be grouped into classifications with similar characteristics. For these summaries, measured SNMOC compounds were grouped into the following categories:

- Light Alkanes: Alkanes are the simplest hydrocarbons, consisting of only carbon and hydrogen with single bonds. Light alkanes, which include alkanes with up to five carbon atoms (ethane, propane, iso/n-butane and iso/n-pentane), along with methane, are components of natural gas.

- Heavy Alkanes: The hydrocarbons in crude oil are mostly heavy alkanes, which here include alkanes with more than five carbon atoms (C5). Crude oil products include gasoline, a refined mix of predominantly C6 to C10 hydrocarbons, and diesel, which is a refined mix ranging from approximately C10 to C15.

- Alkenes: Alkenes are more complex than alkanes, with at least one carbon to carbon double bond. These compounds are not generally found in crude oil. Alkenes are much more reactive than alkanes, and will deplete quickly in the atmosphere. Alkenes are produced in refineries when larger alkane molecules are dissociated (or cracked) into smaller compounds. Some alkene compounds, including terpenes such as isoprene and a- and b-pinene, are naturally emitted from vegetation.

- Aromatics: Aromatic compounds are the most abundant compounds emitted from gas-fired engines. These compounds include the BTEX parameters (benzene, toluene, ethylbenzene and m/p-xylenes), which are commonly associated with motor vehicles, but can also have sources associated with oil and gas production.

Figure 4-1 presents categories of measured SNMOCs in units of ppbV (parts per billion by volume) measured in 2010 at each site. In general, measured compounds consisted mostly of light alkanes, which represented between 77 and 87% of total SNMOCs measured. Seasonal

variation showed higher concentrations in winter and lower concentrations in summer. These trends can be influenced by the variations in temperature, as VOCs deplete faster during the summer due to higher reactivity at higher temperatures. Also, some emissions, including cold-start engine emissions and residential wood burning, are higher in the winter.

Figure 4-2 presents measurements by category in units of ppbC, where ppbC represents the number of carbon molecules measured (ppbV multiplied by the number of carbons in each compound). Carbon content in a molecule is related to the compound reactivity, which contributes to ozone formation potential. Heavier alkanes and aromatics are more significant sources of carbon than the lighter alkanes. The unknown category indicates the part of the total carbon measurements where individual species were not identified.

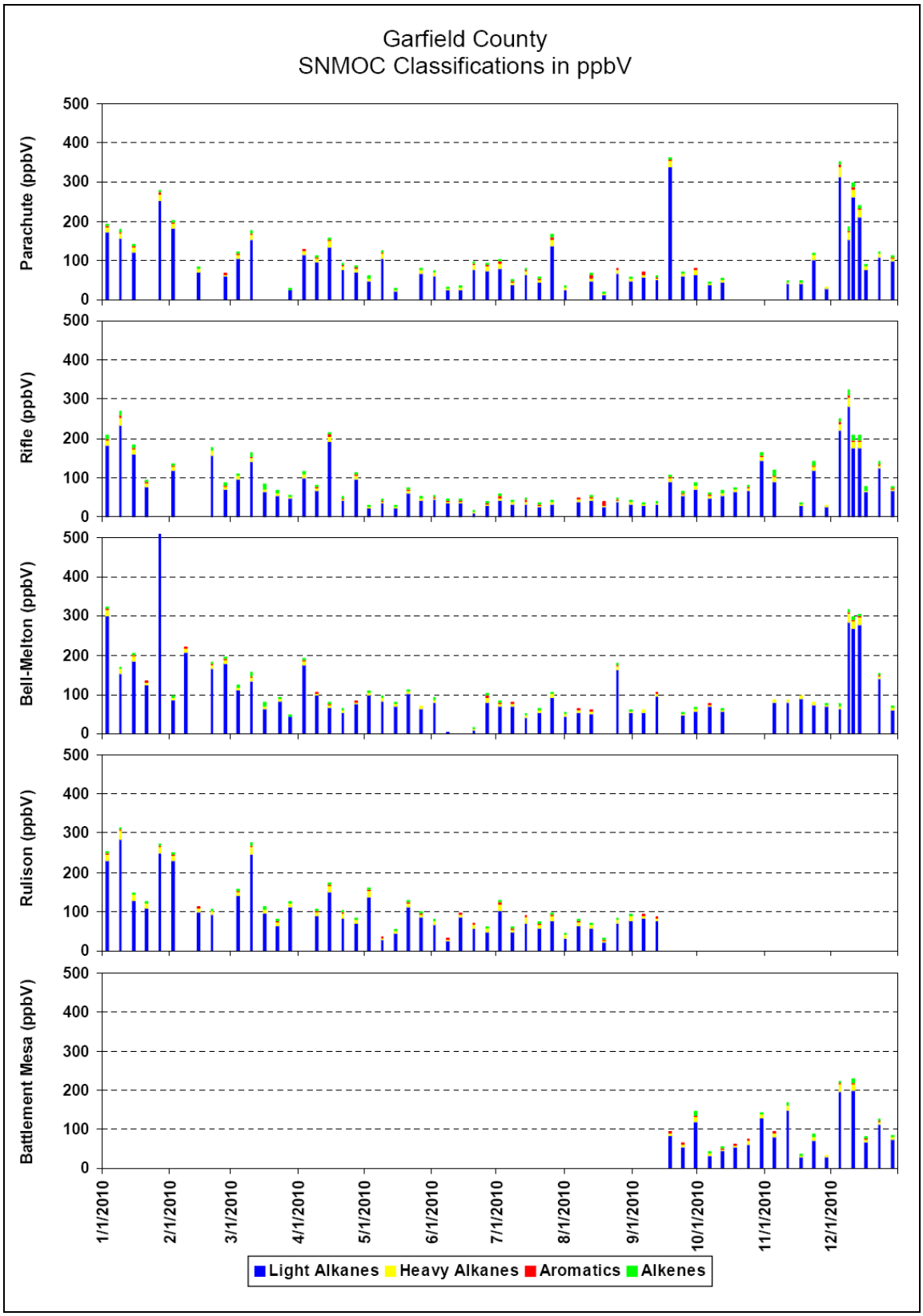

Figure 4-1. 2010 24-Hour SNMOC Measurements by Category in Units of ppbV.

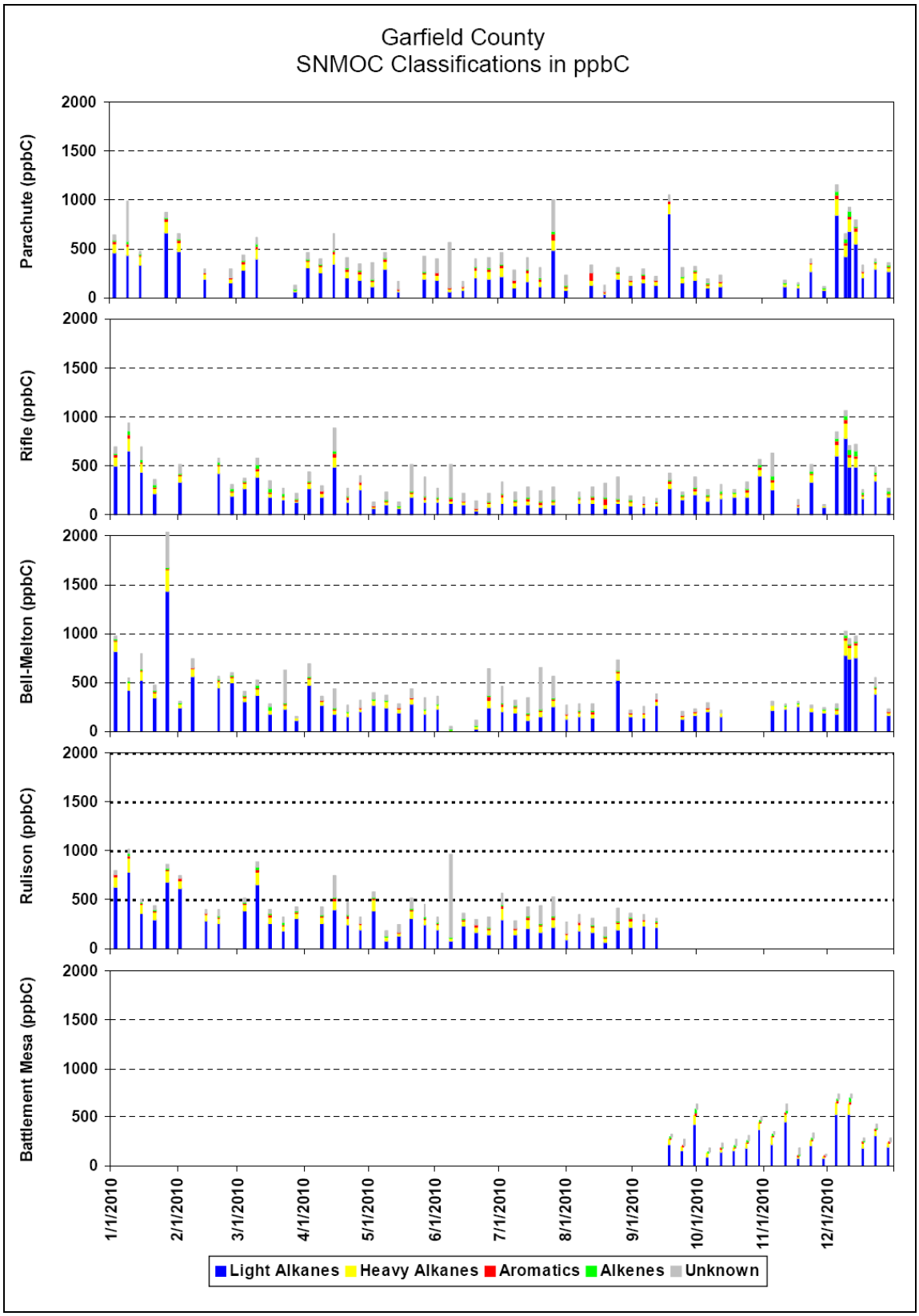

Figure 4-2. 2010 24-Hour SNMOC Measurements by Category in Units of ppbC.

4.1.1 SNMOC Ozone Formation Potential

Ozone is formed from photochemical interactions of VOCs and NO_X in the presence of sunlight, as described in Section 3.1. The potential of individual VOCs to contribute to O_3 formation depends on the reactivity of each compound. Ozone formation potential can be quantified using a maximum incremental reactivity (MIR) scale developed using scenarios where ambient ozone is most sensitive to changes in VOC emissions (Carter 1994). The California Air Resources Board (CARB) regularly updates and publishes these values. This report uses MIR values published by CARB as updated on March 17, 2009. While MIRs are actually calculated in terms of O_3 impact per unit VOC emitted, the MIR potential of measured atmospheric VOCs gives an idea of the relative potential for the VOCs to contribute to ozone formation.

Theoretically, based on MIR numbers, a large mass of a low-reacting VOC could have the same O_3 formation potential as a smaller mass of high-reacting VOC. For example, it would take 25g of ethane to match the ozone formation potential of 1g of m/p-xylenes. Table 4-1 presents the top 10 potential contributors to ozone formation based on MIR reactivity and measured concentration in 2010. Rankings are based on ozone reactivity only, and ranks are not related to chemical toxicity. The top 10 compounds were generally the same for all sites with the exception of n-pentane, toluene, isobutene and ethylene, which were among the top 12 at all sites, but not necessarily the top 10.

The light alkanes that dominate measurements by volume are the least reactive compounds but still contribute significantly to O_3 formation potential. Highly reactive compounds like toluene and m/p-xylenes are less abundant, but high reactivity allows for greater potential to contribute to the O_3 formation. These compounds have sources such as gasoline, diesel, fire sources and oil and gas production. In addition to VOCs, ozone reactions can also be limited by NO_2 availability and meteorological factors. Currently, Garfield County does not violate O_3 standards, but if O_3 levels become more of a concern in Garfield County, it would be useful to monitor NO_2, and to target further controls for emissions of the identified VOCs that have the greatest potential to contribute to O_3 formation.

Table 4-1

Top 10 Ranked Maximum Incremental Reactivity Levels by Component for 2010

Group	ANALYTE	MIR (mol O_3/mol C)	Reactivity Rank (Annual Average ppbC)				
			PACO	RICO	BRCO	RUCO*	BMCO**
Light Alkanes	Ethane	0.08	**2** (111 ppbC)	**8** (81 ppbC)	**4** (112 ppbC)	**5** 109 ppbC)	**4** (93 ppbC)
	Propane	0.14	**3** (62 ppbC)	**7** (53 ppbC)	**3** (82 ppbC)	**2** (70 ppbC)	**5** (54 ppbC)
	n-Butane	0.33	**7** (23 ppbC)	**4** (25 ppbC)	**2** (35 ppbC)	**3** (29 ppbC)	**2** (32 ppbC)
	Isobutane	0.36	**1** (26 ppbC)	**6** (21 ppbC)	**1** (33 ppbC)	**1** (29 ppbC)	**3** (24 ppbC)
	n-Pentane	0.37	12 (12 ppbC)	12 (14 ppbC)	**7** (17 ppbC)	**9** (16 ppbC)	**8** (17 ppbC)
	Isopentane	0.41	**6** (19 ppbC)	**5** (19 ppbC)	**5** (22 ppbC)	**4** (22 ppbC)	**1** (26 ppbC)
Aromatics	Toluene	1.06	**5** (7 ppbC)	**10** (6 ppbC)	11 (4 ppbC)	**8** (5 ppbC)	**9** (5 ppbC)
	m/p-Xylene	2.10	**4** (4 ppbC)	**9** (3 ppbC)	**10** (2 ppbC)	**6** (3 ppbC)	**10** (3 ppbC)
Alkenes	Isobutene	2.27	**1** (26 ppbC)	**6** (21 ppbC)	**1** (33 ppbC)	12 (2 ppbC)	**3** (24 ppbC)
	Ethylene	2.56	**9** (3 ppbC)	**1** (4 ppbC)	**8** (2 ppbC)	**10** (2 ppbC)	11 (2 ppbC)
Carbonyls	Formaldehyde	5.78	**8** (1 ppbC)	**3** (1 ppbC)	**9** (1 ppbC)	**7** (1 ppbC)	**7** (1 ppbC)

*The RUCO site operated between January 2010 and September 2010.
**The BMCO site operated between September 2010 and December 2010.

4.1.2 Annual Average SNMOCs

Garfield County began collecting SNMOC data in 2008, with the Brock (MOCO) station relocated to the Rulison (RUCO) site in February 2009, and the RUCO site relocated to Battlement Mesa (BMCO) in September 2010. Figure 4-3 presents comparisons of annual average SNMOC data collected between 2008 and 2010. For sites that monitored all three years (PACO, RICO and BRCO), SNMOC concentrations have been decreasing between 2008 and 2010. This is due mostly to decreased light alkane concentrations, which are primary components of natural gas.

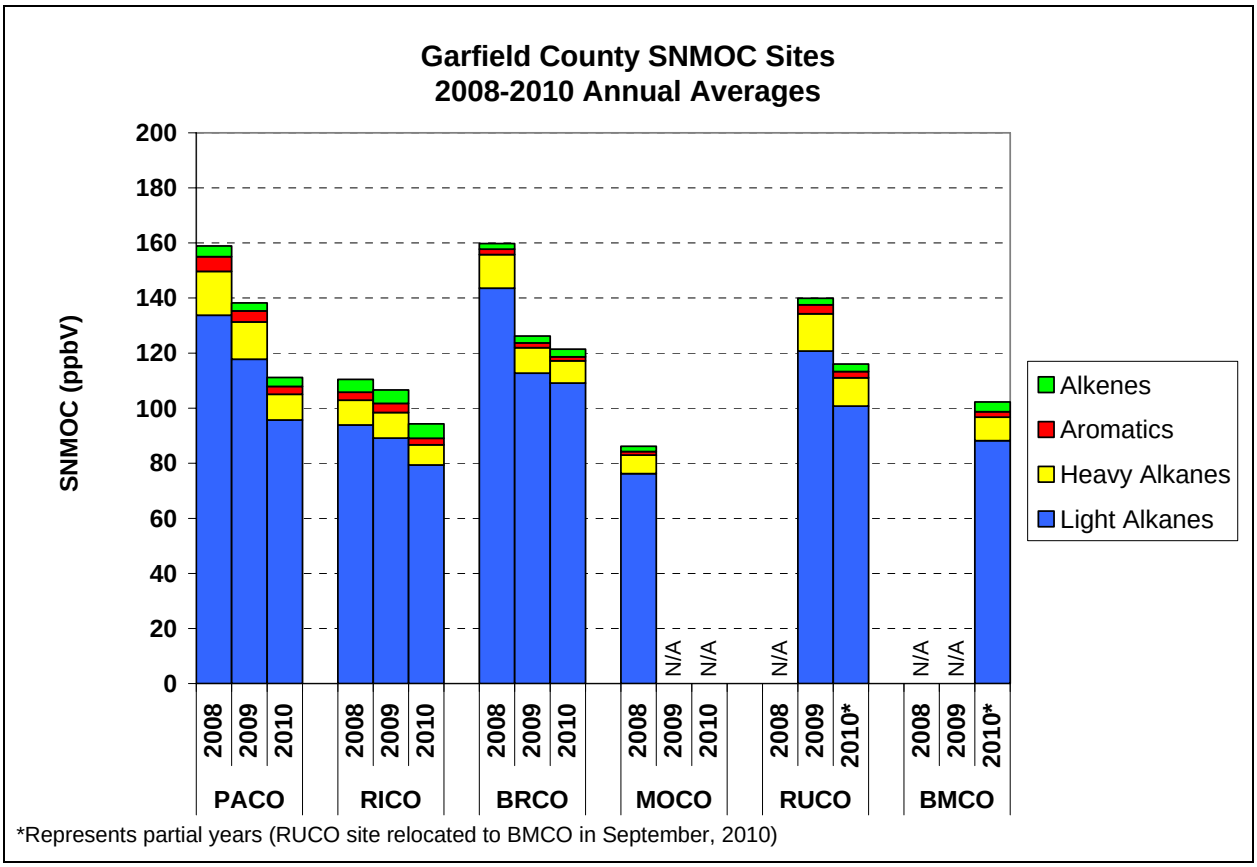

Figure 4-3 Average SNMOC Concentrations Measured by the Garfield County Air Monitoring Program between 2008 and 2010.

4.2 CARBONYLS

Carbonyl compounds were collected and analyzed according to EPA Compendium Method TO-11A, with 24-hour samples collected at all four sites on a 1-in-12 day schedule. This method includes analysis for 12 different carbonyl compounds.

Carbonyls are highly reactive and play a critical role in the formation of O_3. Some carbonyls, including formaldehyde and acetaldehyde, also have adverse chronic and acute health

effects. The major sources of directly emitted carbonyls are fuel combustion, mobile sources, and process emissions from oil refineries (CARB 2009).

Appendix C lists minimum, maximum, and average concentrations of all detected carbonyl compounds. Major compounds included formaldehyde, acetaldehyde, and acetone. Figure 4-4 presents a time series of the major compounds measured in 2010. Carbonyl sampling at the Bell-Melton site was temporarily interrupted due to a power failure in September 2010. Sampling at the Rulison site was discontinued September 2010, when equipment was relocated to the Battlement Mesa site. In general, carbonyl compounds were highest during the summertime. The formation of these compounds during warm months is influenced by photochemical production.

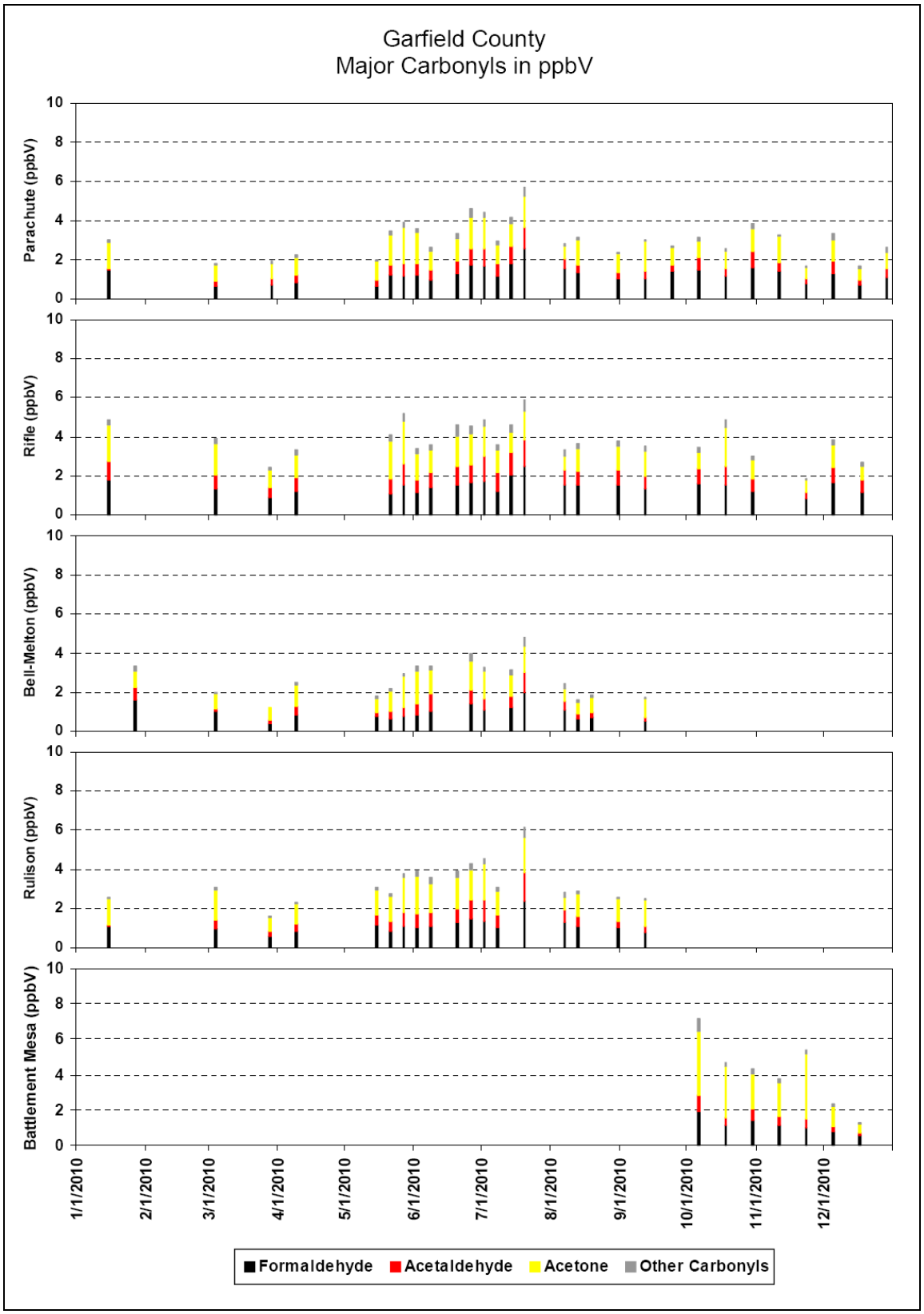

Figure 4-4. 2010 24-Hour Major Carbonyl Compound Concentrations in Units of ppbV.

4.2.1 Annual Average Carbonyl Concentrations

Garfield County began collecting carbonyl data in 2008, with the Brock (MOCO) station relocated to the Rulison (RUCO) site in February 2009, and the RUCO site relocated to Battlement Mesa (BMCO) in September 2010. Figure 4-5 presents comparisons of annual average carbonyl data collected between 2008 and 2010. In 2010, total measured carbonyl levels were slightly lower than 2008 and 2009 at the PACO site, higher than 2009 at the RICO site, and lower than 2009 at the BMCO site.

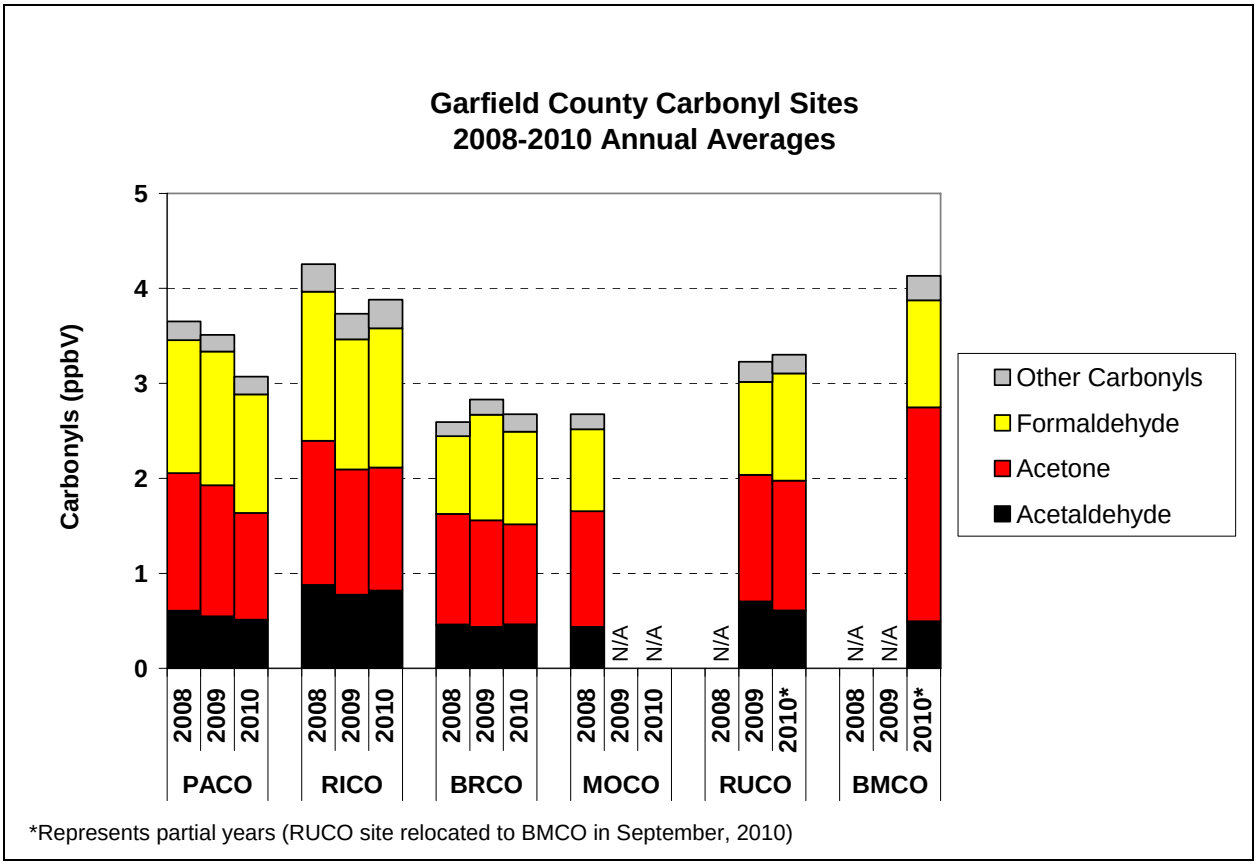

Figure 4-5. Average Carbonyl Concentrations Measured by the Garfield County Air Monitoring Program between 2008 and 2010.

4.3 HAZARDOUS AIR POLLUTANTS (HAPS) SUMMARIES

Not all measured VOCs have associated risk factors, and those that do are also referred to as HAPs. Of the SNMOC and carbonyl compounds measured in Garfield County, 21 compounds have been identified as HAPs. No NAAQS or any other ambient air standards exist for VOCs. Instead, emissions limits on industrial sources have been set. The EPA has developed a set of risk factors for both acute and chronic exposures for HAPs. In addition, risk factors from the Agency for Toxic Substances and Disease Registry (ATSDR), the California Air Resources Board (CARB), the National Institute for Occupational Safety and Health (NIOSH), and others can be used to determine potential risks from exposure to VOCs.

The Garfield County Air Toxics Inhalation Screening Level Human Risk Assessment (CDPHE 2010) assessed data collected in 2008, and a risk assessments based on 2009 and 2010 HAPs levels will be prepared in a separate annual risk assessment report prepared by the CDPHE Disease Control and Environmental Epidemiology Division. Findings of the 2008 report indicated that, individually, the HAPs components were below risk assessment criteria, but cumulative effects approached chronic (70 year exposure period) non-hazard levels. The largest contributors to the cumulative levels were benzene and formaldehyde.

4.3.1 Annual Average HAPs Concentrations

Figures 4-6 through 4-10 present annual averages of HAPs concentrations measured between 2008 and 2010. Overall, many of the annual average detected HAPs concentrations were lower in 2010 than 2009. Actual magnitudes of these HAPs compounds related to possible health risk will be evaluated in the CDPHE risk assessment report.

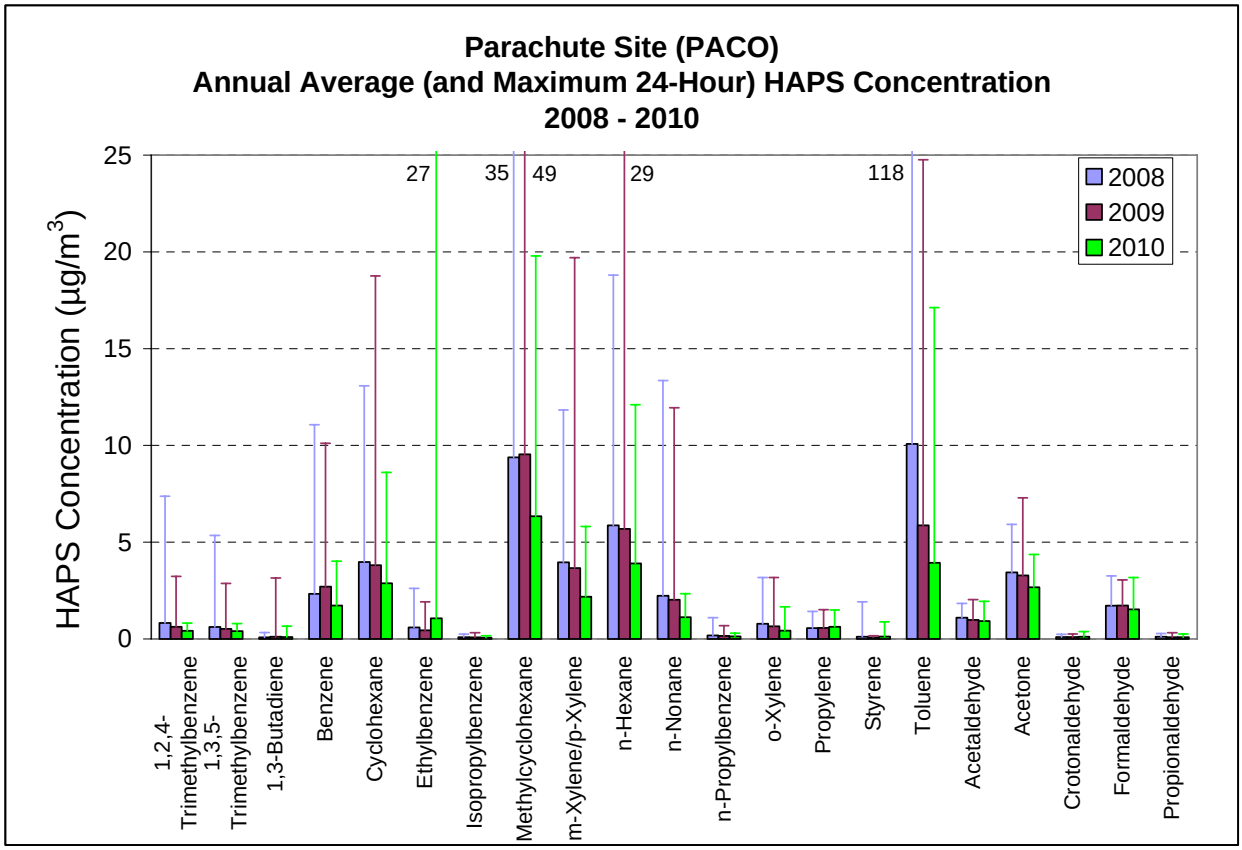

Figure 4-6. Annual Average and 24-hour Maximum HAPs Concentrations Measured at the Parachute Site between 2008 and 2010.

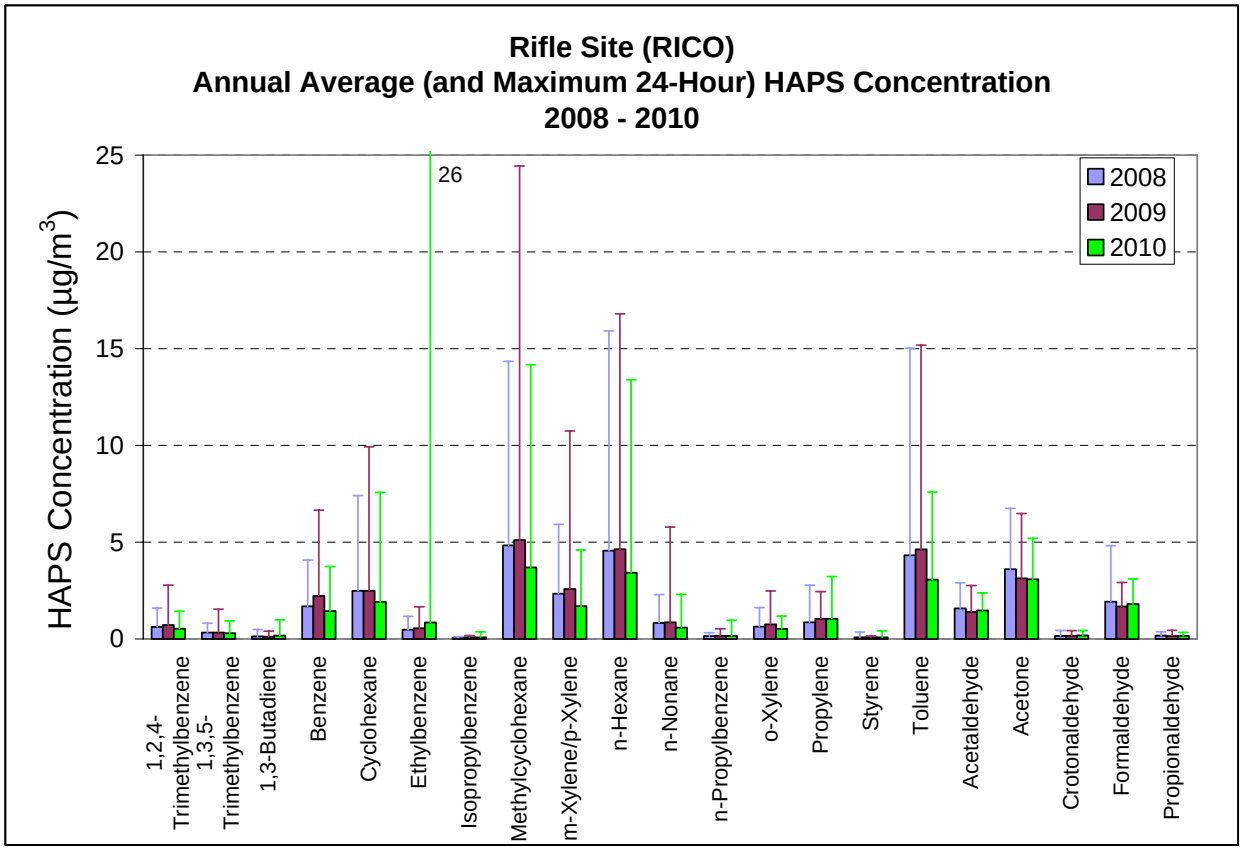

Figure 4-7. Annual Average and 24-Hour Maximum HAPs Concentrations Measured at the Rifle Site between 2008 and 2010.

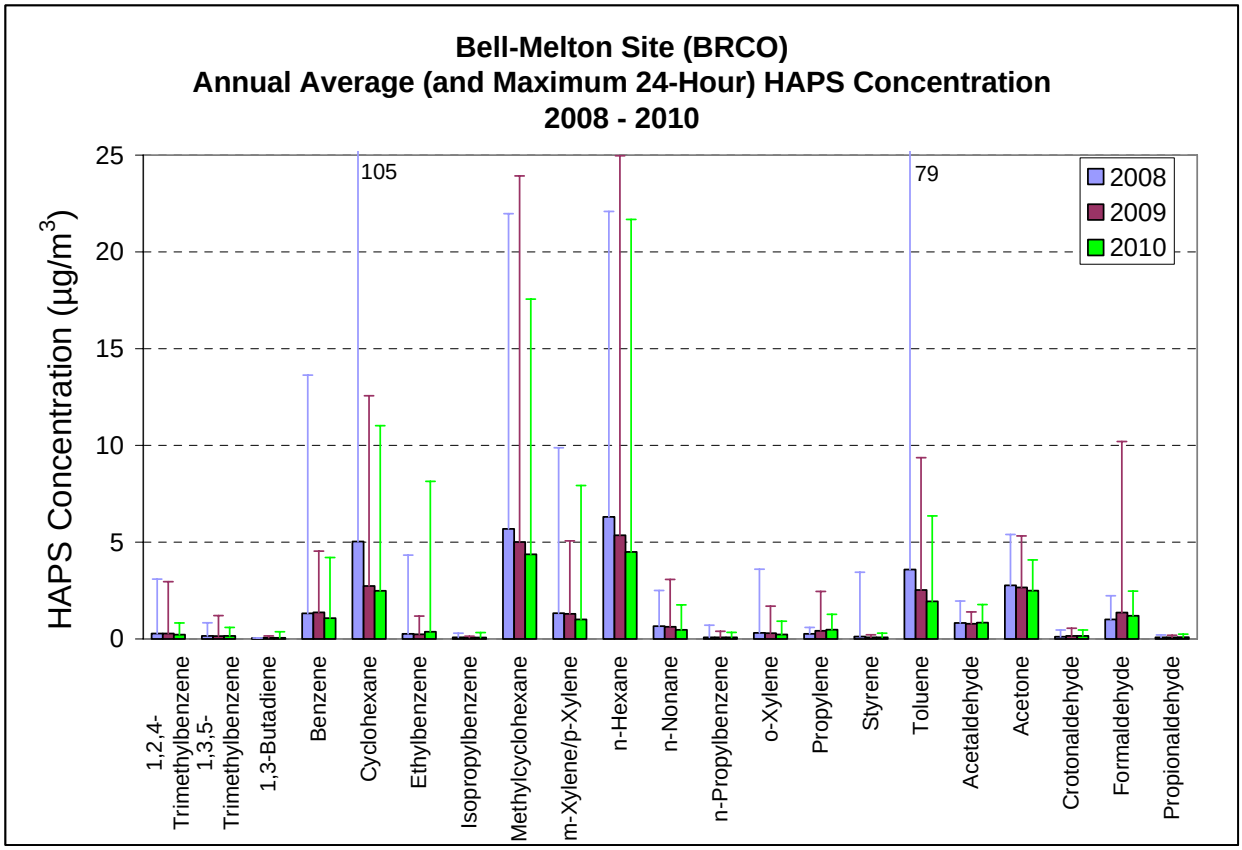

Figure 4-8. Annual Average and 24-Hour Maximum HAPs Concentrations Measured at the Bell-Melton Site between 2008 and 2010.

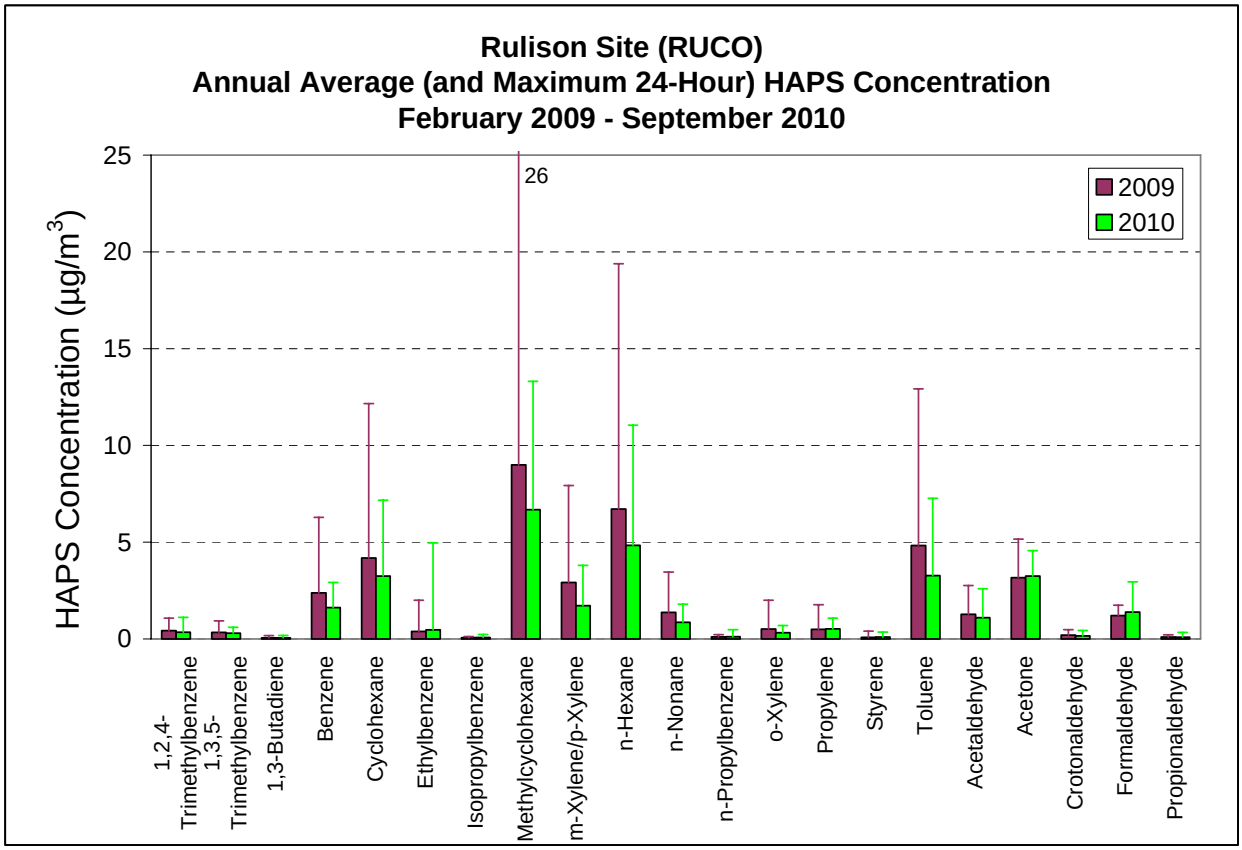

Figure 4-9. Annual Average and 24-Hour Maximum HAPs Concentrations Measured at the Rulison Site between February 2009 and September 2010.

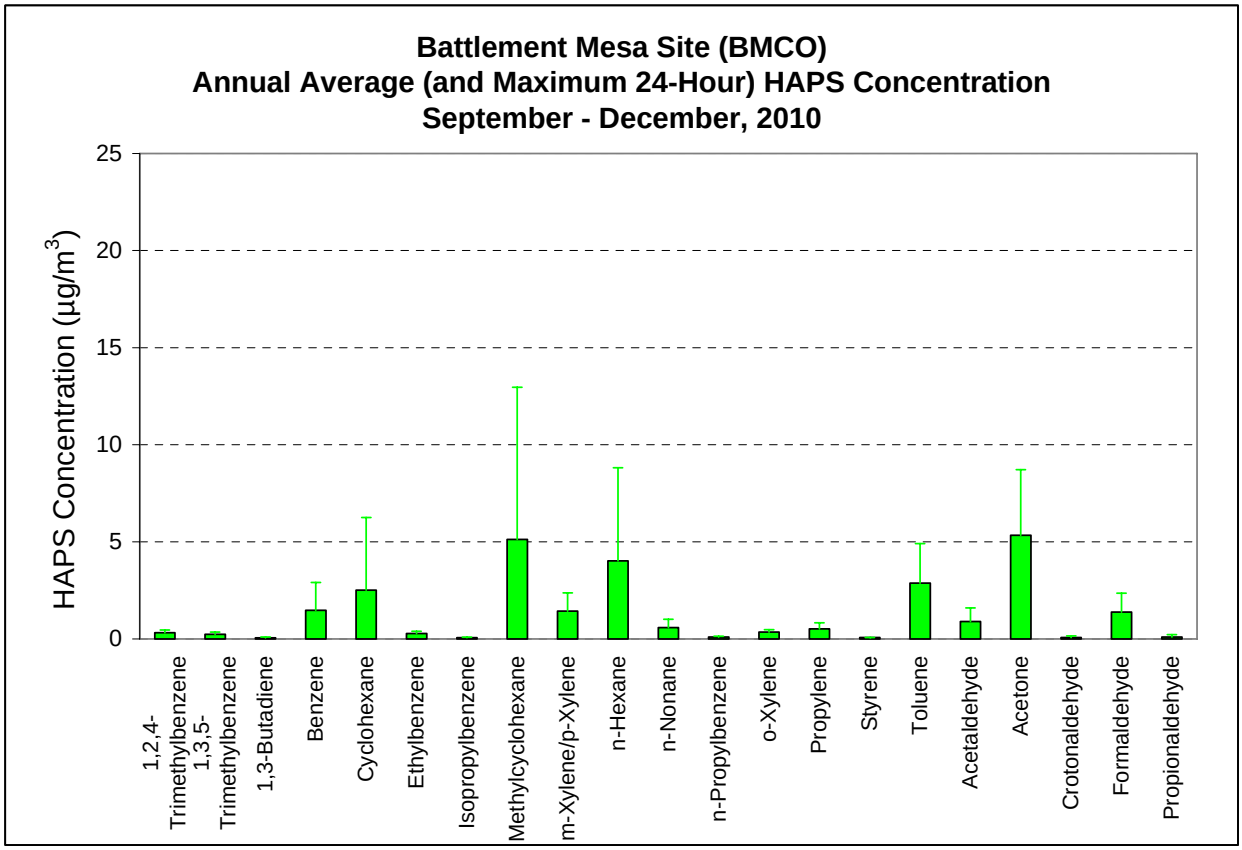

Figure 4-10. Annual Average and 24-Hour Maximum HAPs Concentrations Measured at the Battlement Mesa Site Between September and December 2010.

5.0 REFERENCES

California Air Resources Board (CARB), 2009, California Toxics Inventory, http://www.arb.ca.gov/toxics/cti/cti.htm. (July 17, 2009).

Carter, W.P.L., 1994, Development of ozone reactivity scales for volatile organic compounds. Journal of the Air & Waste Management Association, 44.

CDPHE, 2010, Garfield County Air Toxics Inhalation: Screening Level Human Health Risk Assessment (June 2010).

APPENDIX A

Garfield County

2010 Stackplots

Figure A-1

Garfield County, CO
Parachute Site

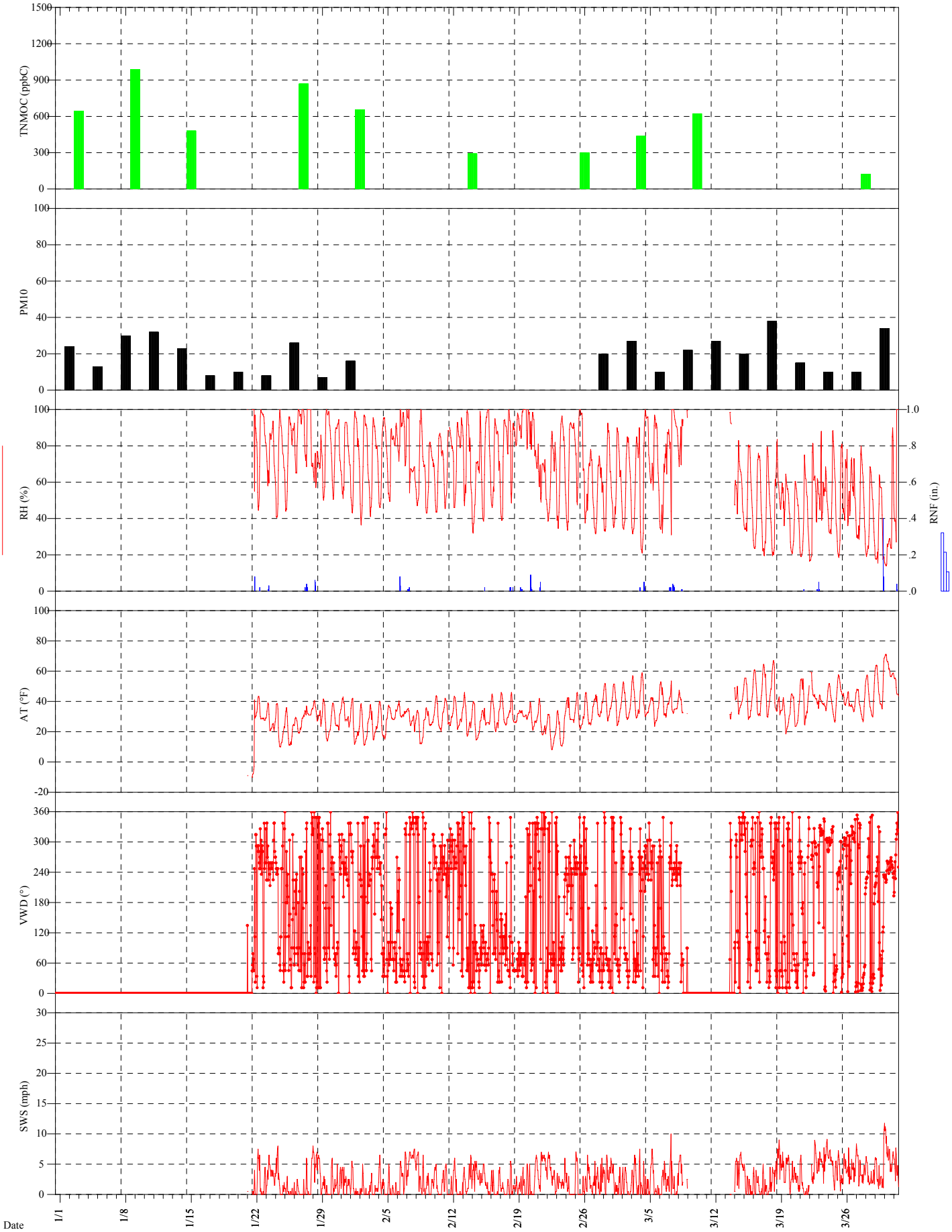

Figure A-2

Garfield County, CO

Parachute Site

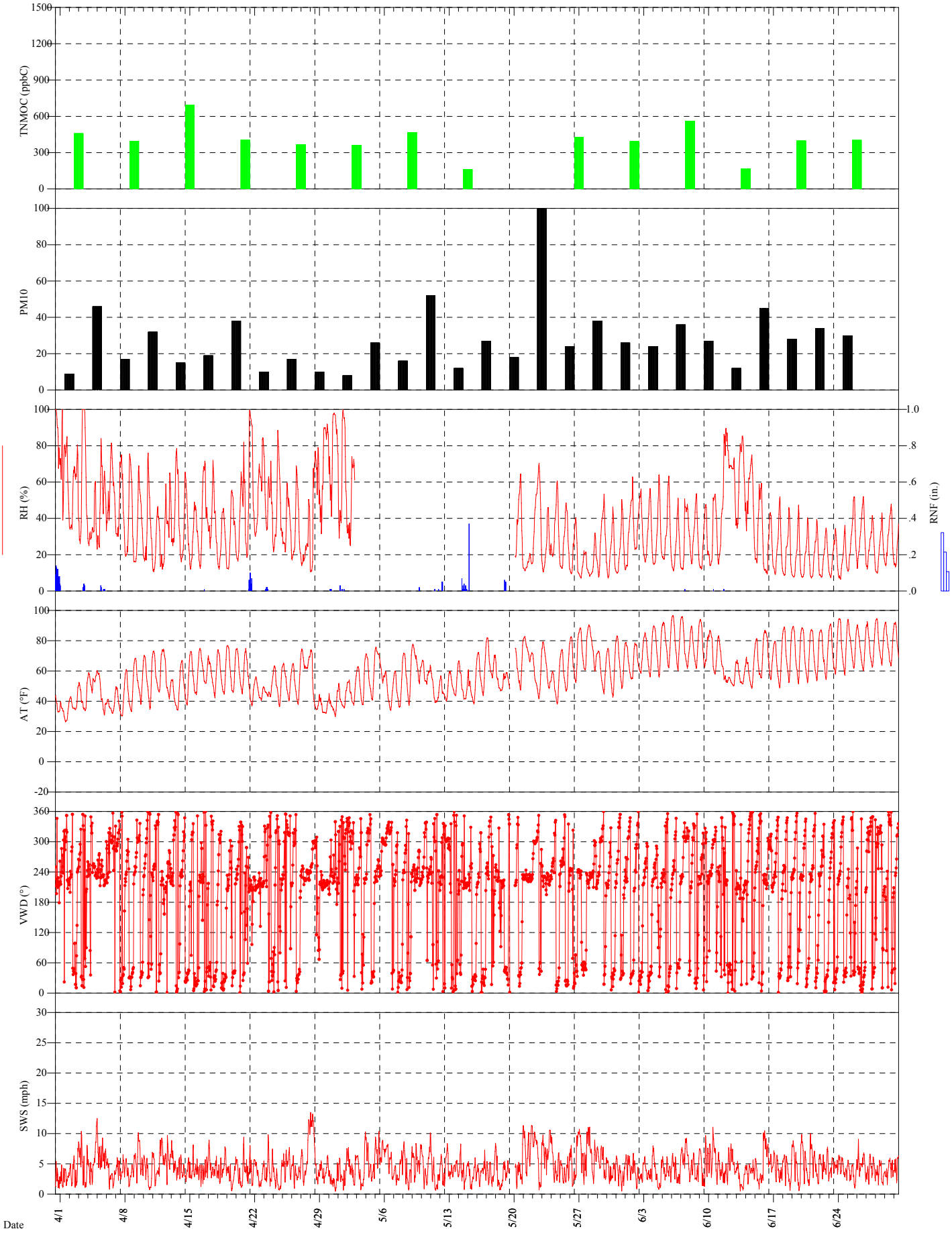

Figure A-3

Garfield County, CO

Parachute Site

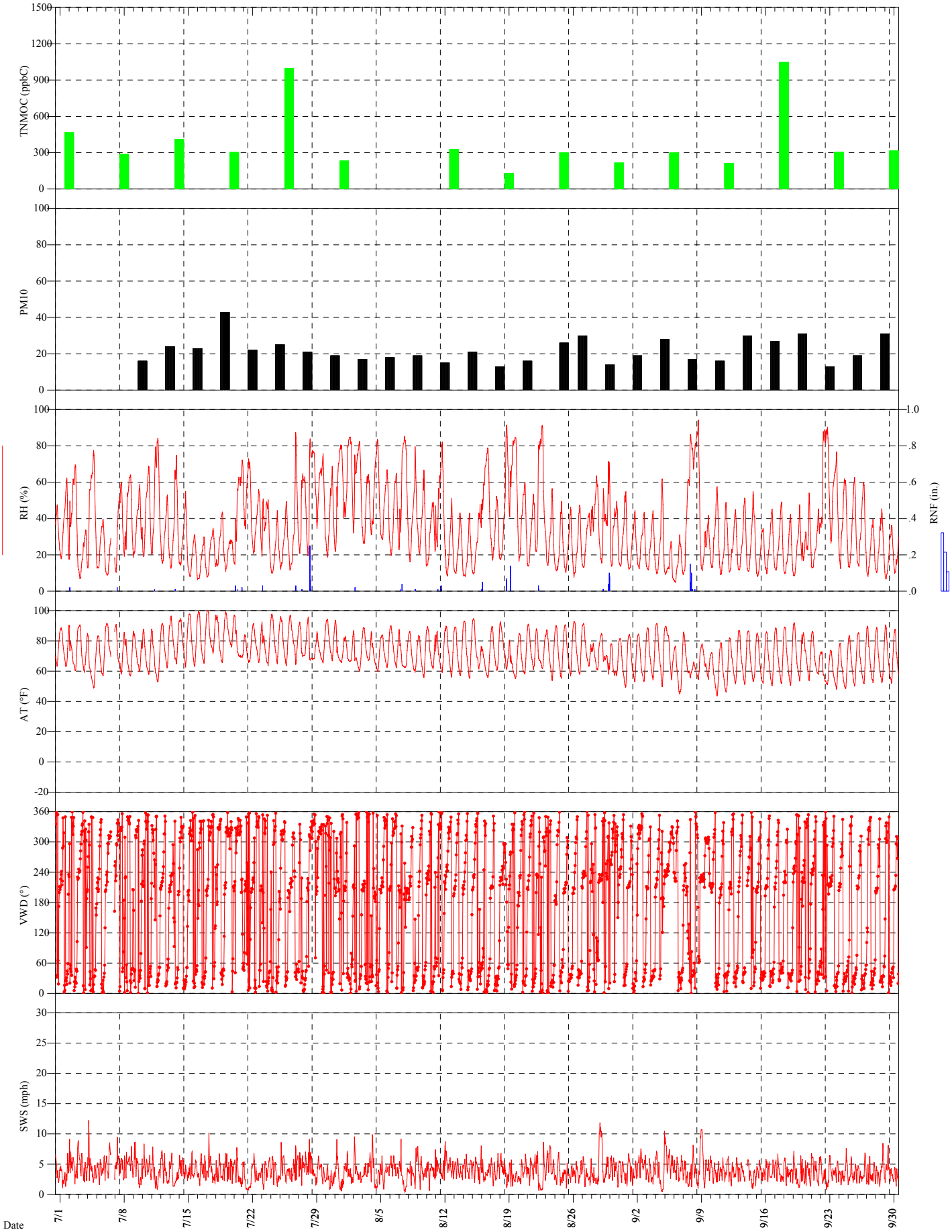

Figure A-4

Garfield County, CO

Parachute Site

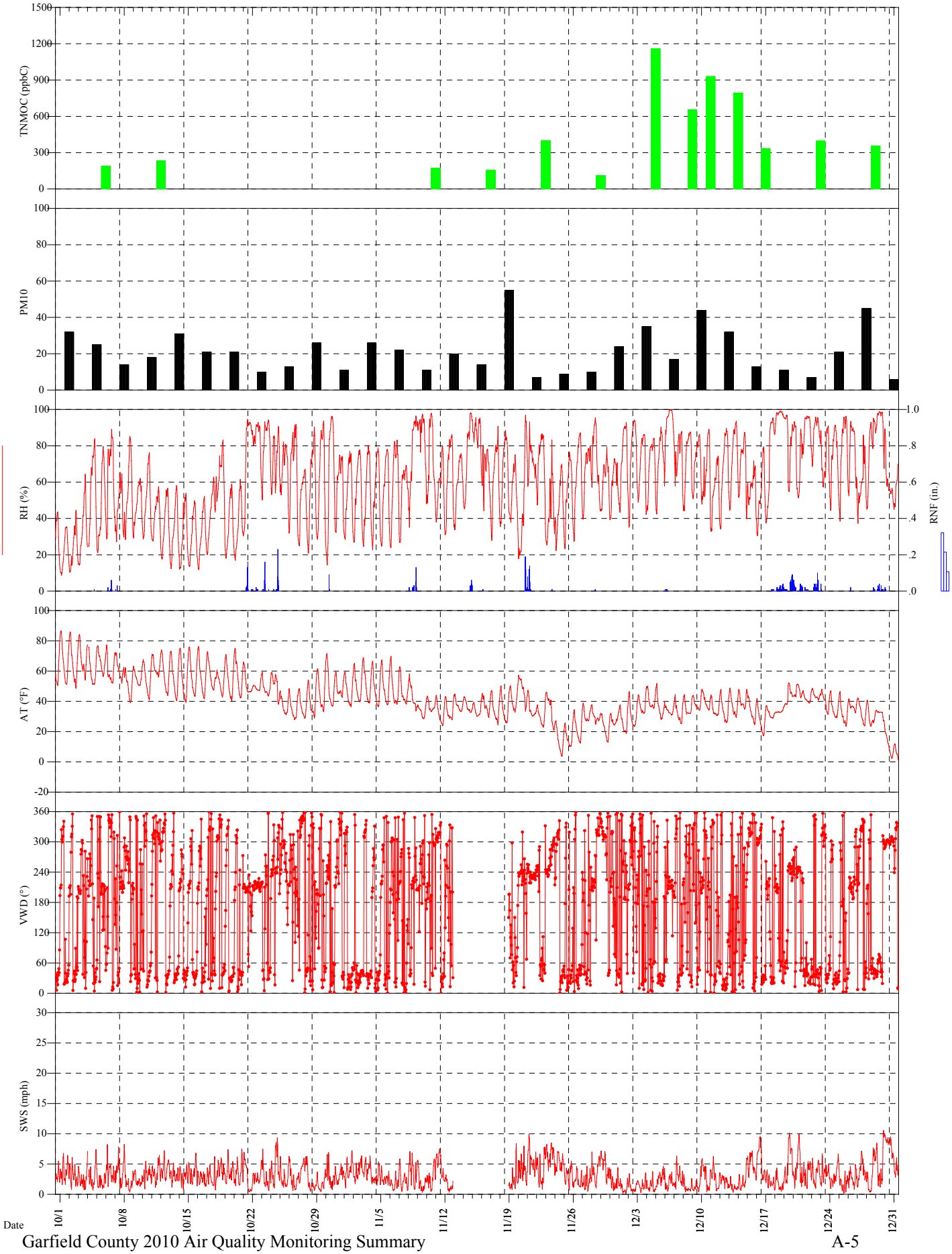

Figure A-5
Garfield County, CO

Rifle Site

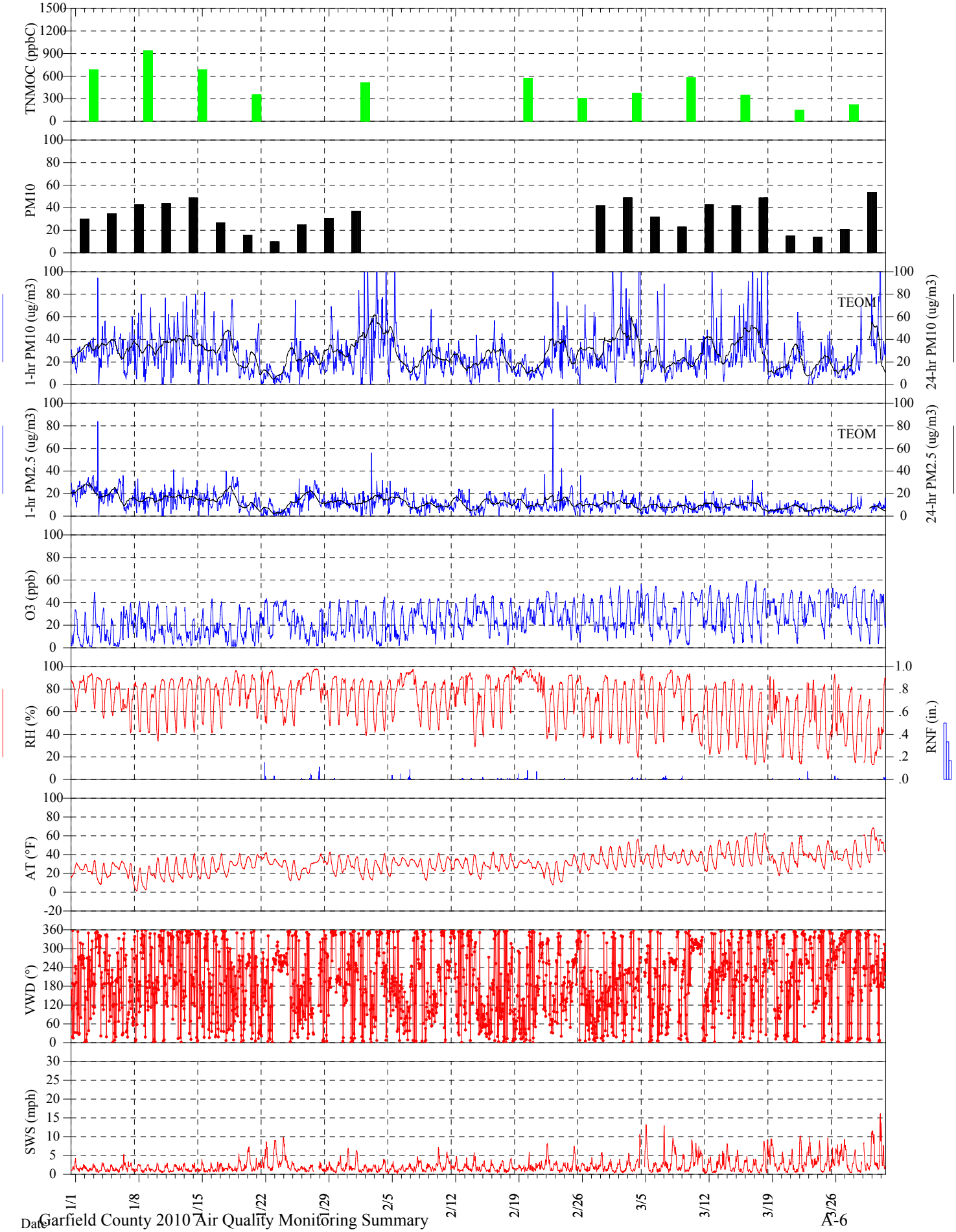

Figure A-6
Garfield County, CO

Rifle Site

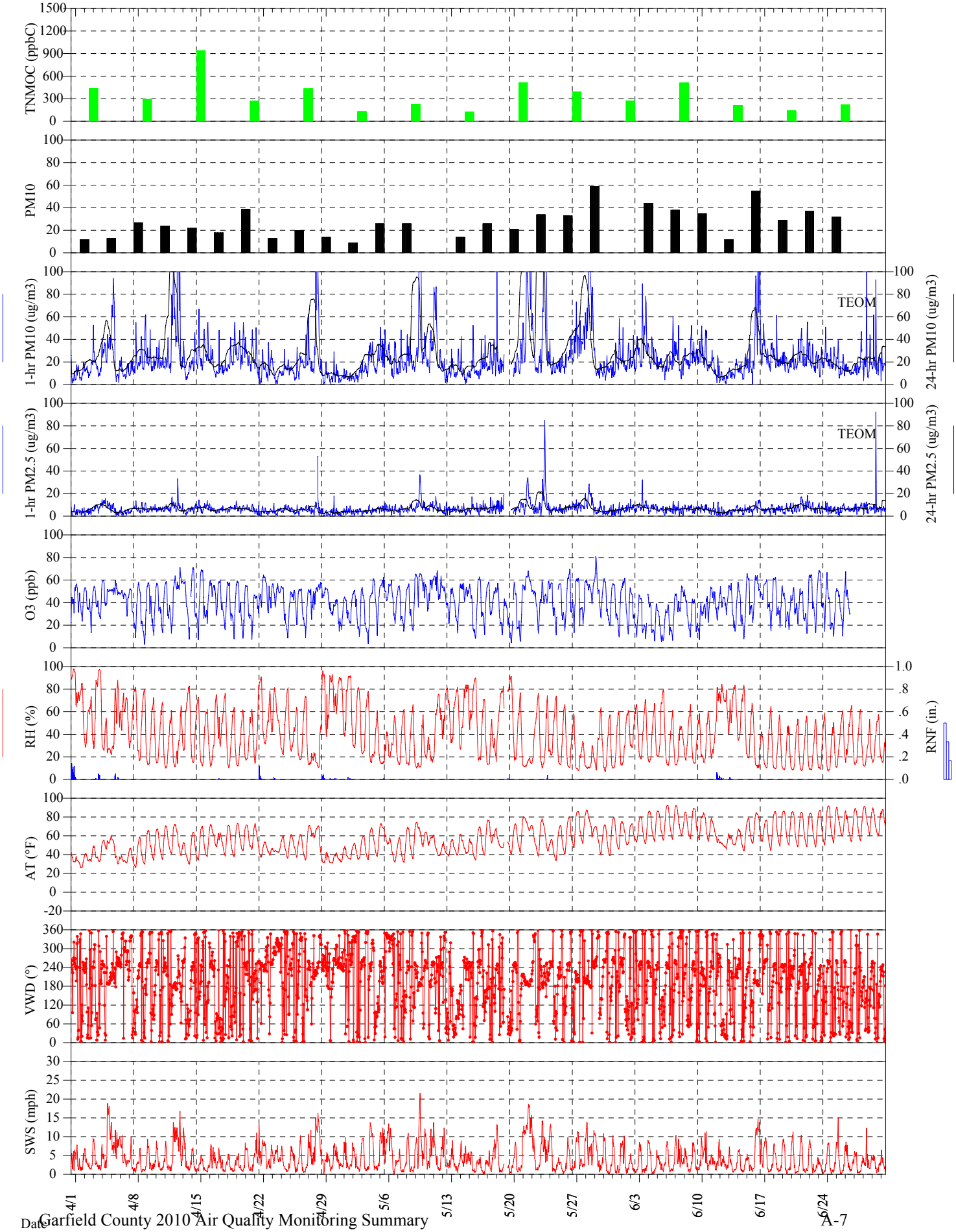

Figure A-7
Garfield County, CO

Rifle Site

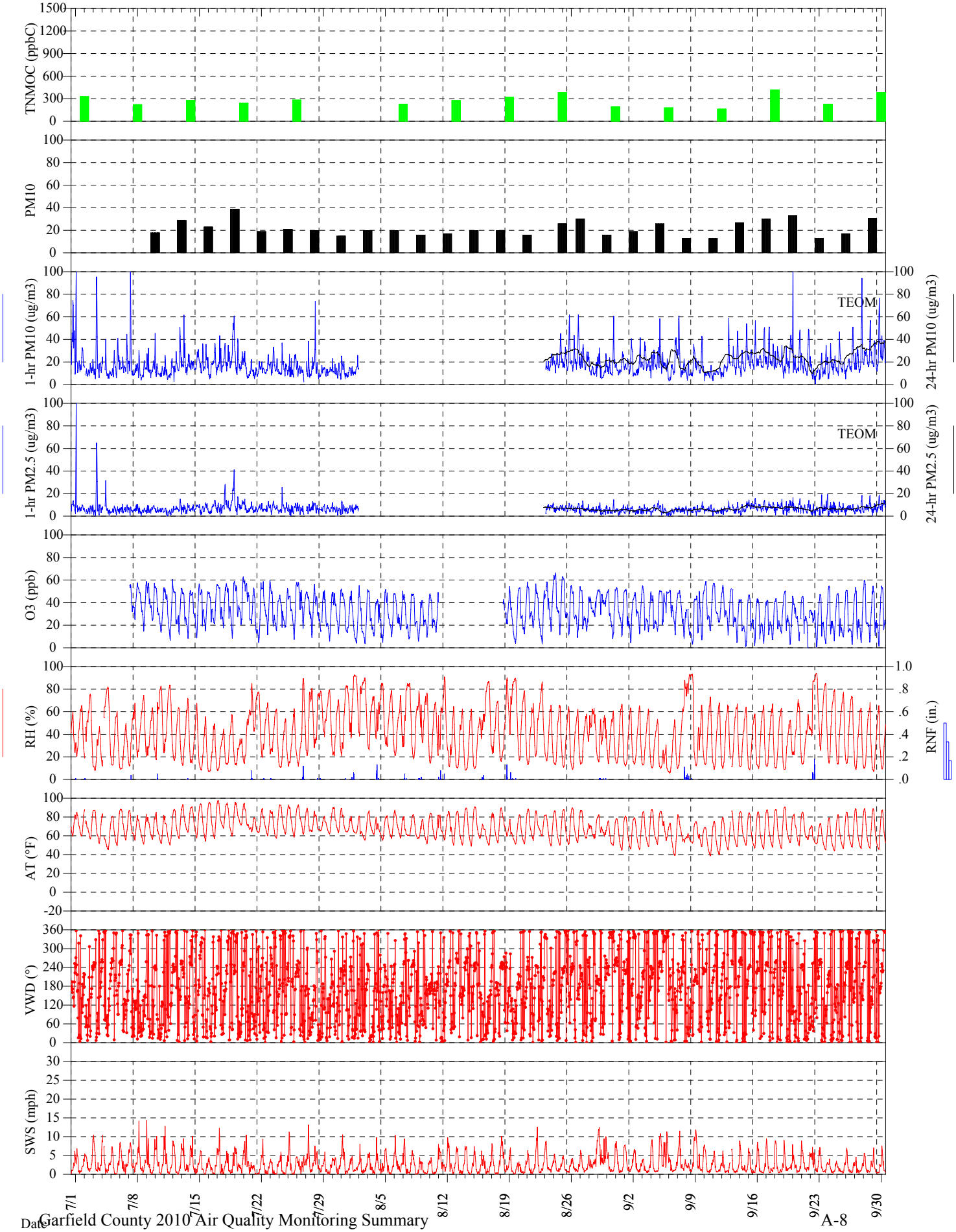

Figure A-8
Garfield County, CO

Rifle Site

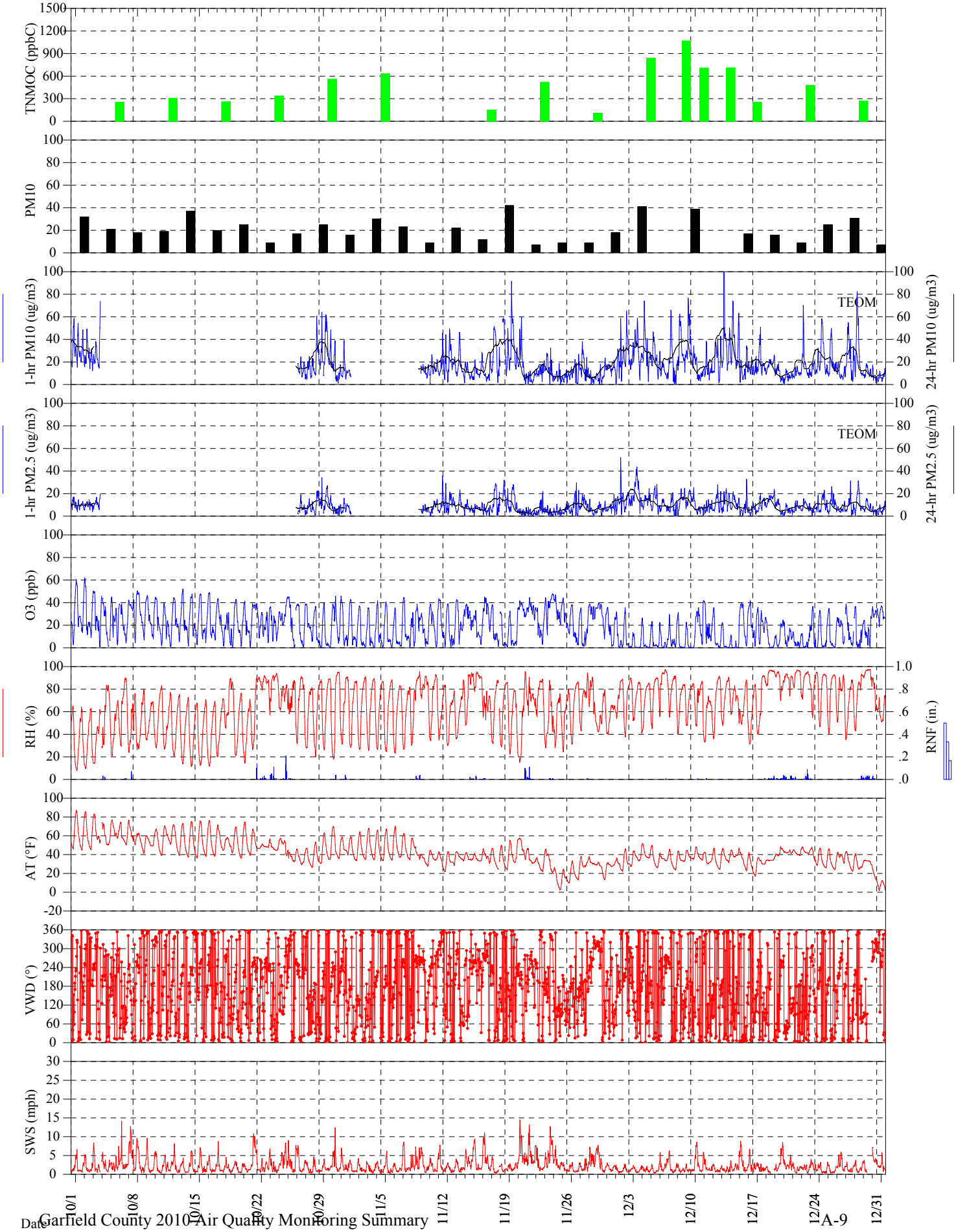

Figure A-9

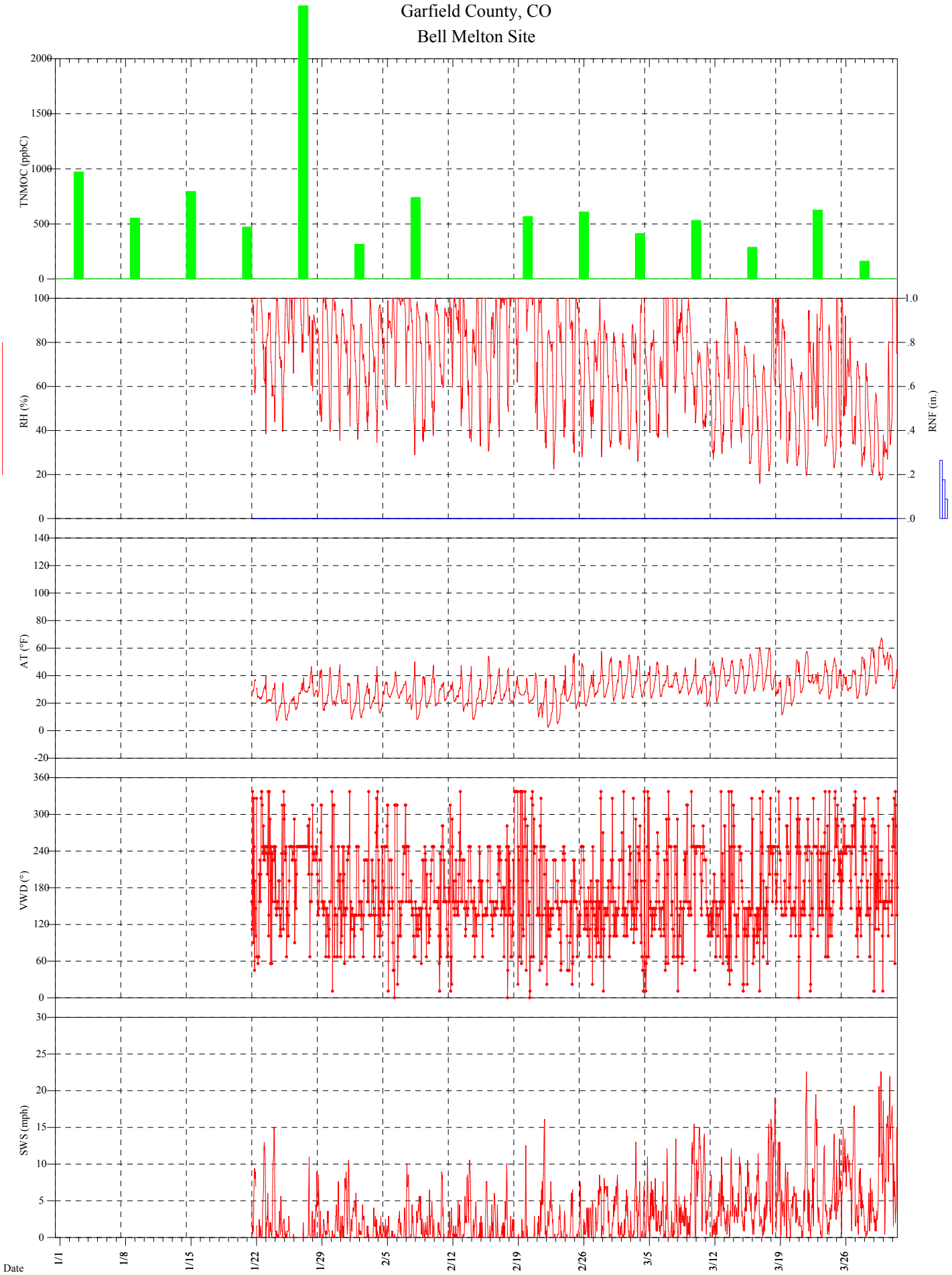
Garfield County, CO
Bell Melton Site
TNMOC (ppbC)
RH (%)
RNF (in.)
AT (°F)
VWD (°)
SWS (mph)
Date
1/1
1/8
1/15
1/22
1/29
2/5
2/12
2/19
2/26
3/5
3/12
3/19
3/26

Figure A-10

Garfield County, CO
Bell Melton Site

Figure A-11

Garfield County, CO
Bell Melton Site

Figure A-12

Garfield County, CO

Bell Melton Site

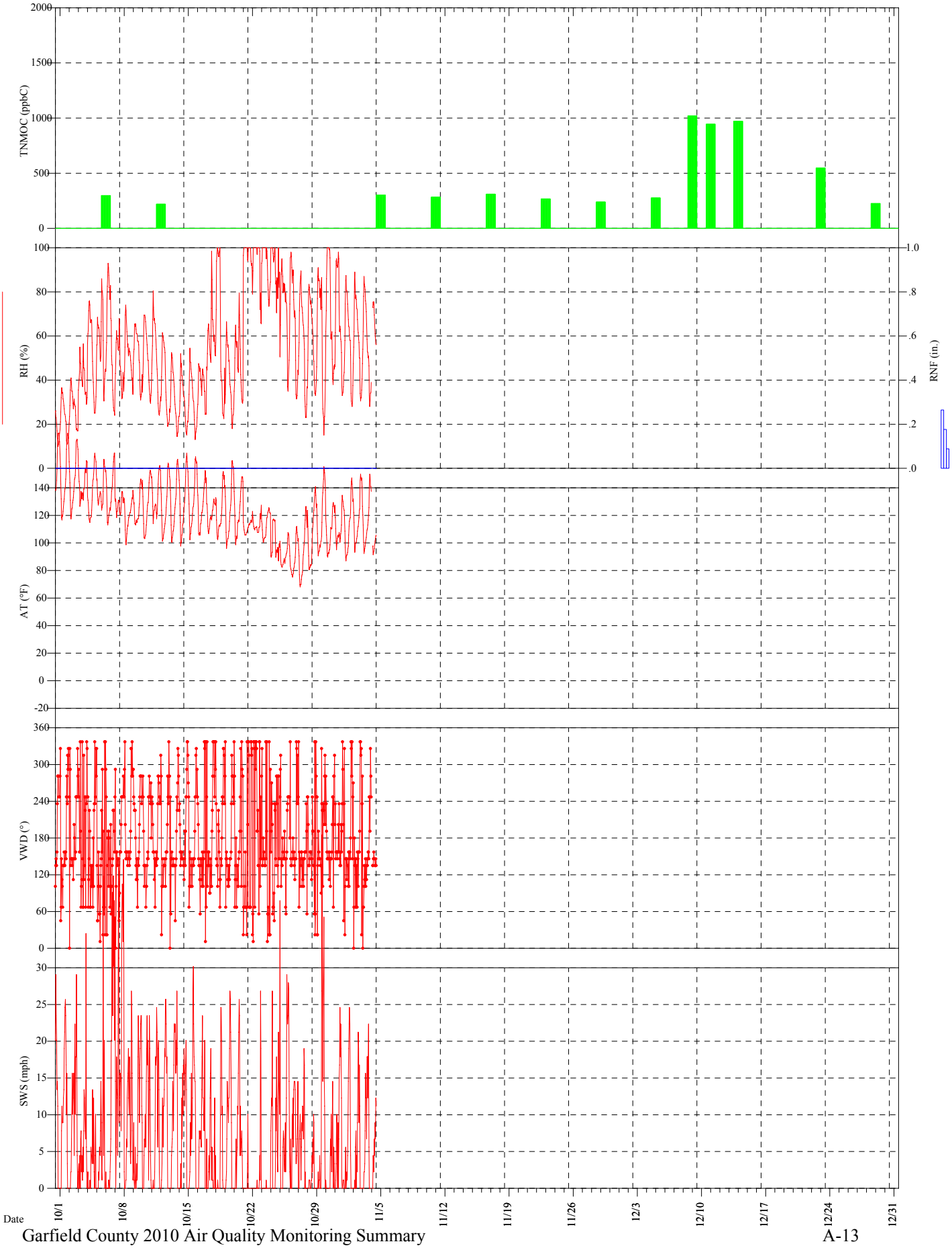

Figure A-13

Garfield County, CO
Rulison Site

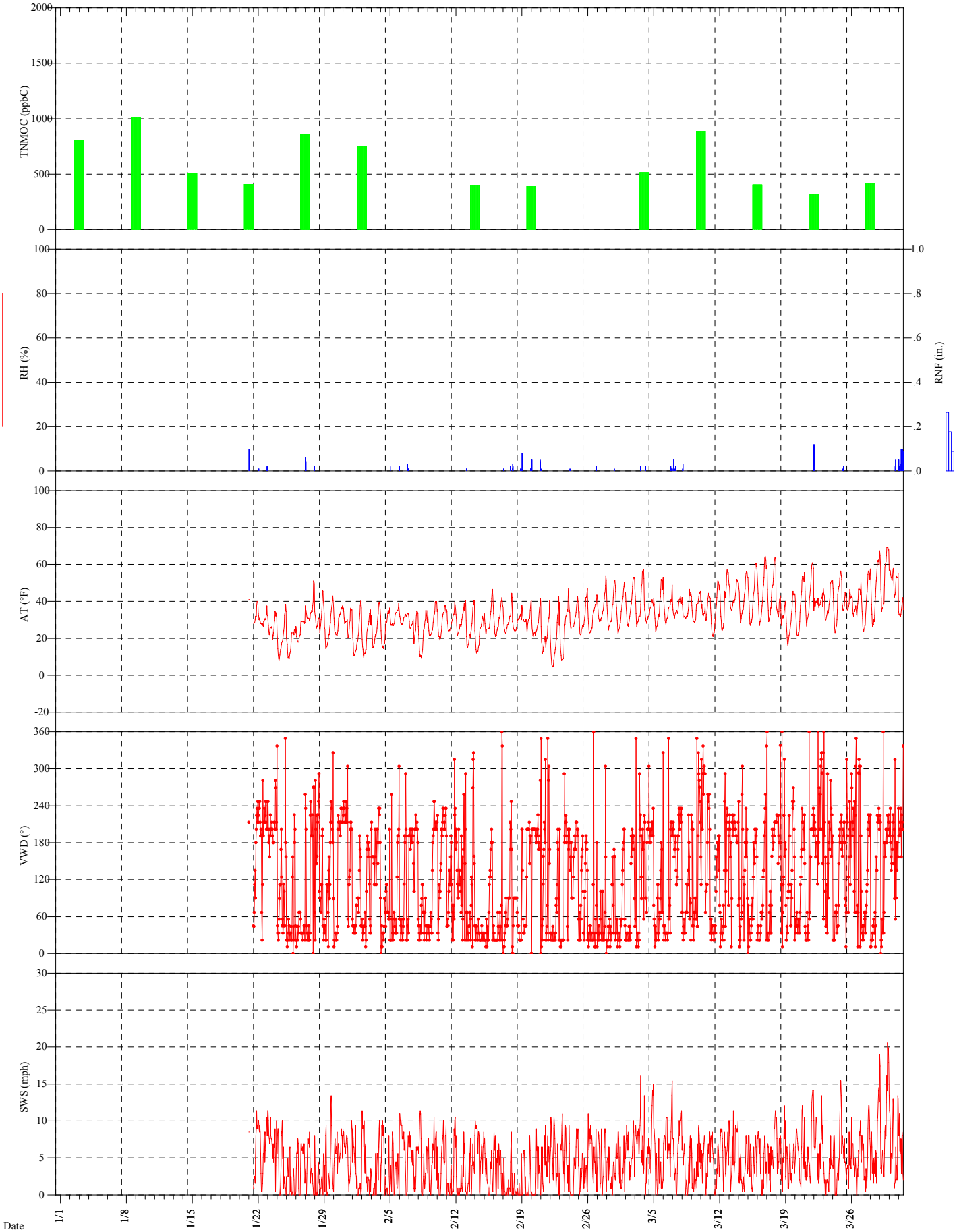

Figure A-14

Garfield County, CO
Rulison Site

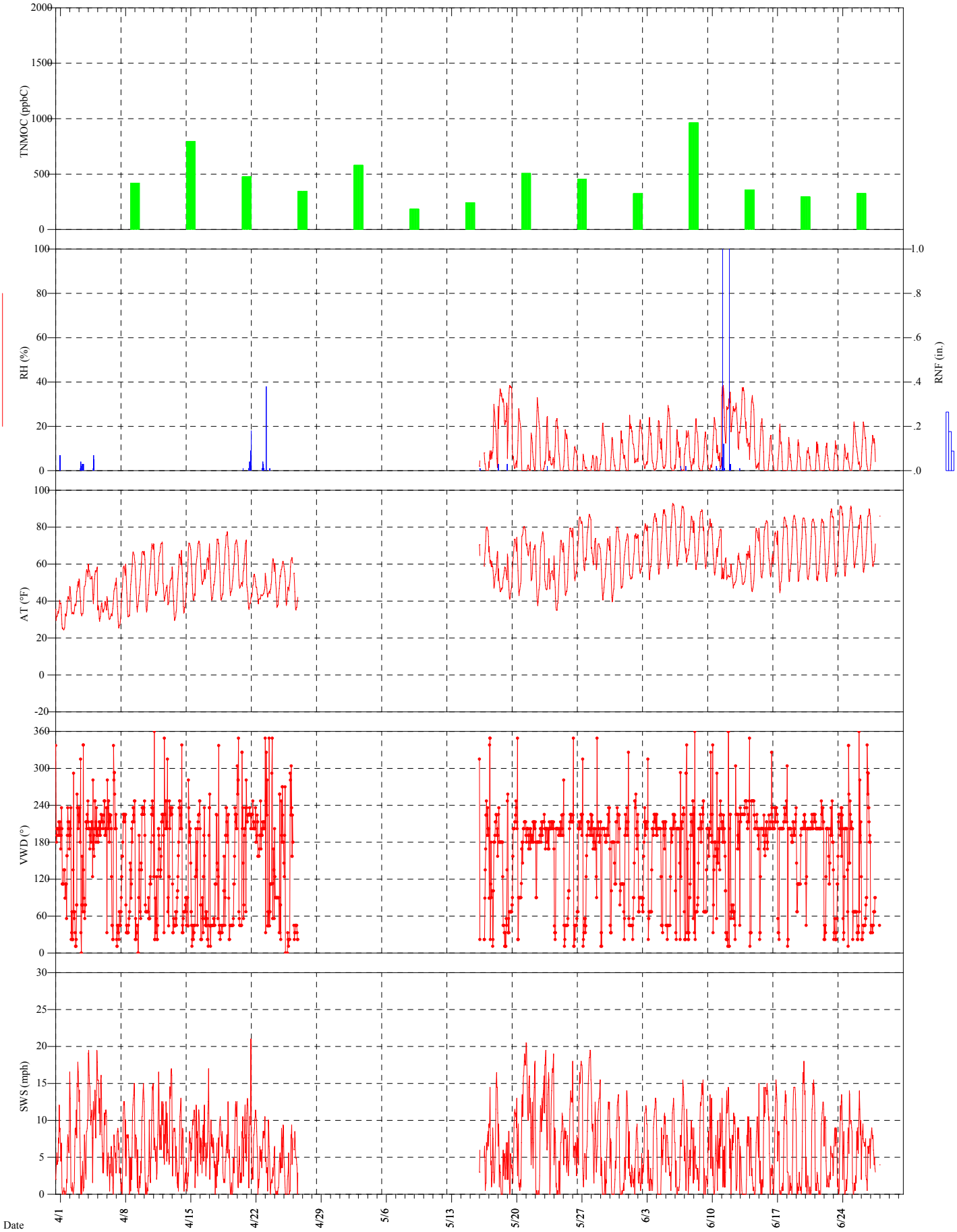

Figure A-15

Garfield County, CO
Rulison Site

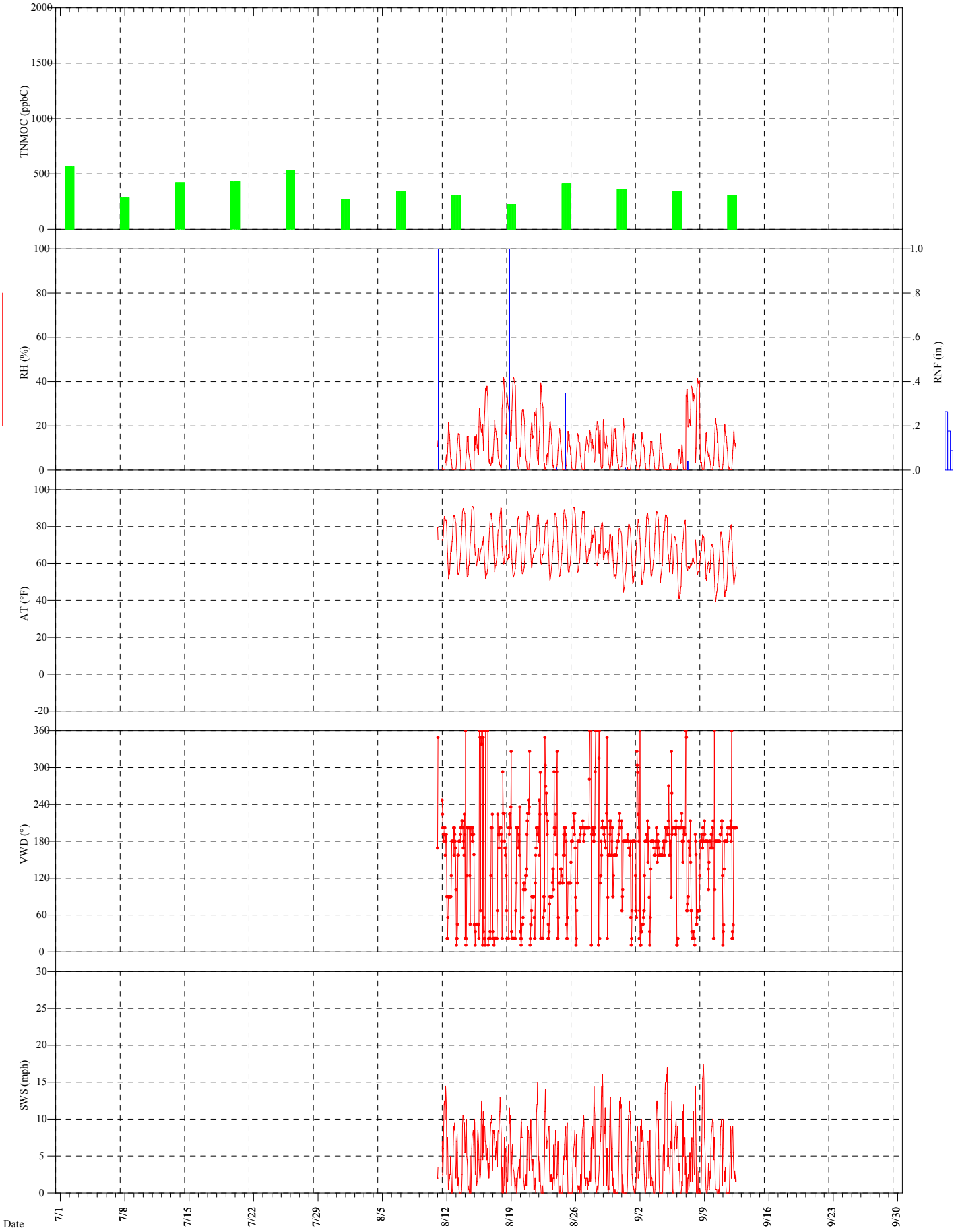

Figure A-16

Garfield County, CO
Battlement Mesa Site

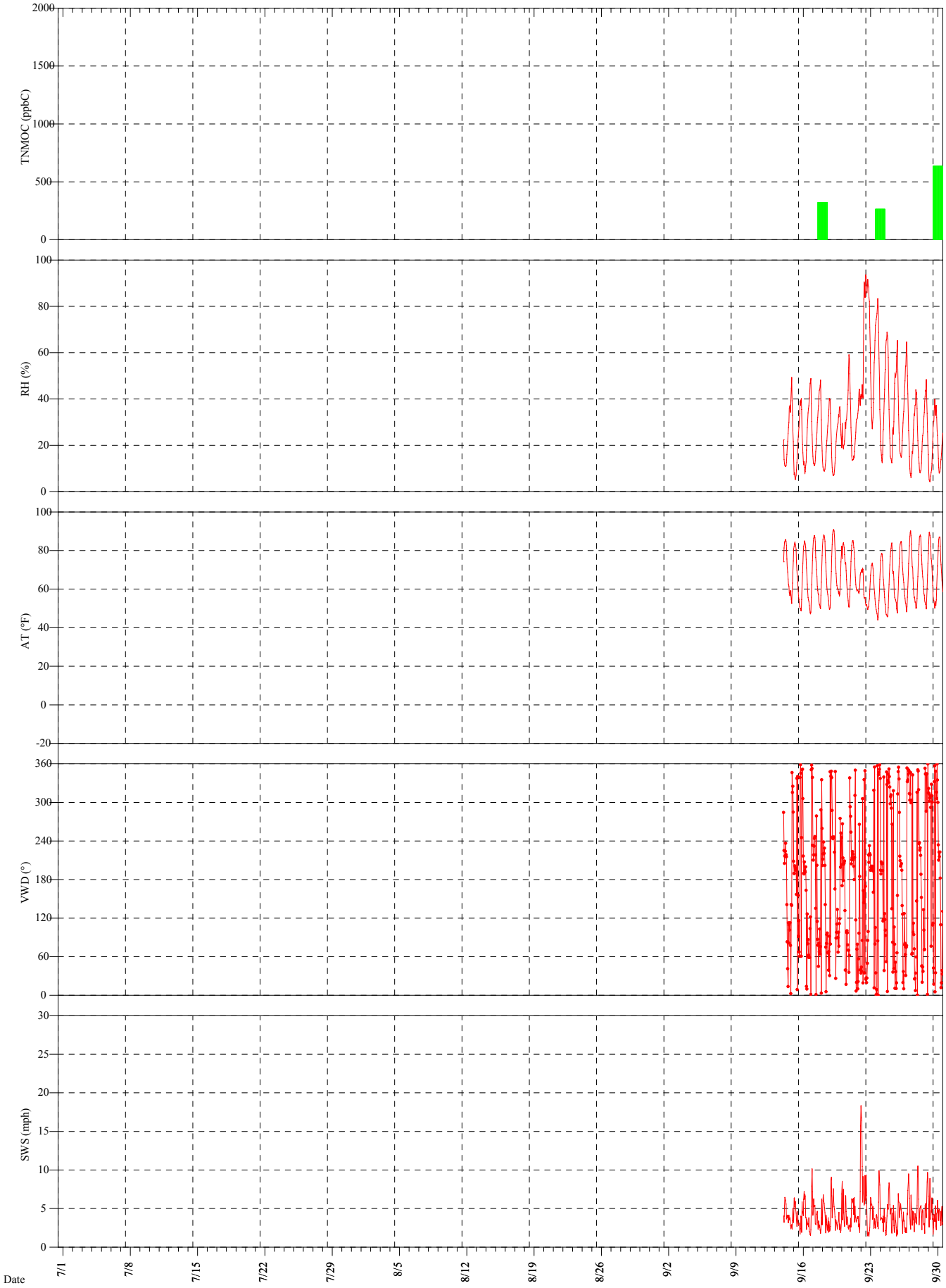

Figure A-17

Garfield County, CO

Battlement Mesa Site

APPENDIX B

Garfield County

2010 SNMOC Concentrations

Table B-1
Garfield County SNMOC Monitoring
Parachute (PACO)
1/3/2010-12/29/2010 (every sixth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
1,2,3-Trimethylbenzene (526-73-8)	52	35	0.01	0.08	0.02
1,2,4-Trimethylbenzene (95-63-6)	52	51	0.02	0.17	0.09
1,3,5-Trimethylbenzene (108-67-8)	52	52	0.02	0.16	0.08
1,3-Butadiene (106-99-0)	52	15	0.02	0.30	0.04
1-Dodecene (112-41-4)	52	46	0.01	0.18	0.03
1-Heptene (592-76-7)	52	50	0.03	0.57	0.20
1-Hexene (592-41-6)	52	45	0.02	0.13	0.04
1-Nonene (124-11-8)	52	38	0.01	0.08	0.02
1-Octene (111-66-0)	52	39	0.01	0.12	0.04
1-Pentene (109-67-1)	52	51	0.03	0.22	0.05
1-Tridecene (2437-56-1)	52	1	0.02	0.02	0.01
1-Undecene (821-95-4)	52	15	0.00	0.45	0.04
2,2,3-Trimethylpentane (564-02-3)	52	39	0.01	0.12	0.04
2,2,4-Trimethylpentane (540-84-1)	52	12	0.01	0.12	0.02
2,2-Dimethylbutane (75-83-2)	52	52	0.05	0.66	0.18
2,3,4-Trimethylpentane (565-75-3)	52	41	0.01	0.09	0.02
2,3-Dimethylbutane (79-29-8)	52	50	0.06	0.79	0.27
2,3-Dimethylpentane (565-59-3)	52	52	0.07	0.35	0.17
2,4-Dimethylpentane (108-08-7)	52	50	0.03	0.26	0.09
2-Methyl-1-butene (563-46-2)	52	25	0.01	0.25	0.04
2-Methyl-2-butene (513-35-9)	52	31	0.02	0.11	0.03
2-Methylheptane (592-27-8)	52	52	0.04	0.44	0.18
2-Methylhexane (591-76-4)	52	52	0.11	0.97	0.38
2-Methylpentane (107-83-5)	52	52	0.22	3.22	1.16
3-Methylheptane (589-81-1)	52	52	0.04	0.34	0.15
3-Methylhexane (589-34-4)	52	46	0.02	0.99	0.36
3-Methylpentane (96-14-0)	52	52	0.13	1.80	0.63
4-Methyl-1-pentene (691-37-2)	52	10	0.02	0.07	0.03
Acetylene (74-86-2)	52	52	0.25	1.59	0.71
a-Pinene (80-56-8)	52	39	0.01	0.51	0.03
Benzene (71-43-2)	52	52	0.15	1.26	0.54
b-Pinene (127-91-3)	52	7	0.01	0.04	0.01
cis-2-Butene (590-18-1)	52	50	0.03	0.22	0.07
cis-2-Hexene (7688-21-3)	52	3	0.03	0.04	0.03
cis-2-Pentene (627-20-3)	52	44	0.02	0.05	0.03
Cyclohexane (110-82-7)	52	52	0.14	2.50	0.84
Cyclopentane (287-92-3)	52	52	0.04	0.49	0.19
Cyclopentene (142-29-0)	52	7	0.02	0.18	0.03
Ethane (74-84-0)	52	52	7.35	213.50	55.54
Ethylbenzene (100-41-4)	52	52	0.02	6.12	0.25
Ethylene (74-85-1)	52	52	0.56	2.86	1.40
Isobutane (75-28-5)	52	52	0.64	65.50	6.56

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table B-1 (continued)
Garfield County SNMOC Monitoring
Parachute (PACO)
1/3/2010-12/29/2010 (every sixth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
Isobutene/1-Butene (115-11-7 / 106-98-9)	52	48	0.06	7.75	0.63
Isopentane (78-78-4)	52	52	0.50	17.10	3.78
Isoprene (78-79-5)	52	47	0.02	0.70	0.13
Isopropylbenzene (98-82-8)	52	35	0.01	0.03	0.01
m-Diethylbenzene (141-93-5)	52	24	0.01	0.08	0.02
Methylcyclohexane (108-87-2)	52	52	0.27	4.93	1.58
Methylcyclopentane (96-37-7)	52	52	0.14	2.02	0.68
m-Ethyltoluene (620-14-4)	52	51	0.01	0.10	0.05
m-Xylene/p-Xylene (108-38-3 / 106-42-3)	52	52	0.10	1.34	0.50
n-Butane (106-97-8)	52	50	1.05	17.90	5.70
n-Decane (124-18-5)	52	52	0.03	0.34	0.14
n-Dodecane (112-40-3)	52	49	0.01	0.17	0.05
n-Heptane (142-82-5)	52	52	0.12	1.57	0.62
n-Hexane (110-54-3)	52	52	0.19	3.43	1.11
n-Nonane (111-84-2)	52	52	0.05	0.45	0.21
n-Octane (111-65-9)	52	52	0.09	1.06	0.44
n-Pentane (109-66-0)	52	52	0.40	7.26	2.49
n-Propylbenzene (103-65-1)	52	48	0.01	0.06	0.03
n-Tridecane (629-50-5)	52	7	0.01	0.03	0.01
n-Undecane (1120-21-4)	52	51	0.02	0.28	0.09
o-Ethyltoluene (611-14-3)	52	48	0.01	0.12	0.05
o-Xylene (95-47-6)	52	52	0.02	0.38	0.10
p-Diethylbenzene (105-05-5)	52	18	0.01	0.06	0.01
p-Ethyltoluene (622-96-8)	52	50	0.01	0.09	0.04
Propane (74-98-6)	52	52	2.63	87.67	20.72
Propylene (115-07-1)	52	52	0.19	0.87	0.36
Styrene (100-42-5)	52	14	0.01	0.21	0.03
Toluene (108-88-3)	52	52	0.19	4.54	1.04
trans-2-Butene (624-64-6)	52	49	0.02	0.44	0.06
trans-2-Hexene (4050-45-7)	52	1	0.03	0.03	0.03
trans-2-Pentene (646-04-8)	52	47	0.02	0.08	0.04

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table B-2
Garfield County SNMOC Monitoring
Rifle (RICO)
1/3/2010-12/29/2010 (every sixth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
1,2,3-Trimethylbenzene (526-73-8)	59	45	0.01	0.05	0.02
1,2,4-Trimethylbenzene (95-63-6)	59	59	0.02	0.29	0.11
1,3,5-Trimethylbenzene (108-67-8)	59	58	0.01	0.19	0.06
1,3-Butadiene (106-99-0)	59	35	0.02	0.44	0.08
1-Dodecene (112-41-4)	59	46	0.01	0.17	0.03
1-Heptene (592-76-7)	59	57	0.03	0.44	0.13
1-Hexene (592-41-6)	59	50	0.03	0.18	0.05
1-Nonene (124-11-8)	59	46	0.01	0.14	0.03
1-Octene (111-66-0)	59	35	0.01	0.09	0.03
1-Pentene (109-67-1)	59	59	0.03	0.31	0.09
1-Tridecene (2437-56-1)	59	1	0.01	0.01	0.01
1-Undecene (821-95-4)	59	19	0.01	0.14	0.03
2,2,3-Trimethylpentane (564-02-3)	59	43	0.02	0.16	0.04
2,2,4-Trimethylpentane (540-84-1)	59	55	0.02	0.17	0.05
2,2-Dimethylbutane (75-83-2)	59	59	0.04	0.42	0.14
2,3,4-Trimethylpentane (565-75-3)	59	57	0.01	0.33	0.03
2,3-Dimethylbutane (79-29-8)	59	57	0.07	0.82	0.24
2,3-Dimethylpentane (565-59-3)	59	59	0.06	0.32	0.17
2,4-Dimethylpentane (108-08-7)	59	58	0.03	0.25	0.09
2-Ethyl-1-butene (760-21-4)	59	1	0.03	0.03	0.03
2-Methyl-1-butene (563-46-2)	59	48	0.02	4.04	0.15
2-Methyl-1-pentene (763-29-1)	59	1	0.02	0.02	0.03
2-Methyl-2-butene (513-35-9)	59	54	0.02	0.50	0.08
2-Methylheptane (592-27-8)	59	59	0.03	0.34	0.12
2-Methylhexane (591-76-4)	59	59	0.10	1.46	0.33
2-Methylpentane (107-83-5)	59	58	0.26	3.53	1.07
3-Methyl-1-butene (563-45-1)	59	1	0.03	0.03	0.02
3-Methylheptane (589-81-1)	59	59	0.03	0.27	0.09
3-Methylhexane (589-34-4)	59	52	0.02	0.81	0.31
3-Methylpentane (96-14-0)	59	59	0.14	1.98	0.57
4-Methyl-1-pentene (691-37-2)	59	18	0.02	0.16	0.04
Acetylene (74-86-2)	59	59	0.40	4.59	1.44
a-Pinene (80-56-8)	59	43	0.01	0.06	0.03
Benzene (71-43-2)	59	59	0.16	1.17	0.45
b-Pinene (127-91-3)	59	9	0.01	0.04	0.01
cis-2-Butene (590-18-1)	59	58	0.04	0.45	0.12
cis-2-Hexene (7688-21-3)	59	5	0.02	0.06	0.03
cis-2-Pentene (627-20-3)	59	53	0.02	0.13	0.05
Cyclohexane (110-82-7)	59	59	0.09	2.20	0.56
Cyclopentane (287-92-3)	59	59	0.06	0.52	0.19
Cyclopentene (142-29-0)	59	13	0.02	0.31	0.04
Ethane (74-84-0)	59	59	3.92	148.50	40.57

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table B-2 (continued)
Garfield County SNMOC Monitoring
Rifle (RICO)
1/3/2010-12/29/2010 (every sixth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
Ethylbenzene (100-41-4)	59	59	0.03	5.91	0.20
Ethylene (74-85-1)	59	59	0.94	6.05	2.20
Isobutane (75-28-5)	59	59	0.72	20.08	5.33
Isobutene/1-Butene (115-11-7 / 106-98-9)	59	59	0.10	8.02	1.01
Isopentane (78-78-4)	59	58	0.80	13.04	3.71
Isoprene (78-79-5)	59	54	0.03	0.69	0.13
Isopropylbenzene (98-82-8)	59	40	0.01	0.08	0.02
m-Diethylbenzene (141-93-5)	59	35	0.01	0.05	0.02
Methylcyclohexane (108-87-2)	59	59	0.13	3.53	0.92
Methylcyclopentane (96-37-7)	59	59	0.12	1.95	0.54
m-Ethyltoluene (620-14-4)	59	59	0.02	0.18	0.07
m-Xylene/p-Xylene (108-38-3 / 106-42-3)	59	59	0.08	1.06	0.39
n-Butane (106-97-8)	59	55	1.32	22.38	6.23
n-Decane (124-18-5)	59	59	0.01	0.32	0.09
n-Dodecane (112-40-3)	59	54	0.01	0.32	0.04
n-Heptane (142-82-5)	59	59	0.08	1.35	0.42
n-Hexane (110-54-3)	59	59	0.18	3.80	0.97
n-Nonane (111-84-2)	59	59	0.02	0.44	0.11
n-Octane (111-65-9)	59	59	0.06	0.86	0.24
n-Pentane (109-66-0)	59	59	0.59	8.76	2.76
n-Propylbenzene (103-65-1)	59	55	0.01	0.20	0.03
n-Tridecane (629-50-5)	59	2	0.01	0.02	0.01
n-Undecane (1120-21-4)	59	55	0.01	0.37	0.06
o-Ethyltoluene (611-14-3)	59	57	0.01	0.12	0.05
o-Xylene (95-47-6)	59	59	0.03	0.27	0.12
p-Diethylbenzene (105-05-5)	59	28	0.01	0.05	0.01
p-Ethyltoluene (622-96-8)	59	55	0.01	0.11	0.04
Propane (74-98-6)	59	59	1.92	65.33	17.78
Propylene (115-07-1)	59	59	0.25	1.87	0.60
Styrene (100-42-5)	59	25	0.01	0.10	0.02
Toluene (108-88-3)	59	59	0.19	2.01	0.81
trans-2-Butene (624-64-6)	59	59	0.04	0.52	0.13
trans-2-Hexene (4050-45-7)	59	11	0.01	0.04	0.03
trans-2-Pentene (646-04-8)	59	59	0.02	0.25	0.09

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table B-3
Garfield County SNMOC Monitoring
Bell-Melton (BRCO)
1/3/2010-12/29/2010 (every sixth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
1,2,3-Trimethylbenzene (526-73-8)	55	26	0.01	0.08	0.01
1,2,4-Trimethylbenzene (95-63-6)	55	53	0.01	0.17	0.05
1,3,5-Trimethylbenzene (108-67-8)	55	52	0.01	0.12	0.03
1,3-Butadiene (106-99-0)	55	4	0.02	0.17	0.03
1-Dodecene (112-41-4)	55	37	0.01	0.15	0.03
1-Heptene (592-76-7)	55	49	0.06	0.60	0.14
1-Hexene (592-41-6)	55	43	0.02	0.09	0.04
1-Nonene (124-11-8)	55	29	0.01	0.17	0.02
1-Octene (111-66-0)	55	29	0.01	0.05	0.02
1-Pentene (109-67-1)	55	53	0.02	0.08	0.04
1-Undecene (821-95-4)	55	15	0.01	0.42	0.04
2,2,3-Trimethylpentane (564-02-3)	55	32	0.01	0.18	0.03
2,2,4-Trimethylpentane (540-84-1)	55	27	0.01	0.17	0.03
2,2-Dimethylbutane (75-83-2)	55	55	0.02	0.59	0.15
2,3,4-Trimethylpentane (565-75-3)	55	38	0.01	0.10	0.02
2,3-Dimethylbutane (79-29-8)	55	53	0.04	1.28	0.28
2,3-Dimethylpentane (565-59-3)	55	55	0.03	0.53	0.15
2,4-Dimethylpentane (108-08-7)	55	54	0.02	0.30	0.08
2-Ethyl-1-butene (760-21-4)	55	1	0.80	0.80	0.04
2-Methyl-1-butene (563-46-2)	55	14	0.02	0.90	0.05
2-Methyl-2-butene (513-35-9)	55	15	0.01	0.08	0.03
2-Methylheptane (592-27-8)	55	55	0.01	0.35	0.11
2-Methylhexane (591-76-4)	55	55	0.05	0.98	0.31
2-Methylpentane (107-83-5)	55	55	0.02	5.50	1.25
3-Methylheptane (589-81-1)	55	55	0.02	0.25	0.08
3-Methylhexane (589-34-4)	55	48	0.01	0.93	0.28
3-Methylpentane (96-14-0)	55	55	0.03	2.93	0.64
4-Methyl-1-pentene (691-37-2)	55	13	0.02	0.17	0.04
Acetylene (74-86-2)	55	55	0.10	1.83	0.70
a-Pinene (80-56-8)	55	32	0.01	0.15	0.03
Benzene (71-43-2)	55	55	0.03	1.32	0.34
b-Pinene (127-91-3)	55	7	0.01	0.03	0.01
cis-2-Butene (590-18-1)	55	43	0.03	0.42	0.05
cis-2-Hexene (7688-21-3)	55	1	0.02	0.02	0.03
cis-2-Pentene (627-20-3)	55	30	0.02	0.04	0.02
Cyclohexane (110-82-7)	55	55	0.03	3.20	0.72
Cyclopentane (287-92-3)	55	55	0.03	0.85	0.21
Cyclopentene (142-29-0)	55	9	0.02	0.34	0.04
Ethane (74-84-0)	55	55	0.88	274.50	56.19
Ethylbenzene (100-41-4)	55	54	0.02	1.88	0.09
Ethylene (74-85-1)	55	55	0.56	2.24	1.14
Isobutane (75-28-5)	55	55	0.13	39.50	8.21

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table B-3 (continued)
Garfield County SNMOC Monitoring
Bell-Melton (BRCO)
1/3/2010-12/29/2010 (every sixth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
Isobutene/1-Butene (115-11-7 / 106-98-9)	55	51	0.05	5.92	0.71
Isopentane (78-78-4)	55	55	0.08	20.60	4.42
Isoprene (78-79-5)	55	47	0.02	0.75	0.11
Isopropylbenzene (98-82-8)	55	31	0.01	0.07	0.01
m-Diethylbenzene (141-93-5)	55	23	0.01	0.16	0.02
Methylcyclohexane (108-87-2)	55	55	0.04	4.37	1.09
Methylcyclopentane (96-37-7)	55	55	0.03	2.70	0.62
m-Ethyltoluene (620-14-4)	55	52	0.01	0.08	0.03
m-Xylene/p-Xylene (108-38-3 / 106-42-3)	55	55	0.04	1.82	0.23
n-Butane (106-97-8)	55	52	0.15	40.50	8.86
n-Decane (124-18-5)	55	53	0.01	0.30	0.06
n-Dodecane (112-40-3)	55	47	0.00	0.28	0.03
n-Heptane (142-82-5)	55	55	0.03	1.79	0.48
n-Hexane (110-54-3)	55	55	0.04	6.15	1.28
n-Nonane (111-84-2)	55	55	0.01	0.34	0.09
n-Octane (111-65-9)	55	55	0.03	0.79	0.23
n-Pentane (109-66-0)	55	55	0.08	15.46	3.36
n-Propylbenzene (103-65-1)	55	40	0.01	0.07	0.02
n-Tridecane (629-50-5)	55	1	0.09	0.09	0.01
n-Undecane (1120-21-4)	55	53	0.01	0.39	0.05
o-Ethyltoluene (611-14-3)	55	47	0.01	0.07	0.02
o-Xylene (95-47-6)	55	54	0.02	0.21	0.05
p-Diethylbenzene (105-05-5)	55	15	0.01	0.07	0.01
p-Ethyltoluene (622-96-8)	55	45	0.01	0.06	0.02
Propane (74-98-6)	55	55	0.68	129.67	27.21
Propylene (115-07-1)	55	55	0.13	0.74	0.28
Styrene (100-42-5)	55	16	0.01	0.07	0.02
Toluene (108-88-3)	55	55	0.03	1.69	0.52
trans-2-Butene (624-64-6)	55	46	0.02	0.95	0.06
trans-2-Pentene (646-04-8)	55	38	0.02	0.17	0.03

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table B-4
Garfield County SNMOC Monitoring
Rulison (RUCO)
1/3/2010-9/12/2010 (every sixth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
1,2,3-Trimethylbenzene (526-73-8)	40	17	0.01	0.04	0.01
1,2,4-Trimethylbenzene (95-63-6)	40	40	0.02	0.23	0.07
1,3,5-Trimethylbenzene (108-67-8)	40	40	0.02	0.12	0.06
1,3-Butadiene (106-99-0)	40	4	0.02	0.08	0.03
1-Decene (872-05-9)	40	1	0.05	0.05	0.01
1-Dodecene (112-41-4)	40	32	0.01	0.12	0.03
1-Heptene (592-76-7)	40	38	0.06	0.41	0.20
1-Hexene (592-41-6)	40	29	0.02	0.16	0.04
1-Nonene (124-11-8)	40	22	0.01	0.07	0.02
1-Octene (111-66-0)	40	31	0.01	0.15	0.05
1-Pentene (109-67-1)	40	39	0.02	0.19	0.04
1-Undecene (821-95-4)	40	15	0.01	0.24	0.03
2,2,3-Trimethylpentane (564-02-3)	40	29	0.02	0.09	0.04
2,2,4-Trimethylpentane (540-84-1)	40	13	0.02	0.33	0.03
2,2-Dimethylbutane (75-83-2)	40	40	0.08	0.46	0.21
2,3,4-Trimethylpentane (565-75-3)	40	23	0.01	0.09	0.02
2,3-Dimethylbutane (79-29-8)	40	38	0.11	0.82	0.32
2,3-Dimethylpentane (565-59-3)	40	40	0.08	0.32	0.19
2,4-Dimethylpentane (108-08-7)	40	40	0.04	0.20	0.10
2-Ethyl-1-butene (760-21-4)	40	1	1.45	1.45	0.06
2-Methyl-1-butene (563-46-2)	40	11	0.02	0.88	0.07
2-Methyl-2-butene (513-35-9)	40	14	0.01	0.13	0.03
2-Methylheptane (592-27-8)	40	40	0.06	0.34	0.18
2-Methylhexane (591-76-4)	40	40	0.13	0.77	0.41
2-Methylpentane (107-83-5)	40	40	0.39	2.97	1.37
3-Methylheptane (589-81-1)	40	40	0.05	0.27	0.13
3-Methylhexane (589-34-4)	40	33	0.02	1.08	0.40
3-Methylpentane (96-14-0)	40	40	0.22	1.68	0.72
4-Methyl-1-pentene (691-37-2)	40	10	0.02	0.13	0.04
Acetylene (74-86-2)	40	40	0.18	1.50	0.55
a-Pinene (80-56-8)	40	26	0.01	0.08	0.03
Benzene (71-43-2)	40	40	0.19	0.92	0.51
b-Pinene (127-91-3)	40	4	0.01	0.03	0.01
cis-2-Butene (590-18-1)	40	33	0.03	0.07	0.04
cis-2-Hexene (7688-21-3)	40	1	0.06	0.06	0.03
cis-2-Pentene (627-20-3)	40	25	0.02	0.04	0.02
Cyclohexane (110-82-7)	40	40	0.26	2.08	0.94
Cyclopentane (287-92-3)	40	40	0.08	0.53	0.22
Cyclopentene (142-29-0)	40	9	0.02	0.14	0.03
Ethane (74-84-0)	40	40	11.40	153.50	54.37
Ethylbenzene (100-41-4)	40	39	0.03	1.14	0.11
Ethylene (74-85-1)	40	40	0.62	1.91	1.14

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table B-4 (continued)
Garfield County SNMOC Monitoring
Rulison (RUCO)
1/3/2010-9/12/2010 (every sixth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
Isobutane (75-28-5)	40	40	1.50	20.10	7.20
Isobutene/1-Butene (115-11-7 / 106-98-9)	40	38	0.07	3.85	0.47
Isopentane (78-78-4)	40	40	1.18	12.42	4.40
Isoprene (78-79-5)	40	32	0.03	0.65	0.15
Isopropylbenzene (98-82-8)	40	25	0.01	0.05	0.01
m-Diethylbenzene (141-93-5)	40	18	0.01	0.13	0.02
Methylcyclohexane (108-87-2)	40	40	0.50	3.31	1.66
Methylcyclopentane (96-37-7)	40	40	0.25	1.68	0.79
m-Ethyltoluene (620-14-4)	40	40	0.02	0.20	0.05
m-Xylene/p-Xylene (108-38-3 / 106-42-3)	40	40	0.14	0.88	0.40
n-Butane (106-97-8)	40	38	1.87	21.28	7.38
n-Decane (124-18-5)	40	40	0.02	0.20	0.09
n-Dodecane (112-40-3)	40	37	0.01	0.09	0.03
n-Heptane (142-82-5)	40	40	0.18	1.41	0.69
n-Hexane (110-54-3)	40	40	0.37	3.13	1.37
n-Nonane (111-84-2)	40	40	0.03	0.34	0.16
n-Octane (111-65-9)	40	40	0.12	0.82	0.41
n-Pentane (109-66-0)	40	40	0.96	8.60	3.19
n-Propylbenzene (103-65-1)	40	32	0.01	0.10	0.02
n-Tridecane (629-50-5)	40	2	0.00	0.01	0.01
n-Undecane (1120-21-4)	40	40	0.01	0.12	0.06
o-Ethyltoluene (611-14-3)	40	37	0.01	0.10	0.03
o-Xylene (95-47-6)	40	40	0.03	0.16	0.07
p-Diethylbenzene (105-05-5)	40	15	0.01	0.07	0.01
p-Ethyltoluene (622-96-8)	40	36	0.02	0.13	0.04
Propane (74-98-6)	40	40	4.43	67.33	23.44
Propylene (115-07-1)	40	40	0.20	0.62	0.30
Styrene (100-42-5)	40	9	0.01	0.08	0.02
Toluene (108-88-3)	40	40	0.26	1.93	0.87
trans-2-Butene (624-64-6)	40	31	0.02	0.15	0.03
trans-2-Pentene (646-04-8)	40	28	0.02	0.07	0.03

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table B-5
Garfield County SNMOC Monitoring
Battlement Mesa (BMCO)
9/18/2010-12/29/2010 (every sixth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
1,2,3-Trimethylbenzene (526-73-8)	18	18	0.01	0.02	0.02
1,2,4-Trimethylbenzene (95-63-6)	18	18	0.03	0.09	0.06
1,3,5-Trimethylbenzene (108-67-8)	18	18	0.02	0.07	0.05
1,3-Butadiene (106-99-0)	18	8	0.02	0.05	0.03
1-Dodecene (112-41-4)	18	13	0.01	0.04	0.02
1-Heptene (592-76-7)	18	18	0.03	0.41	0.17
1-Hexene (592-41-6)	18	18	0.02	0.08	0.04
1-Nonene (124-11-8)	18	16	0.01	0.02	0.02
1-Octene (111-66-0)	18	13	0.01	0.06	0.03
1-Pentene (109-67-1)	18	18	0.03	0.48	0.09
1-Undecene (821-95-4)	18	2	0.03	0.03	0.01
2,2,3-Trimethylpentane (564-02-3)	18	18	0.02	0.07	0.04
2,2,4-Trimethylpentane (540-84-1)	18	11	0.02	0.10	0.03
2,2-Dimethylbutane (75-83-2)	18	18	0.08	0.40	0.17
2,3,4-Trimethylpentane (565-75-3)	18	17	0.01	0.05	0.02
2,3-Dimethylbutane (79-29-8)	18	18	0.11	0.80	0.32
2,3-Dimethylpentane (565-59-3)	18	18	0.08	0.29	0.15
2,4-Dimethylpentane (108-08-7)	18	18	0.03	0.20	0.10
2-Methyl-1-butene (563-46-2)	18	16	0.03	1.98	0.22
2-Methyl-1-pentene (763-29-1)	18	1	0.07	0.07	0.03
2-Methyl-2-butene (513-35-9)	18	16	0.02	0.96	0.13
2-Methylheptane (592-27-8)	18	18	0.03	0.26	0.12
2-Methylhexane (591-76-4)	18	18	0.10	0.67	0.33
2-Methylpentane (107-83-5)	18	17	0.39	3.07	1.20
3-Methylheptane (589-81-1)	18	18	0.04	0.22	0.10
3-Methylhexane (589-34-4)	18	18	0.09	0.73	0.36
3-Methylpentane (96-14-0)	18	18	0.22	1.70	0.69
4-Methyl-1-pentene (691-37-2)	18	4	0.02	0.04	0.03
Acetylene (74-86-2)	18	18	0.28	1.22	0.66
a-Pinene (80-56-8)	18	10	0.01	0.04	0.02
Benzene (71-43-2)	18	18	0.14	0.91	0.46
b-Pinene (127-91-3)	18	1	0.04	0.04	0.01
cis-2-Butene (590-18-1)	18	18	0.04	1.52	0.23
cis-2-Hexene (7688-21-3)	18	1	0.02	0.02	0.03
cis-2-Pentene (627-20-3)	18	18	0.02	0.49	0.08
Cyclohexane (110-82-7)	18	18	0.15	1.82	0.73
Cyclopentane (287-92-3)	18	18	0.09	0.62	0.23
Cyclopentene (142-29-0)	18	1	0.02	0.02	0.02
Ethane (74-84-0)	18	18	16.20	122.00	46.57
Ethylbenzene (100-41-4)	18	18	0.03	0.09	0.06
Ethylene (74-85-1)	18	18	0.57	1.94	0.98
Isobutane (75-28-5)	18	18	1.26	15.50	5.97

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table B-5 (continued)
Garfield County SNMOC Monitoring
Battlement Mesa (BMCO)
9/18/2010-12/29/2010 (every sixth day)

	Sample Count		Concentration (ppbV)		
Detected Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
Isobutene/1-Butene (115-11-7 / 106-98-9)	18	17	0.11	5.88	0.75
Isopentane (78-78-4)	18	18	0.80	22.60	5.21
Isoprene (78-79-5)	18	18	0.02	0.11	0.06
Isopropylbenzene (98-82-8)	18	14	0.01	0.02	0.01
m-Diethylbenzene (141-93-5)	18	11	0.01	0.02	0.01
Methylcyclohexane (108-87-2)	18	18	0.24	3.23	1.28
Methylcyclopentane (96-37-7)	18	18	0.15	1.54	0.70
m-Ethyltoluene (620-14-4)	18	18	0.01	0.07	0.04
m-Xylene/p-Xylene (108-38-3 / 106-42-3)	18	18	0.09	0.55	0.33
n-Butane (106-97-8)	18	17	2.85	21.62	8.08
n-Decane (124-18-5)	18	18	0.02	0.11	0.07
n-Dodecane (112-40-3)	18	18	0.01	0.10	0.03
n-Heptane (142-82-5)	18	18	0.11	1.04	0.49
n-Hexane (110-54-3)	18	18	0.26	2.50	1.14
n-Nonane (111-84-2)	18	18	0.03	0.19	0.11
n-Octane (111-65-9)	18	18	0.07	0.59	0.27
n-Pentane (109-66-0)	18	18	0.67	10.54	3.48
n-Propylbenzene (103-65-1)	18	18	0.01	0.03	0.02
n-Undecane (1120-21-4)	18	18	0.01	0.16	0.05
o-Ethyltoluene (611-14-3)	18	17	0.01	0.05	0.03
o-Xylene (95-47-6)	18	18	0.03	0.11	0.08
p-Diethylbenzene (105-05-5)	18	9	0.01	0.04	0.01
p-Ethyltoluene (622-96-8)	18	18	0.02	0.04	0.03
Propane (74-98-6)	18	18	5.53	48.00	18.02
Propylene (115-07-1)	18	18	0.20	0.48	0.30
Styrene (100-42-5)	18	5	0.01	0.02	0.02
Toluene (108-88-3)	18	18	0.18	1.30	0.76
trans-2-Butene (624-64-6)	18	18	0.03	1.67	0.26
trans-2-Hexene (4050-45-7)	18	3	0.02	0.07	0.03
trans-2-Pentene (646-04-8)	18	18	0.02	0.93	0.13

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

APPENDIX C

Garfield County

2010 Carbonyl Concentrations

Table C-1
Garfield County Carbonyl Monitoring
Parachute (PACO)
1/15/2010-12/29/2010 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
2,5-Dimethylbenzaldehyde (5779-94-2)	28	0	ND	ND	0.00
Acetaldehyde (75-07-0)	28	28	0.09	1.08	0.51
Acetone (67-64-1)	28	28	0.57	1.84	1.12
Benzaldehyde (100-52-7)	28	28	0.01	0.09	0.03
Butyraldehyde (123-72-8)	28	28	0.01	0.08	0.04
Crotonaldehyde (123-73-9)	28	28	0.01	0.13	0.04
Formaldehyde (50-00-0)	28	28	0.62	2.58	1.25
Hexaldehyde (66-25-1)	28	27	0.00	0.04	0.02
Isovaleraldehyde (590-86-3)	28	0	ND	ND	0.00
Propionaldehyde (123-38-6)	28	26	0.01	0.11	0.04
Tolualdehydes (NA)	28	26	0.01	0.05	0.02
Valeraldehyde (110-62-3)	28	22	0.00	0.03	0.01

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table C-2
Garfield County Carbonyl Monitoring
Rifle (RICO)
1/15/2010-12/18/2010 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
2,5-Dimethylbenzaldehyde (5779-94-2)	24	0	ND	ND	0.00
Acetaldehyde (75-07-0)	24	24	0.34	1.32	0.82
Acetone (67-64-1)	24	24	0.66	2.19	1.30
Benzaldehyde (100-52-7)	24	24	0.02	0.09	0.04
Butyraldehyde (123-72-8)	24	23	0.01	0.12	0.06
Crotonaldehyde (123-73-9)	24	24	0.02	0.15	0.06
Formaldehyde (50-00-0)	24	24	0.82	2.52	1.46
Hexaldehyde (66-25-1)	24	24	0.00	0.06	0.03
Isovaleraldehyde (590-86-3)	24	1	0.07	0.07	0.00
Propionaldehyde (123-38-6)	24	23	0.01	0.14	0.07
Tolualdehydes (NA)	24	21	0.02	0.09	0.03
Valeraldehyde (110-62-3)	24	24	0.00	0.04	0.02

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table C-3
Garfield County Carbonyl Monitoring
Bell-Melton (BRCO)
1/27/2010-9/12/2010 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
2,5-Dimethylbenzaldehyde (5779-94-2)	17	0	ND	ND	0.00
Acetaldehyde (75-07-0)	17	17	0.11	0.99	0.47
Acetone (67-64-1)	17	17	0.61	1.72	1.05
Benzaldehyde (100-52-7)	17	17	0.01	0.06	0.02
Butyraldehyde (123-72-8)	17	17	0.01	0.09	0.03
Crotonaldehyde (123-73-9)	17	16	0.01	0.16	0.05
Formaldehyde (50-00-0)	17	17	0.40	2.01	0.98
Hexaldehyde (66-25-1)	17	15	0.01	0.03	0.02
Isovaleraldehyde (590-86-3)	17	0	ND	ND	0.00
Propionaldehyde (123-38-6)	17	15	0.02	0.10	0.04
Tolualdehydes (NA)	17	12	0.01	0.04	0.01
Valeraldehyde (110-62-3)	17	13	0.00	0.02	0.01

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table C-4
Garfield County Carbonyl Monitoring
Rulison (RUCO)
1/15/2010-9/12/2010 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
2,5-Dimethylbenzaldehyde (5779-94-2)	18	0	ND	ND	0.00
Acetaldehyde (75-07-0)	18	18	0.09	1.44	0.61
Acetone (67-64-1)	18	18	0.68	1.92	1.37
Benzaldehyde (100-52-7)	18	18	0.01	0.07	0.03
Butyraldehyde (123-72-8)	18	18	0.01	0.10	0.04
Crotonaldehyde (123-73-9)	18	18	0.01	0.15	0.06
Formaldehyde (50-00-0)	18	18	0.58	2.40	1.13
Hexaldehyde (66-25-1)	18	18	0.00	0.04	0.02
Isovaleraldehyde (590-86-3)	18	0	ND	ND	0.00
Propionaldehyde (123-38-6)	18	16	0.01	0.14	0.04
Tolualdehydes (NA)	18	14	0.01	0.04	0.01
Valeraldehyde (110-62-3)	18	12	0.01	0.03	0.01

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.

Table C-5
Garfield County Carbonyl Monitoring
Battlement Mesa (BMCO)
10/6/2010-12/17/2010 (every twelfth day)

	Sample Count		Concentration (ppbV)		
Compound (CAS Number)	**# Samples**	**# Detects**	**Minimum**	**Maximum**	**Average***
2,5-Dimethylbenzaldehyde (5779-94-2)	7	0	ND	ND	0.00
Acetaldehyde (75-07-0)	7	7	0.19	0.89	0.50
Acetone (67-64-1)	7	7	0.49	3.67	2.25
Benzaldehyde (100-52-7)	7	7	0.01	0.24	0.08
Butyraldehyde (123-72-8)	7	7	0.02	0.07	0.03
Crotonaldehyde (123-73-9)	7	7	0.01	0.05	0.03
Formaldehyde (50-00-0)	7	7	0.54	1.92	1.13
Hexaldehyde (66-25-1)	7	7	0.01	0.10	0.03
Isovaleraldehyde (590-86-3)	7	0	ND	ND	0.00
Propionaldehyde (123-38-6)	7	7	0.01	0.09	0.04
Tolualdehydes (NA)	7	7	0.01	0.10	0.04
Valeraldehyde (110-62-3)	7	6	0.01	0.04	0.01

*Samples reported as non-detects (ND) were included in averages as 1/2 minimum detection limits.