Colorado

2012 Air Quality Data Report

Air Pollution Control Division

Colorado Department of Public Health and Environment

Cover photograph – Blue Lake in the Mt. Sneffels Wilderness

COLORADO AIR QUALITY DATA REPORT 2012

Colorado Department of Public Health and Environment

Air Pollution Control Division
APCD-TS-B1
4300 Cherry Creek Drive South
Denver, Colorado 80246-1530
(303) 692-3100

November 2013

This report is available electronically at http://www.colorado.gov/airquality/tech_doc_repository.aspx

Table of Contents

Table of Figures

Table of Tables

1. PURPOSE OF THE ANNUAL DATA REPORT

The Colorado Department of Public Health and Environment, Air Pollution Control Division (APCD) publishes the Colorado Air Quality Data Report as a companion document to the Colorado Air Quality Control Commission Report to the Public. The Air Quality Data Report addresses changes in ambient air quality measured by APCD monitors. The Report to the Public discusses the policies and programs designed to improve and protect Colorado's air quality.

1.1. Symbols and Abbreviations

The following symbols and abbreviations have been used throughout this report:

APCD	Air Pollution Control Division
CDPHE	Colorado Department of Public Health and Environment
CO	Carbon monoxide
EPA	U.S. Environmental Protection Agency
Met	Meteorological measurements which typically include wind speed, wind direction, temperature, relative humidity and standard deviation of horizontal wind direction
NAAQS	National Ambient Air Quality Standard
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen
NOy	Reactive oxides of nitrogen
O_3	Ozone
PM_{10}	Particulate matter less than 10 microns in aerometric diameter
$PM_{2.5}$	Particulate matter less than 2.5 microns in aerometric diameter
Pb	Lead
ppb	parts per billion – used with gaseous pollutants
ppm	parts per million – used with gaseous pollutants
SO_2	Sulfur dioxide
SO_X	Oxides of sulfur
TSP	Total suspended particulates
$\mu g/m^3$	micrograms per cubic meter

1.2. Description of Monitoring Areas in Colorado

The state has been divided into eight multi-county areas that are generally based on topography and have similar airshed characteristics. These areas are the Central Mountains, Denver Metro/North Front Range, Eastern High Plains, Pikes Peak, San Luis Valley, South Central, Southwestern, and Western Slope regions. Table 1 lists the locations of the pollutant monitors by area.

In the past this report divided the state into five regions. While this served a topographic and climatologic purpose, the Division has determined the eight area approach to more accurately reflect local air pollution conditions. Figure 1 shows the approximate boundaries of these areas and the locations of air quality monitoring stations.

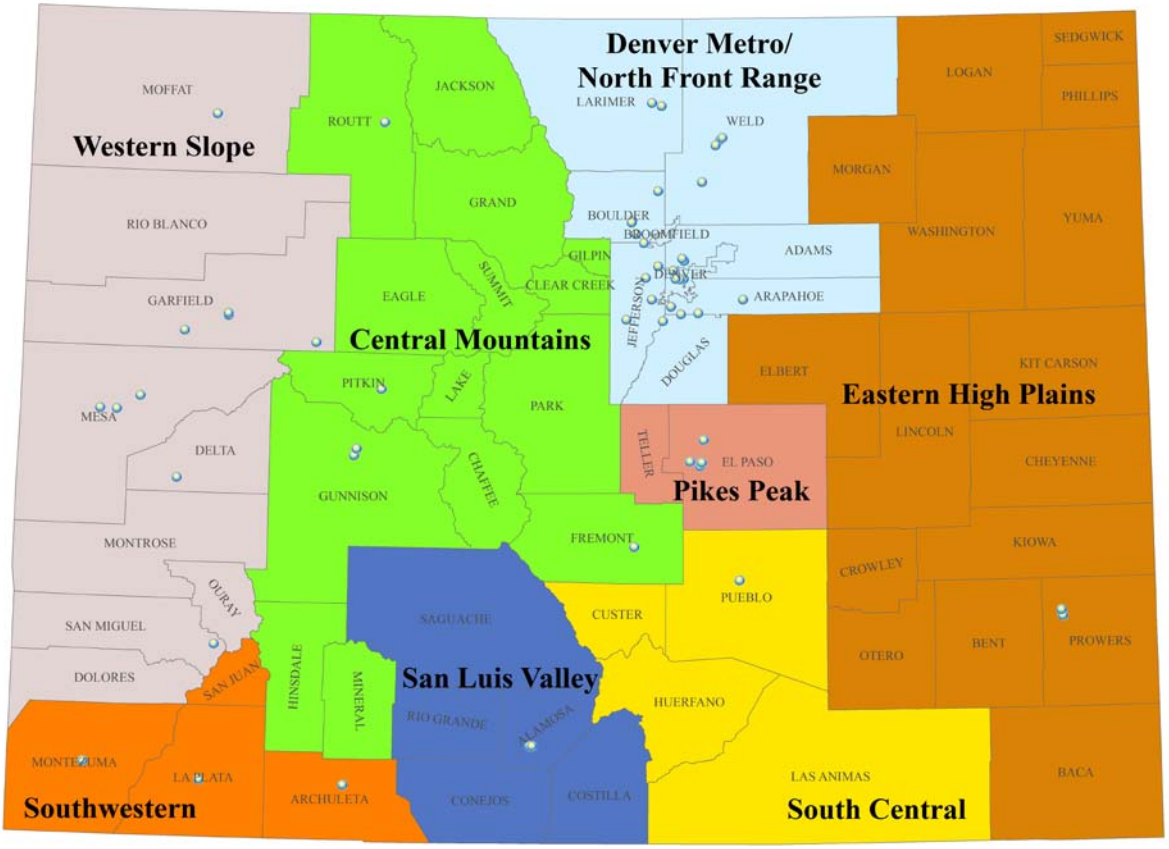


Figure 1. Monitoring Areas in Colorado

1.2.1 Central Mountains Region

The Central Mountains Region consists of 15 counties in the central area of the state. The Continental Divide passes through much of this region. Mountains and mountain valleys are the dominant landscape. Leadville, Steamboat Springs, Cañon City, Salida, Buena Vista and Aspen represent the larger communities. The population of this region is about 256,800, according to U.S. Census Bureau estimates. Skiing, tourism, ranching, mining, and correctional facilities are the primary industries. Black Canyon of the Gunnison National Park is located in this region. All of the area complies with National Ambient Air Quality Standards.

The primary monitoring concern is with particulate pollution from wood burning and road sanding. Currently, there are no gaseous and five particulate monitoring sites operated by the APCD in the Central Mountains region.

1.2.2 Denver Metro/North Front Range Region

The Denver-Metro/North Front Range Region includes Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer and Weld counties. It includes the largest population area of the state, with 2.8 million people living in the seven-county Denver-metro area and another half-million living in the northern Colorado area of Larimer and Weld counties. This area includes Rocky Mountain National Park and several wilderness areas.

Since 2002, the region complies with all National Ambient Air Quality Standards, except for ozone. The area has been exceeding the EPA's most recent ozone standards since the early 2000s, and in 2007 was formally designated as a "nonattainment" area. This designation was re-affirmed in 2012 when the U.S. Environmental Protection

Agency (EPA) designated the region as a “marginal” nonattainment area for the more stringent ozone standard adopted by EPA in 2008.

In the past, the Denver-metropolitan area violated health-based air quality standards for carbon monoxide and fine particles. In response, the Regional Air Quality Council, the Colorado Air Quality Control Commission and the APCD developed, adopted and implemented air quality improvement plans to reduce each of the pollutants.

For the rest of the Northern Front Range, Fort Collins, Longmont, and Greeley were nonattainment areas for carbon monoxide in the 1980s and early 1990s, but have met the federal standards since 1995. Air quality improvement plans have been implemented for each of these communities.

1.2.3 Eastern High Plains Region

The Eastern High Plains region encompasses the counties on the plains of eastern Colorado. The area is semiarid and often windy. The area's population is approximately 157,000 according to U.S. Census Bureau estimates. Its major urban centers have developed around farming, ranching and trade centers such as Sterling, Fort Morgan, Limon, La Junta, and Lamar. The agricultural base includes both irrigated and dry land farming. All of the area complies with National Ambient Air Quality Standards.

Historically, there have been a number of communities that were monitored for particulates and meteorology but not for any of the gaseous pollutants. In the northeast along the I-76 corridor, the communities of Sterling, Brush, and Fort Morgan have been monitored. Along the I-70 corridor only the community of Limon has been monitored for particulates. Along the US-50/Arkansas River corridor the APCD has monitored for particulates in the communities of La Junta and Rocky Ford. These monitoring sites were all discontinued in the late 1970s and early 1990s after a review showed that the concentrations were well below the standard and trending downward.

1.2.4 Pikes Peak Region

The Pikes Peak Region includes El Paso and Teller counties. The area has a population of approximately 626,200 according to U.S. Census Bureau estimates. Eastern El Paso County is rural prairie, while the western part of the region is mountainous. All of the area complies with National Ambient Air Quality Standards.

The U.S. Government is the largest employer in the area, and major industries include Fort Carson and the U.S. Air Force Academy in Colorado Springs, both military installations. Aerospace and technology are also large employers in the area.

1.2.5 San Luis Valley Region

Colorado's San Luis Valley Region is in the south central portion of Colorado and includes a broad alpine valley situated between the Sangre de Cristo Mountains on the northeast and the San Juan Mountains of the Continental Divide to the west. The valley is some 71 miles wide and 122 miles long, extending south into New Mexico. The average elevation is 7,500 feet. Principal towns include Alamosa, Monte Vista, and Del Norte. The population is about 45,100 according to U.S. Census Bureau estimates. Agriculture and tourism are the primary industries. The valley is semiarid and croplands of potatoes, head lettuce, and barley are typically irrigated. The valley is home to Great Sand Dunes National Park.

The air quality planning region consists of Saguache, Rio Grande, Alamosa, Conejos and Costilla counties. All of the area complies with National Ambient Air Quality Standards.

1.2.6 South Central Region

The South Central Region is comprised of Pueblo, Huerfano, Las Animas and Custer counties. Its population is approximately 184,800 according to U.S. Census Bureau estimates. Urban centers include Pueblo, Trinidad and

Walsenburg. The region has rolling semiarid plains to the east and is mountainous to the west. All of the area complies with National Ambient Air Quality Standards.

In the past the APCD has conducted particulate monitoring in both Walsenburg and Trinidad but that monitoring was discontinued in 1979 and 1985 respectively, due to low concentrations.

1.2.7 Southwest Region

The Southwestern Region includes the Four Corners area counties of Montezuma, La Plata, Archuleta and San Juan. The population of this region is about 89,800, according to U.S. Census Bureau estimates. The landscape includes mountains, plateaus, high valleys and canyons. Durango and Cortez are the largest towns, while lands of the Southern Ute and Ute Mountain Ute tribes make up large parts of this region. The region is home to Mesa Verde National Park, tourism and agriculture are dominant industries. Though the oil and gas industry is growing in this area, all of the area complies with National Ambient Air Quality Standards.

1.2.8 Western Slope Region

The Western Slope Region includes nine counties on the far western border of Colorado. A mix of mountains on the east, and mesas, plateaus, valleys and canyons to the west form the landscape of this region. Grand Junction is the largest urban area, and other cities include Telluride, Montrose, Delta, Rifle, Glenwood Springs, Meeker, Rangely, and Craig. The population of this region is about 309,700, according to U.S. Census Bureau estimates. Primary industries include ranching, agriculture, mining, energy development and tourism. Dinosaur and Colorado National Monuments are located in this region.

The Western Slope, along with the central mountains, are projected to be the fastest growing areas of Colorado through 2020 with greater than two percent annual population increases, according to the Colorado Department of Local Affairs. All of the area complies with National Ambient Air Quality Standards.

Table 1. Statewide Air Quality Monitors in Operation

County	*Site Name*	*Location*	*CO*	*SO_2*	*NO_X*	*O_3*	*Met*	*TSP*	*Pb*	*PM_{10}*	*$PM_{2.5}$*
Central Mountains											
Fremont	Canon City City Hall	128 Main St.								**X6**	
Gunnison	Crested Butte	603 6th St.								**X3**	
	Mt. Crested Butte	19 Emmons Rd.								**X1**	
Pitkin	Aspen Library	120 Mill St.								**X3**	
Routt	Steamboat Springs	136 6th St.								**X1**	
Summit	Breckenridge	501 N. Park Ave.								**X1**	
Eastern High Plains											
Prowers	Lamar Municipal	104 E. Parmenter St.								**X1**	
	Lamar POE	7100 Hwy 50					**X**				
	Lamar Power Plant	100 N. 2nd St.								**X1**	
Denver Metro/Northern Front Range											
Adams	Alsup Elementary	7101 Birch St.					**X**			**X1**	**X3/H/S6**

County	*Site Name*	*Location*	*CO*	*SO_2*	*NO_X*	*O_3*	*Met*	*TSP*	*Pb*	*PM_{10}*	*$PM_{2.5}$*
	Welby	3174 E. 78th Ave.	**X**	**X**	**X**	**X**	**X**			**X6/H**	
Arapahoe	Arapahoe Community College	6190 S. Santa Fe Dr.									**X3**
	Aurora East	36001 E. Quincy Ave.				**X**	**X**				
	Centennial Airport	7800 S. Peoria St.						**X6**	**X6**		
	Highland Res.	8100 S. University Blvd.				**X**	**X**				
Boulder	Boulder Chamber	2440 Pearl St.								**X6**	**X3**
	CU Athens	2102 Athens St.									**H**
	Longmont Municipal	350 Kimbark St.								**X6**	**X3/H**
	South Boulder Creek	1405½ S. Foothills Pkwy.				**X**					
Denver	CAMP	2105 Broadway	**X**	**X**	**X**	**A**	**X**			**X6/H**	**X1/H**
	Carriage	2325 Irving St.				**X**	**X**				
	DESCI (Visibility)	1901 E. 13th Ave.									
	DMAS	678 S. Jason St	**X**	**X**	**NOy**	**X**	**X**	**X6**	**X6**	**X3/H**	**X3/H/S3**
	La Casa	4587 Navajo St.							**A**	**A(X6)**	**A(X3)**
	NJH	14th Ave. & Albion St.									**H**
	Swansea Elementary	4650 Columbine St.									**X1**
	Visitor Center	225 W. Colfax Ave.								**X1**	
Douglas	Chatfield Reservoir	11500 N. Roxborough Pk. Rd.				**X**	**X**				**X3/H**
Jefferson	Arvada	9101 W. 57th Ave.				**D**	**X**				
	Aspen Park	26137 Conifer Rd.				**X**	**X**				
	NREL	2054 Quaker St.				**X**					
	Rocky Flats N	16600 W. Hwy. 128				**X**	**X**				
	Welch	12400 W. Hwy. 285				**X**	**X**				
Larimer	CSU Edison	251 Edison Dr.								**X3/H**	**X3/H**
	Fort Collins Mason	708 S. Mason St.	**X**			**X**	**X**				
	Fort Collins (Visibility)	300 Remington St.									
	Fort Collins West	3416 Laporte Ave.				**X**					
	Rist Canyon	11835 Rist Canyon Rd.				**X**	**X**				
Weld	Greeley County Tower	3101 35th Ave.				**X**	**A**				
	Greeley Hospital	1516 Hospital Rd.								**X3**	**X3/H**
	Greeley West Annex	905 10th Ave.	**X**								

County	*Site Name*	*Location*	*CO*	*SO_2*	*NO_X*	*O_3*	*Met*	*TSP*	*Pb*	*PM_{10}*	*$PM_{2.5}$*
	Platteville Middle School	1004 Main St.									**X3/S6**
Pikes Peak											
El Paso	Colorado College	130 W. Cache La Poudre								**X6**	**X3/H**
	CO Springs Hwy. 24	690 W. Hwy. 24	**X**								
	Manitou Springs	101 Banks Pl.				**X**					
	U.S. Air Force Academy	USAFA Rd. 640				**X**					
San Luis Valley											
Alamosa	Alamosa Municipal	425 4th St.								**X1**	
	Alamosa State Coll.	208 Edgemont Blvd.								**X1**	
South Central											
Pueblo	Fountain School	925 N. Glendale Ave.								**X3**	**X3**
Southwestern											
Archuleta	Pagosa Springs School	309 Lewis St.								**X1**	
La Plata	Durango River City Hall	1235 Camino del Rio								**X3**	
Montezuma	Cortez Health Dept.	106 W. North St.				**X**					**X6**
Western Slope											
Delta	Delta Health Dept.	560 Dodge St.								**X3**	
Garfield	Parachute Elementary	100 E. 2nd St.								**X3**	
	Henry Building	144 E. 3rd St.								**X3/H**	**H**
	Rifle Health Dept	195 W. 14th St.				**X**					
Moffat	Lay Peak	17820 CR 17				**X**	**X**				
Mesa	Clifton	Hwy. 141 & D Rd.								**X3**	
	Pitkin	645¼ Pitkin Ave.	**X**				**X**				
	Palisade Water Treatment	865 Rapid Creek Rd.				**X**	**X**				
	Powell	650 South Ave.								**X3**	**X3/H**
San Miguel	Telluride	333 W. Colorado Ave.								**X3**	

(A) – Added, (D) – Discontinued, (H) – Hourly particulate monitor, (Sn) – Chemical Speciation, (X) – Continued, (Xn) – Filter Sample Continued; n=frequency in days

2. CRITERIA POLLUTANTS

Criteria pollutants are those for which the federal government has established National Ambient Air Quality Standards in the Federal Clean Air Act and its amendments. There are six criteria pollutants. They are carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), lead (Pb), and particulate matter which is currently split into two size fractions. The standards for criteria pollutants are established to protect the most sensitive members of society. These are usually defined as those with heart and / or respiratory problems, the very young, and the elderly. The standards for each of the criteria pollutants are discussed in the following sections. A summary of these levels is presented in Table 2 (United States Environmental Protection Agency 2010). The primary standards are set to protect human health. The secondary standards are set to protect public welfare, and take into consideration such factors as crop damage, architectural damage, damage to ecosystems, and visibility in scenic areas.

Table 2. National Ambient Air Quality Standards

Pollutant		Primary / Secondary	Averaging Time	Level	Form
CO		Primary	8-hour	9 ppm	Not to be exceeded more than once per year
			1-hour	35 ppm	
Pb		Both	Rolling 3-Month	0.15 $\mu g/m^3$ (1)	Not to be exceeded
NO_2		Primary	1-hour	100 ppb	98th percentile, averaged over 3 years
		Both	Annual	53 ppb (2)	Annual mean
O_3		Both	8-hour	0.075 ppm (3)	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle	$PM_{2.5}$	Primary	Annual	15 $\mu g/m^3$	Annual mean, averaged over 3 years
		Secondary	Annual	15 $\mu g/m^3$	Annual mean, averaged over 3 years
		Both	24-hour	35 $\mu g/m^3$	98th percentile, averaged over 3 years
	PM_{10}	Both	24-hour	150 $\mu g/m^3$	Not to be exceeded more than once per year on average over 3 years
SO_2		Primary	1-hour	75 ppb (4)	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		Secondary	3-hour	500 ppb (2)	Not to be exceeded more than once per year

2.1. Exceedance Summary Table

Table 3 is a summary of the sites with exceedances of the ambient air quality standards for Colorado, with the number of days in exceedance listed. An exceedance of a NAAQS is defined in 40 CFR § 50.1(I) as

> …one occurrence of a measured or modeled concentration that exceeds the specified concentration level of such standard for the averaging period specified by the standard.

A violation of the NAAQS consists of one or more exceedances of a NAAQS. The precise number of exceedances necessary to cause a violation depend on the form of the standard and other factors, including quality of the data, defined in federal rules such as 40 CFR § 50.

The right-most column of the table illustrates sites in violation. These exceedances contain exceptional event data, see Section 2.2.5.1. Standards are discussed in Section 2.2 below.

1 Final rule signed October 15, 2008.
2 The official level of the annual standard is expressed in ppm, but is shown here in ppb for the purpose of clearer comparison to the 1-hour standard.
3 Final rule signed March 12, 2008. The 1997 ozone standard (0.089 ppm, annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years) and related implementation rules remain in place.
4 Final rule signed June 2, 2010. The 1971 annual and 24-hour SO2 standards were revoked in that same rule making. However, these standards remain in effect until one year after an area is designated for the 2012 standard, except in areas designated nonattainment for the 1971 standards, where the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standards are approved.

Table 3. Exceedance Summary Table[5]

AQS ID	Location	2011			2012			Violation
		O_3	PM_{10}	$PM_{2.5}$	O_3	PM_{10}	$PM_{2.5}$	O_3
08 001 0006	Commerce City			1				
08 001 3001	Welby	3			*5*			
08 003 0001	Alamosa Adams State Coll.		*2*			*4*		
08 003 0003	Alamosa Municipal Building		*2*			*5*		
08 005 0002	Highlands Reservoir	5			*6*			X
08 005 0006	Aurora East	4			*2*			
08 013 0003	Longmont Municipal						1	
08 013 0011	South Boulder Creek	4			*4*			
08 031 0002	CAMP				*1*		1	
08 031 0014	Carriage	2			*5*			
08 031 0025	DMAS				*3*			
08 035 0004	Chatfield State Park	9			*15*			X
08 041 0013	U.S. Air Force Academy	3			*2*			
08 041 0016	Manitou Springs	2			*3*			
08 045 0012	Rifle				1			
08 051 0007	Mt. Crested Butte Realty					*1*		
08 059 0002	Arvada	6						
08 059 0005	Welch	6			*6*			X
08 059 0006	Rocky Flats N	8			*19*			X
08 059 0011	NREL	10			*13*			X
08 059 0013	Aspen Park	1			*5*			
08 067 7001	*SUIT-Ignacio*	1						
08 067 7003	*SUIT-Bondad*	1						
08 069 0007	*Rocky Mountain NP*	8			*15*			
08 069 0011	Fort Collins West	8			*13*			X
08 069 0012	Rist Canyon	1			*2*			
08 069 1004	Fort Collins CSU				*2*			
08 083 0101	*Mesa Verde NP*	1						
08 099 0001	Lamar Power Plant		*2*			*3*		
08 099 0002	Lamar Municipal					*2*		
08 103 0006	Rangely Golf Course	3					1	
08 123 0006	Greeley Hospital						1	
08 123 0008	Platteville Middle School						1	
08 123 0009	Greeley County Tower	6			*5*			X

2.2. General Statistics for Criteria Pollutants

The EPA produces a National Emissions Inventory every three years. The latest complete inventory is for 2008, though Version 1 summaries are available for 2011 and annual emissions trends are estimated for 2012. However, the EPA's monitor ranking report has not been published since 2008. Monitors across the nation have been ranked in the following sections by the CDPHE, based on maximum relevant concentrations found in the respective

5 *Underlined numbers to the right or in parentheses* are exceedance events (or subsets) that the Division is documenting as exceptional events. Station names in italics are stations reported to the EPA Air Quality System in Colorado that are not considered part of the State of Colorado network.

references. Should a conflict occur between this report and a future publication of the EPA's monitor ranking, it should be considered that the EPA is correct.

In this section NAAQS are used in the analyses. This comparison is for reference only because the NAAQS apply to one station and not an average of all concentrations across the state. Section 4 below discusses concentrations in a manner directly relatable to the NAAQS.

2.2.1 Carbon Monoxide

CO is a colorless and odorless gas, formed when carbon compounds in fuel are not burned completely. It is a component of motor vehicle exhaust, which contributes about 50 percent of all CO emissions nationwide. Non-road vehicles account for the remaining CO emissions from transportation sources. High concentrations of CO generally occur in areas with heavy traffic congestion. In cities, as much as 85 percent of all CO emissions may come from automobile exhaust. Peak CO concentrations typically occur during the colder months of the year when CO automotive emissions are greater, and nighttime temperature inversions (conditions where air pollutants are trapped near the ground beneath a layer of warm air) are more frequent (United States Environmental Protection Agency 2009).

2.2.1.1 Carbon Monoxide - Standards

The EPA has developed two national standards for CO. They are 35 ppm averaged over a 1-hour period and 9 ppm averaged over an 8-hour period. These values are not to be exceeded more than once in a year at the same location. A site will violate the standard with a second exceedance of either the 1-hour or 8-hour standard in the same calendar year. The EPA directive states that comparison with the CO standards will be made in integers. Fractions of 0.5 or greater are rounded up, thus, actual concentrations of 9.5 ppm and 35.5 ppm or greater are necessary to exceed the 8-hour and 1-hour standards, respectively (United States Environmental Protection Agency 2009).

2.2.1.2 Carbon Monoxide - Health Effects

CO affects the central nervous system by depriving the body of oxygen. It enters the body through the lungs, where it combines with hemoglobin in the red blood cells, forming carboxyhemoglobin. Normally, hemoglobin carries oxygen from the lungs to the cells. The oxygen attached to the hemoglobin is exchanged for the carbon dioxide generated by the cell's metabolism. The carbon dioxide is then carried back to the lungs where it is exhaled from the body. Hemoglobin binds approximately 240 times more readily with CO than with oxygen. How quickly the carboxyhemoglobin builds up is a factor of the concentration of the gas being inhaled (measured in ppm) and the duration of the exposure. Compounding the effects of the exposure is the long half-life of approximately 5 hours of carboxyhemoglobin in the blood. Half-life is a measure of how quickly levels return to normal. This means that for a given exposure level, it will take about 5 hours for the level of carboxyhemoglobin in the blood to drop to half its current level after the exposure is terminated.

The health effects of CO vary with concentration. At low concentrations, effects include fatigue in healthy people and chest pain in people with heart disease. At moderate concentrations, angina, impaired vision, and reduced brain function may result. At higher concentrations, effects include impaired vision and coordination, headaches, dizziness, confusion, and nausea. It can cause flu-like symptoms that clear up after leaving the polluted area. CO is fatal at very high concentrations. The EPA has concluded that the following groups may be particularly sensitive to CO exposures: angina patients, individuals with other types of cardiovascular disease, persons with chronic obstructive pulmonary disease, anemic individuals, fetuses, and pregnant women. Concern also exists for healthy children because of increased oxygen requirements that result from their higher metabolic rate (Occupational Health and Safety Administration 2007).

2.2.1.3 Carbon Monoxide – Emissions and Sources

The 2012 National Emissions Trends report estimates that 36 percent of CO emissions are from highway vehicle sources. They also estimate that off-highway sources contribute an additional 18 percent of emissions. Table 4

gives a breakdown of CO emissions by source for 2012 (United States Environmental Protection Agency 2013). Figure 2 illustrates the downward trend of national CO emissions from 1970 through 2012.

Table 4. Carbon Monoxide National Emissions for 2012

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	724	1.2
Fuel Combustion - Industrial	894	1.4
Fuel Combustion - Other	2,748	4.4
Chemical Processing/Mfg	183	0.3
Metal Processing	840	1.3
Petroleum Processing	262	0.4
Other Industrial Processes	426	0.7
Solvent Utilization	7	0.0
Storage & Transportation	18	0.0
Waste Disposal & Recycling	1,378	2.2
Highway Vehicles	22,766	36.3
Off- Highway	11,409	18.2
Miscellaneous	21,115	33.6
Total	***62,770***	***100.0***

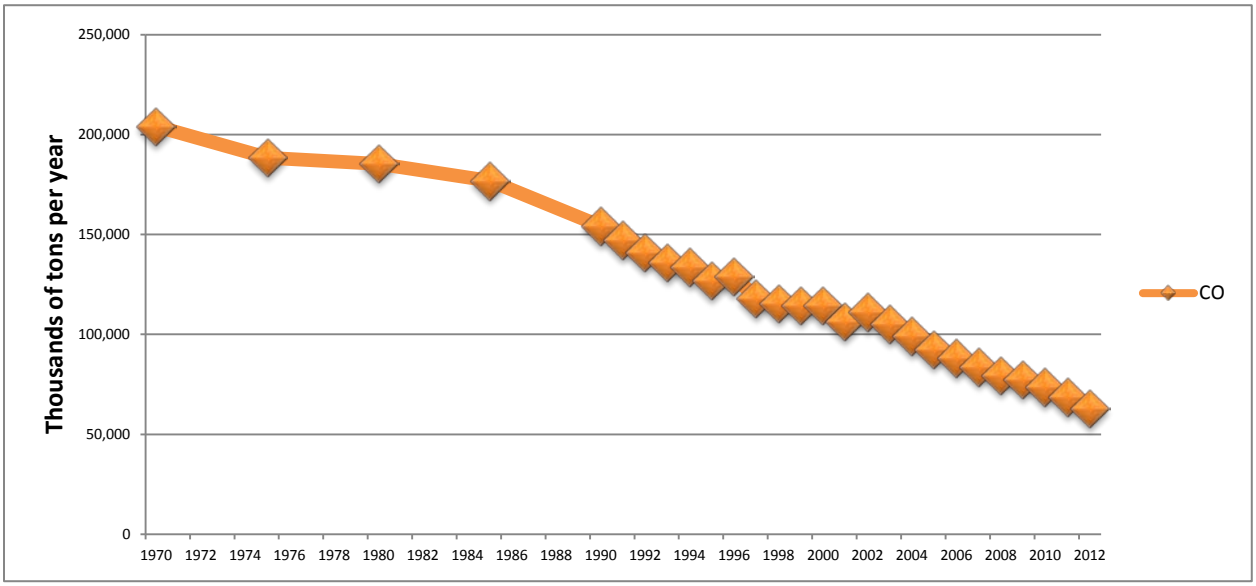


Figure 2. Changes in National Carbon Monoxide Emissions from 1970 to 2012

2.2.1.4 Carbon Monoxide – Statewide Summaries

CO concentrations have dropped dramatically from the early 1970s. This change can be seen in both the concentrations measured and the number of monitors that exceeded the level of the 8-hour standard. In 1975, 9 of the 11 (81%) state-operated monitors exceeded the 8-hour standard. In 1980, 13 of the 17 (77%) state-operated monitors exceeded the 8-hour standard. Since 1996 none of the state-operated monitors have recorded a violation of the 8-hour standard. In 2012 the highest statewide 2nd maximum 8-hour concentration was 2.0 ppm recorded at the CAMP monitor.

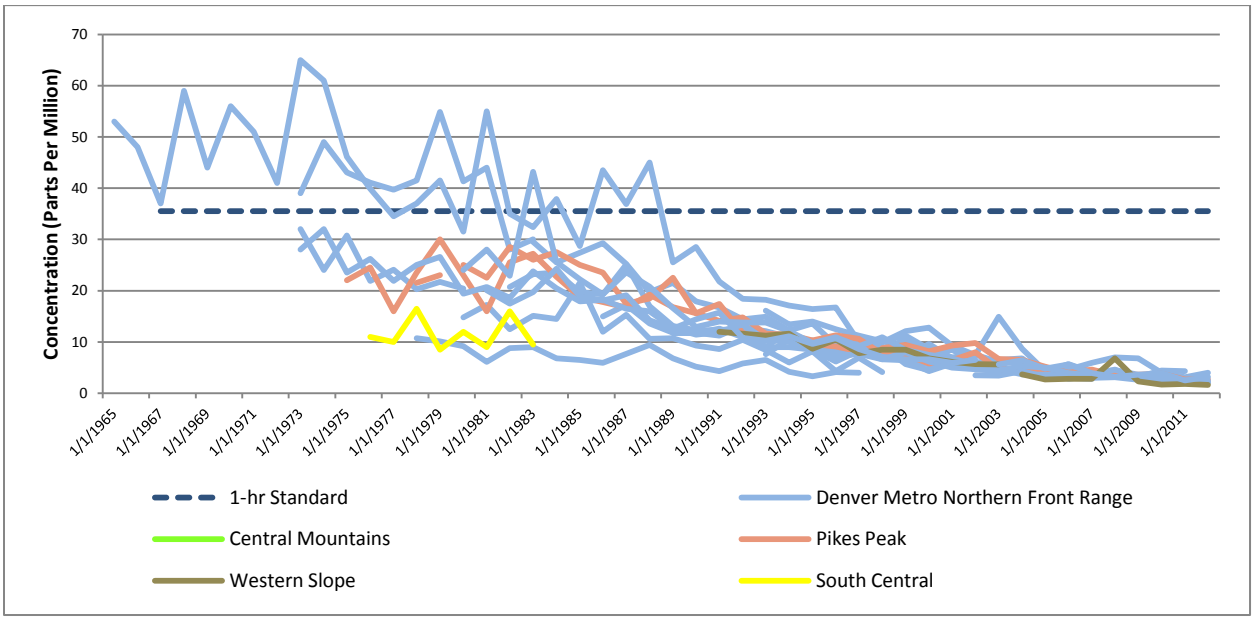


Figure 3. Statewide Ambient Trends for Carbon Monoxide

Figure 3 shows the trend of the statewide average for the second maximum 1-hour concentrations for CO between 1970 and 2012 by monitoring area state-wide. For the last several years the downward trend in concentrations has continued, but at a slower rate. The maximum 1-hour concentration ever recorded at any of the state-operated monitors was a 79.0 ppm recorded at the Denver CAMP monitor in 1968. In 2012, the second maximum 1-hour concentration recorded was 4.0 ppm recorded at the CAMP monitor. The 1-hour annual maximum concentrations have declined from more than twice the standard in the late 1960s to about one quarter of the standard. Table 5 presents the historical maximum values (United States Environmental Protection Agency 2012).

Table 5. Historical Maximum 1-Hour and 8-Hour Carbon Monoxide Concentrations

1-Hour (ppm)	Location	Date	Number of Annual Exceedances	8-Hour (ppm)	Location	Date	Number of Annual Exceedances
79.0	CAMP	11-20-68	13	48.1	CAMP	12-21-73	133
70.0	CAMP	11-21-74	15	33.9	CAMP	12-28-65	197
67.0	CAMP	12-21-73	21	33.4	CAMP	12-04-81	42
65.0	CAMP	12-21-73	21	33.2	CAMP	12-23-71	188
64.9	NJH-W	11-16-79	15	33.1	CAMP	11-20-68	98
2012 Maximum Carbon Monoxide Concentration							
4.2	CAMP	11-27-12	0	2.7	CAMP	12/21/12	0

2.2.1.5 Carbon Monoxide – National Comparisons

According to the EPA's emissions trends report, between 1980 and 2010, national average ambient CO concentrations decreased approximately 80 percent, though the report no longer specifically discusses CO (United States Environmental Protection Agency 2013). As recently as 1998, the National Ranking of CO monitors showed that the top sixteen monitors recorded at least one exceedance of the 8-hour CO standard with nine monitors reporting two or more exceedances (United States Environmental Protection Agency 2008). In 2012, one monitor reported an exceedance of the level of the 1-hour standard. This data is illustrated in Table 6 below (United States Environmental Protection Agency 2012).

Table 6. 2012 National Ranking of Carbon Monoxide Monitors by 8-hour Concentration in ppm

Nationwide (351 monitors)					Colorado (9 Monitors)				
National Rank	**City/Area**	**Max**	**2nd Max**	**# ≥9.5**	**National Rank**	**City/Area**	**Max**	**2nd Max**	**# ≥9.5**
1	El Centro, CA	7.4	4.9	0	33	CAMP	2.7	2.0	0
2	State Line, NV	7.1	5.4	0	58	Greeley Annex	2.3	1.6	0
3	Anchorage, AK	6.6	5.5	0	79	Hwy 24	2.0	1.4	0
4	Evansville, IN	5.7	5.3	0	110	Ft Collins CSU	1.8	1.7	0
5	Compton, CA	5.7	4.7	0	124	Welby	1.7	1.3	0

2.2.2 Ozone

Ozone (O_3) is a gas composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground-level is created by a chemical reaction between oxides of nitrogen (NO_X) and volatile organic compounds (VOC) in the presence of sunlight. Ozone has the same chemical structure whether it occurs miles above the earth or at ground-level and can be beneficial or detrimental, depending on its location in the atmosphere.

In the earth's lower atmosphere, ground-level ozone is of concern to human health. Motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents as well as natural sources emit NO_X and VOCs that help form ozone. Ground-level ozone is the primary constituent of smog. Sunlight and hot weather cause ground-level ozone to form in harmful concentrations in the air. As a result, it is known as a summertime air pollutant. Many urban areas tend to have high levels of ozone, but even rural areas are also subject to increased ozone levels because wind carries ozone and pollutants that form it hundreds of miles away from their original sources. Recently several rural areas are suffering very high ozone concentrations because of the increase in oil and gas production in these areas. Urban areas are now becoming subject to the increase in ozone from the increase in oil and gas production.

Ozone may be a wintertime pollutant in some areas. Emerging science is indicating that closed basins may be subject to higher ozone concentrations under the appropriate conditions. Low mixing boundaries (inversions) combined with high albedo snow cover can create and maintain high ozone concentrations within the basin. This is thought to occur because the stable atmospheric conditions allow for a build-up of precursor chemicals and the reflectivity of the snow cover increases the ultraviolet reactions during the day creating high ozone concentrations. The ozone, and its precursors, is then held in place by the inversion. The Upper Green River Basin in Wyoming has been studied to model such effects(Wyoming Department of Environmental Quality 2010). Exceptionally high ozone concentrations have been measured in the Uinta basin in Utah under such conditions, with the added impact of hundreds of natural gas wells in the basin.

In the stratosphere the beneficial ozone layer extends upward from about 6 to 30 miles and protects life on Earth from the sun's harmful ultraviolet (UV) rays. This natural shield had been gradually depleted by man-made chemicals like chlorofluorocarbons (CFCs), though evidence suggests that the total ozone column has not decreased since 1998 (Elizabeth C. Weatherhead 2006). A depleted ozone shield allows more UV from the sun to reach the ground, leading to more cases of skin cancer, cataracts, and other health problems." (United States Environmental Protection Agency 2009)

2.2.2.6 Ozone - Standards

On March 12, 2008, the U.S. Environmental Protection Agency promulgated a new level of the NAAQS for O_3 of 0.075 ppm as an annual fourth-highest daily maximum eight-hour concentration, averaged over three years. This made a significant change in the number of O_3 monitors that violate the standard.

The EPA will likely propose a new primary O_3 standard by the end of 2014. The APCD operates seven sites out of 20 that have three-year design values (2010 – 2012) in excess of the current eight-hour O_3 NAAQS standard of 0.075 ppm, up from three sites last year.

For more details, see http://www.epa.gov/ozonepollution/actions.html.

2.2.2.7 Ozone - Health Effects

Exposure to ozone has been linked to a number of health effects, including significant decreases in lung function, inflammation of the airways, and increased respiratory symptoms, such as cough and pain when taking a deep breath. Exposure can also aggravate lung diseases such as asthma, leading to increased medication use and increased hospital admissions and emergency room visits. Active children are the group at highest risk from ozone exposure because they often spend a large part of the summer playing outdoors. Children are also more likely to have asthma, which may be aggravated by ozone exposure. Other at-risk groups include adults who are active outdoors (e.g., some outdoor workers) and individuals with lung diseases such as asthma and chronic obstructive pulmonary disease. In addition, long-term exposure to moderate levels of ozone may cause permanent changes in lung structure, leading to premature aging of the lungs and worsening of chronic lung disease.

Ozone also affects vegetation and ecosystems, leading to reductions in agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased plant susceptibility to disease, pests, and other environmental stresses (e.g., harsh weather). In long-lived species, these effects may become evident only after several years or even decades and may result in long-term effects on forest ecosystems. Ground level ozone injury to trees and plants can lead to a decrease in the natural beauty of our national parks and recreation areas (United States Environmental Protection Agency 2009).

2.2.2.8 Ozone – Emissions and Sources

Ozone is not emitted directly from a source, as are other pollutants, but forms as a secondary pollutant. Its precursors are certain reactive hydrocarbons and oxides of nitrogen, which react chemically in sunlight to form ozone. The main sources for these reactive hydrocarbons are automobile exhaust, gasoline, oil storage and transfer facilities, industrial paint solvents, degreasing agents, cleaning fluids, and ink solvents. Vegetation can also emit reactive hydrocarbons such as terpenes from pine trees (United States Environmental Protection Agency 2009). High temperature combustion combines nitrogen and oxygen in the air to form oxides of nitrogen.

Although some ozone is produced all year, the highest concentrations usually occur in the summer. The stagnant air and intense sunlight on hot, bright summer days provide the conditions for the precursor chemicals to react and form ozone. The ozone produced under these stagnant summer conditions remains as a coherent air mass and can be transported many miles from its point of origin. The way to reduce ozone in the atmosphere is to reduce the compounds that react to form it. Table 7 and Figure 4 are included in the ozone section because of the importance of volatile organic compounds (VOC's) in the formation of ozone. Emissions of VOCs are shown in Table 7 (United States Environmental Protection Agency 2013) and Figure 4.

Table 7. VOC National Emissions for 2012

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	43	0.3
Fuel Combustion - Industrial	107	0.7
Fuel Combustion - Other	406	2.6
Chemical Processing/Mfg	88	0.6
Metal Processing	37	0.2
Petroleum Processing	1,742	11.1
Other Industrial Processes	362	2.3
Solvent Utilization	3,298	21.1

Description	National	
	Thousand-Tons/Year	Percent
Storage & Transportation	1,193	7.6
Waste Disposal & Recycling	185	1.2
Highway Vehicles	1,953	12.5
Off- Highway	1,572	10.1
Miscellaneous	4,694	30.0
Total	***15,680***	***100.0***

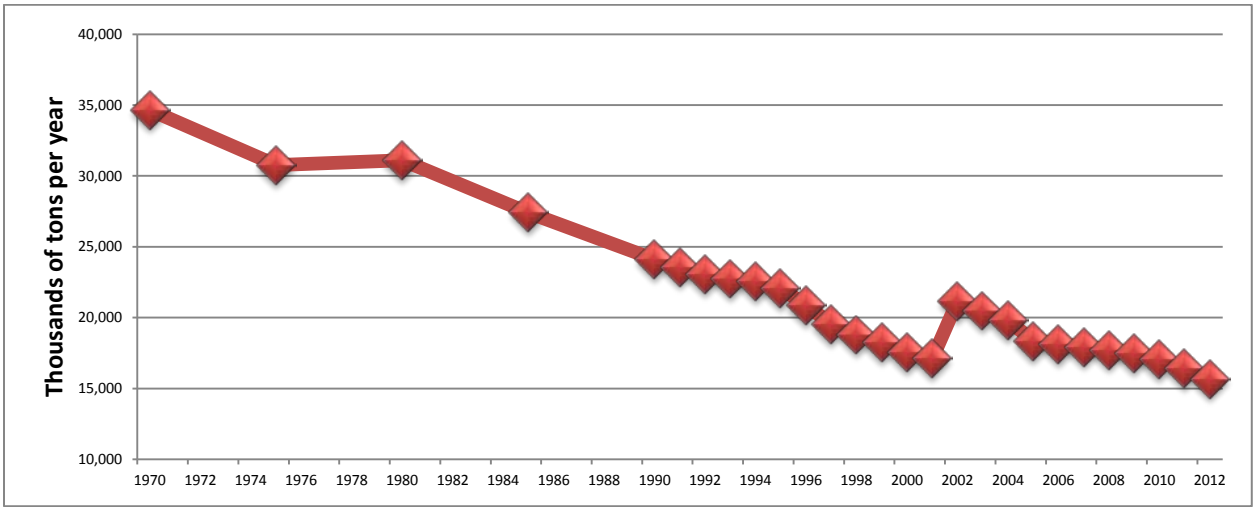


Figure 4. Changes in National VOC Emissions from 1970 to 2012

2.2.2.9 Ozone – Statewide Summaries

As illustrated in Figure 5, an average of sites state-wide, O_3 averages have fluctuated around the standard. In recent years, the trend has been downward, but the averages seem to fluctuate within the amount of variance seen for the last several years.

Ozone monitoring began in 1972 at the Denver CAMP station, and eight exceedances of the then-applicable 1-hour standard were recorded that year. Table 8 lists the 5 highest 8-hour ozone concentrations recorded in Colorado (United States Environmental Protection Agency 2010). Note that four of the top five were within the first two years of ozone monitoring.

Table 8. Historical Maximum 8-Hour Ozone Concentrations

8-Hour ppm	Monitor	Date
0.310	Denver CAMP	1972
0.264	Denver CAMP	1973
0.198	Arvada	1973
0.194	Denver Carriage (recorded at nearby CARIH)	1973
0.146	Denver CAMP	1980
2012 Maximum Ozone Concentration		
0.101	Rocky Flats North	2012

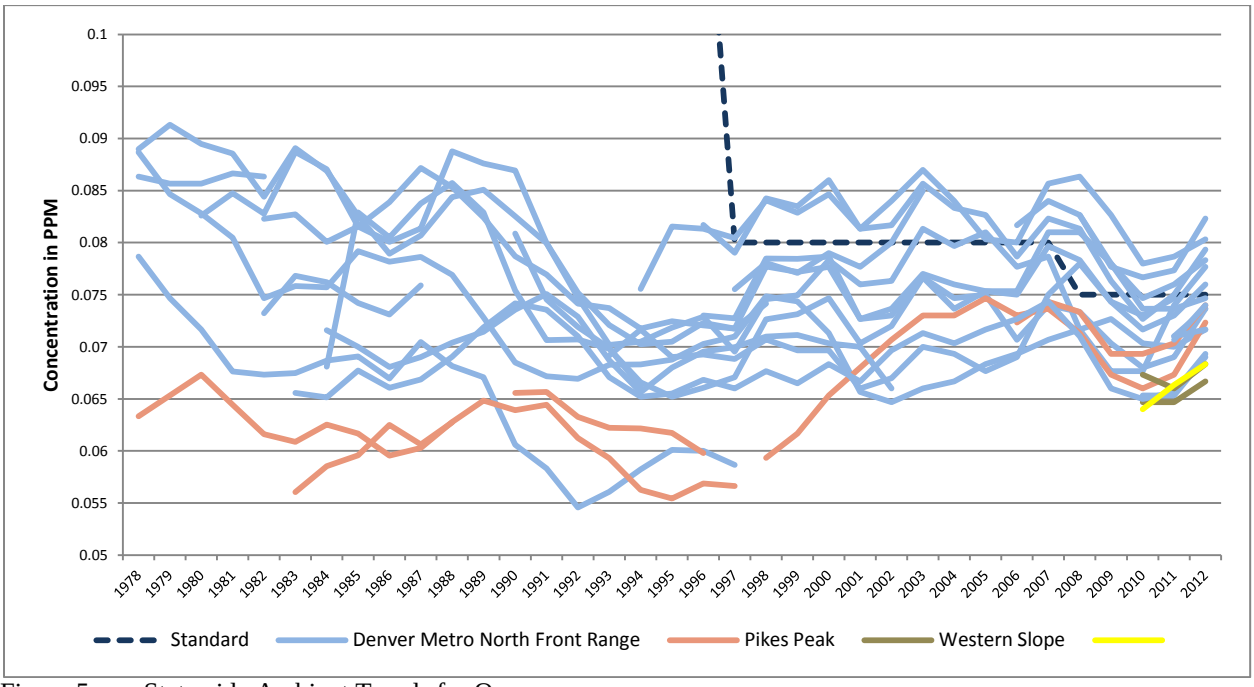


Figure 5. Statewide Ambient Trends for Ozone

Note that the NAAQS standard in Figure 5 was a 1-hour standard until 1997 when it became an 8-hour standard.

2.2.2.10 Ozone – National Comparisons

Between 1990 and 2012, NO_X and VOC emissions have declined 56 percent and 35 percent respectively. These are two of the primary factors in ozone production. This decline has been accomplished in spite of increases in energy consumption (up 20 percent), population (up 21 percent), vehicle miles traveled (up 45 percent) and gross national product (up 63 percent) (United States Environmental Protection Agency 2008). Table 9 lists the five highest ranked ozone monitors nationwide and in Colorado, by the number of days over the standard (United States Environmental Protection Agency 2010).

Table 9. 2012 National Ranking of Ozone Monitors by 8-hour Concentration in ppm

Nationwide (2,668 Monitors)					Colorado (30 Monitors)[6]				
National Rank	City/Area	Max	2nd Max	Days ≥0.075	National Rank	City/Area	Max	2nd Max	Days ≥0.075
1	Crestline, CA	0.112	0.107	86	1367	Rocky Flats North	0.101	0.092	19
2	Sequoia NP, CA	0.103	0.098	82	1394	Chatfield Res	0.098	0.096	15
3	Redlands, CA	0.109	0.108	79	1427	NREL	0.095	0.088	13
4	Banning, CA	0.101	0.101	63	1428	Ft Collins West	0.093	0.086	13
5	Parlier, CA	0.097	0.096	62	1662	Highlands	0.094	0.093	6

6 Some recorded maximum 8-hour concentrations in Colorado were due to a stratospheric inversion, in which air from the stratosphere comes down to the troposphere and is detected by ground-level monitors. These exceptional events are being documented and sent to EPA.

2.2.3 Sulfur Dioxide

Sulfur dioxide (SO_2) belongs to the family of sulfur oxide gases. These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron. Sulfur dioxide gases are formed when fuel containing sulfur, such as coal and oil, is burned, when gasoline is extracted from oil, or metals are extracted from ore. Sulfur dioxide dissolves in water vapor to form sulfuric acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment (United States Environmental Protection Agency 2007).

2.2.3.1 Sulfur Dioxide - Standards

The primary standard for sulfur dioxide, set on June 22, 2010, is defined as a 3-year average of the 99th percentile of the daily maximum 1-hour average not to exceed 75 ppb. The secondary standard is a 3-hour average not to exceed 500 ppb more than once per year (National Primary and Secondary Ambient Air Quality Standards for Sulfer Dioxide 2010). The State standard for sulfer dioxide is 267 ppb (700 $\mu g/m^3$) as a three-hour maximum not to be exceeded more than once in any twelve-month period.

2.2.3.2 Sulfur Dioxide - Health Effects

High concentrations of sulfur dioxide can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Short-term exposures of asthmatic individuals to elevated sulfur dioxide levels during moderate activity may result in breathing difficulties that can be accompanied by symptoms such as wheezing, chest tightness, or shortness of breath. Other effects that have been associated with longer-term exposures to high concentrations of sulfur dioxide, in conjunction with high levels of particulate matter, include aggravation of existing cardiovascular disease, respiratory illness, and alterations in the lungs' defenses. The subgroups of the population that may be affected under these conditions include individuals with heart or lung disease, as well as the elderly and children (United States Environmental Protection Agency 2006). Sulfur dioxide also is a major precursor to $PM_{2.5}$, which is a significant health concern, and a main contributor to poor visibility (AirNow 2003).

2.2.3.3 Sulfur Dioxide – Emissions and Sources

Nationwide, nearly 59 percent of sulfur dioxide released to the air, or more than 3.3 million tons per year, comes from electric utilities, especially those that burn coal. Other sources of sulfur dioxide are industrial facilities that derive their products from raw materials like metallic ore, coal, and crude oil, or that burn coal or oil to produce process heat. Examples are petroleum refineries, cement manufacturing, and metal processing facilities. Also, locomotives, large ships, and some non-road diesel equipment currently burn high sulfur fuel and release sulfur dioxide emissions to the air in large quantities (United States Environmental Protection Agency 2007). Table 10 (United States Environmental Protection Agency 2013) and Figure 6 illustrate the national emissions quantities and trends for sulfur dioxide.

Table 10. Sulfur Dioxide National Emissions For 2012

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	3,308	58.9
Fuel Combustion - Industrial	1,069	19.0
Fuel Combustion - Other	291	5.2
Chemical Processing/Mfg	185	3.3
Metal Processing	177	3.2
Petroleum Processing	149	2.7
Other Industrial Processes	253	4.5
Solvent Utilization	1	0.0
Storage & Transportation	6	0.1
Waste Disposal & Recycling	21	0.4

Description	National	
	Thousand-Tons/Year	Percent
Highway Vehicles	10	0.2
Off- Highway	11	0.2
Miscellaneous	139	2.5
Total	***5,620***	***100.0***

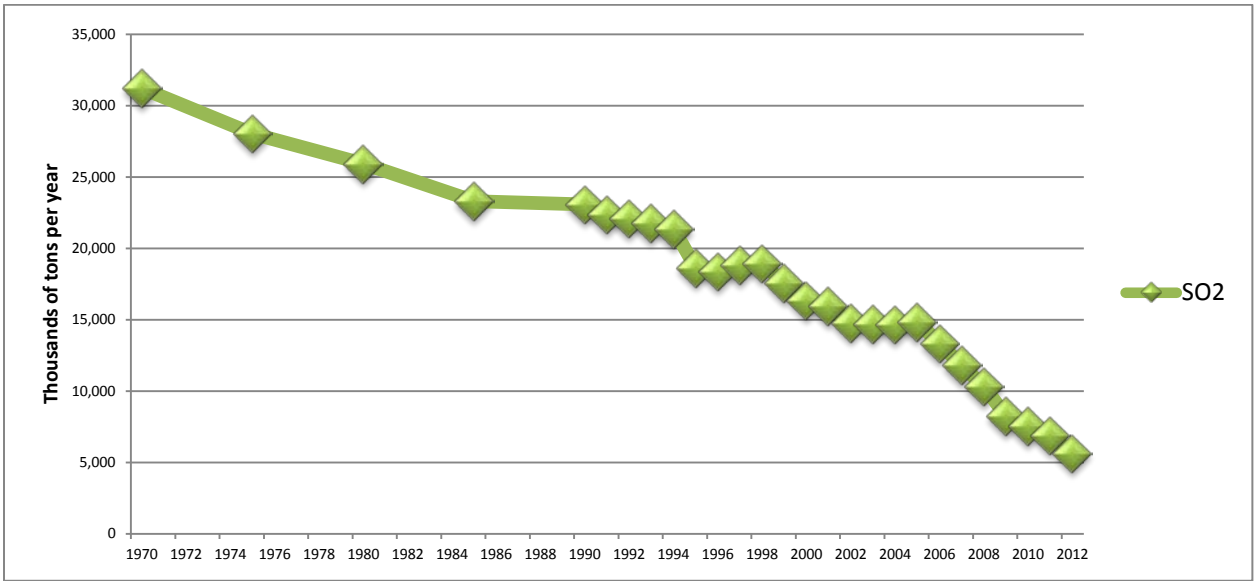


Figure 6. Changes in National Sulfur Dioxide Emissions from 1970 to 2012

2.2.3.4 Sulfur Dioxide – Statewide Summaries

The concentrations of sulfur dioxide in Colorado have never been a major health concern since we have few industries that burn large amounts of coal. Additionally, western coal that is mined or imported into Colorado is naturally low in sulfur. The concern in Colorado with sulfur dioxide has been associated with acid deposition and its effects on the mountain lakes and streams, as well as the formation of fine aerosols. Historically the maximum annual concentration recorded by APCD monitors was 18 ppb in 1979 at the Denver CAMP monitor. Since 1990, the annual average at the Denver CAMP monitor has declined from a high in 1992 of 10 ppb to 2 in 2012.

Table 11 (United States Environmental Protection Agency 2012) and Figure 7 show both the declining trend in sulfur dioxide readings, as well as the generally low concentrations of sulfur dioxide recorded at the APCD's monitors. This same trend is evident, although not as pronounced, in the 3-hour and 24-hour averages.

Table 11. Historical Maximum Annual Average Sulfur Dioxide Concentrations

Annual Average (ppb)	Monitor	Date
18	CAMP	1979
13	CAMP	1981
13	CAMP	1983
13	CAMP	1980
11	CAMP	1984
2012 Maximum Sulfur Dioxide Concentration		
2	CAMP	2012

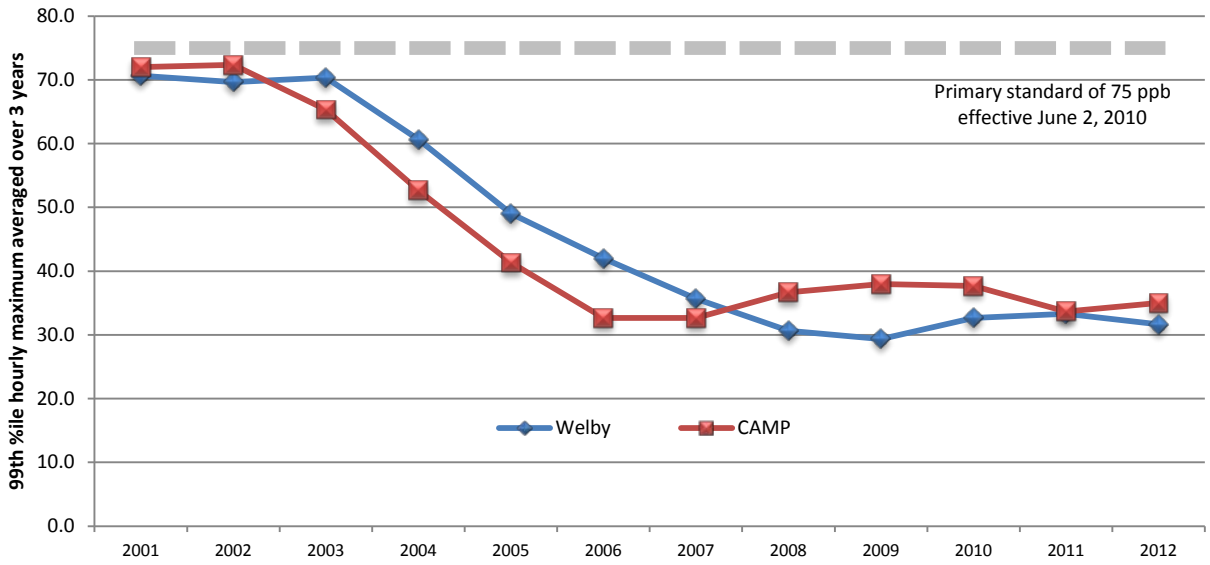


Figure 7. Statewide Ambient Trends for Sulfur Dioxide

2.2.3.5 Sulfur Dioxide – National Comparisons

"Nationally, average sulfur dioxide ambient concentrations have decreased 71 percent from 1980 to 2008 and 37 percent over the more recent 10-year period of 1999 to 2008. Reductions in sulfur dioxide concentrations and emissions since 1990 are due, in large part, to controls implemented under EPA's Acid Rain Program beginning in 1995." (United States Environmental Protection Agency 2006) Table 12 lists the national ranking of sulfur dioxide monitors by 24-hour concentration nationwide, and for the State of Colorado. (United States Environmental Protection Agency 2012)

Table 12. 2012 National Ranking of Sulfur Dioxide Monitors by 24-hour Concentration in ppb

Nationwide (475 Monitors)					Colorado (3 Monitors)				
National Rank	**City/Area**	**Max**	**2nd Max**	**#>140**	**National Rank**	**City/Area**	**Max**	**2nd Max**	**#>140**
1	Volcanoes National Park, HI[7]	649	491	14	145	CAMP	10.3	9.6	0
2	Sullivan County, TN	131	107.4	0	200	DMAS	7.5	5.6	0
3	Chalmette, LA	104.6	54.2	0	270	Welby	5.0	4.8	0
4	Muscatine, IA	98.4	60.7	0					
5	Rhinelander, WI	97.5	85.7	0					

2.2.4 Nitrogen Dioxide

In its pure state, NO_2 is a reddish brown gas with a characteristic pungent odor. It is corrosive and a strong oxidizing agent. As a pollutant in ambient air, however, it is virtually colorless and odorless. NO_2 can be an irritant to the eyes and throat. Oxides of nitrogen (nitric oxide and NO_2) are formed when the nitrogen and oxygen in the air are combined in high temperature combustion.

7 For this ranking, the state of Hawaii was grouped as one site. Individually considering each site, Hawaii claims four of the top five ranks.

2.2.4.1 Nitrogen Dioxide – Standards

The standard for NO_2 was first established by the EPA in 1971. Both the primary standard, to protect public health, and the secondary standard, to protect public welfare, were set as an annual average of 53 ppb. On June 26, 2009, EPA proposed to strengthen the primary National Ambient Air Quality Standards for nitrogen dioxide. The proposed changes would protect public health, especially the health of sensitive populations, people with asthma, children, and the elderly.

On January 22, 2010, EPA established a new 1-hour nitrogen dioxide standard at 100 ppb, over a 3-year average of the 98th percentile of the annual distribution of daily 1-hour maximum nitrogen dioxide concentrations. This new standard does not alter the existing standard of 53 ppb annual average (United States Environmental Protection Agency 2010).

2.2.4.2 Nitrogen Dioxide – Health Effects

Elevated concentrations of nitrogen dioxide cause respiratory distress, degradation of vegetation, clothing, and visibility, and increased acid deposition. Nitrogen dioxide also causes concern with the formation of fine aerosols. Nitrate aerosols, which result from nitric oxide and nitrogen dioxide combining with water vapor in the air, have been consistently linked to Denver's visibility problems.

2.2.4.3 Nitrogen Dioxide – Emissions and Sources

Nationally, about 55 percent of the oxides of nitrogen emissions come from on and off-road vehicles and about 28 percent come from industrial sources (United States Environmental Protection Agency 2013). In Denver, about 26 percent of the emissions of nitrogen dioxide come from large combustion sources such as power plants, 14 percent comes from oil and gas point and area sources, 36 percent comes from motor vehicles, 7 percent from aircraft and railroad, and 18 percent from miscellaneous off-road vehicles. Minor sources include fireplaces and woodstoves and high temperature combustion processes used in industrial work (Air Pollution Control Division 2010). Table 13 (United States Environmental Protection Agency 2013) and Figure 8 illustrate the oxides of nitrogen emissions values and trends.

Table 13. Oxides of Nitrogen National Emissions for 2012

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	1,720	15.4
Fuel Combustion - Industrial	1,391	12.5
Fuel Combustion - Other	585	5.2
Chemical Processing/Mfg	55	0.5
Metal Processing	79	0.7
Petroleum Processing	425	3.8
Other Industrial Processes	416	3.7
Solvent Utilization	6	0.1
Storage & Transportation	10	0.1
Waste Disposal & Recycling	97	0.9
Highway Vehicles	3,858	34.6
Off- Highway	2,256	20.2
Miscellaneous	262	2.3
Total	***11,160***	***100.0***

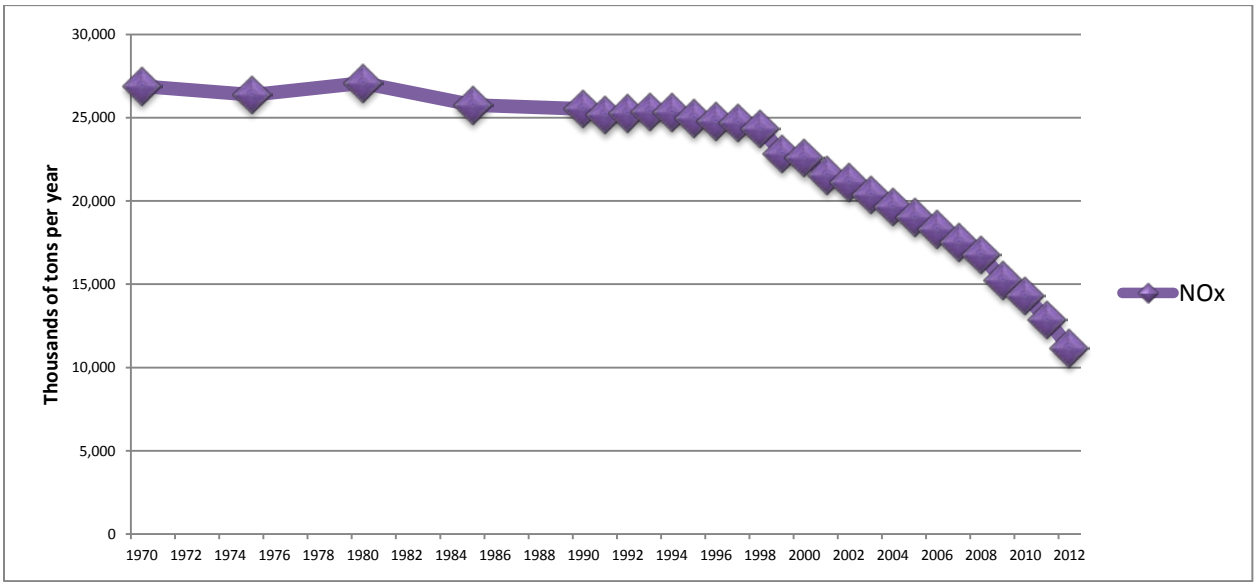


Figure 8. Changes in National Oxides of Nitrogen Emissions from 1970 to 2012

2.2.4.4 Nitrogen Dioxide – Statewide Summaries

Colorado exceeded the NO_2 standard in 1977 at the Denver CAMP monitor. Concentrations have shown a gradual decline for the past 20 years. However, the trend of annual averages for the past ten years has been nearly flat. Figure 9 shows that levels have declined at the Welby monitor over the past ten years while the annual average at the Denver CAMP monitor has shown little to no change at all. The cause of this is most likely due to an increase in the number of vehicles and increased power generation associated with the increases in population in the Denver-metro area. Table 14 (United States Environmental Protection Agency 2012) and Figure 9 illustrate the NO_2 trends for the State of Colorado.

Table 14. Historical Maximum Annual Average Nitrogen Dioxide Concentrations

Annual Average (ppb)	Monitor	Date
54	CAMP	1977
52	CAMP	1983
52	CAMP	1979
52	CAMP	1975
52	CAMP	1976
2012 Maximum Nitrogen Dioxide Concentration		
25	CAMP	2012

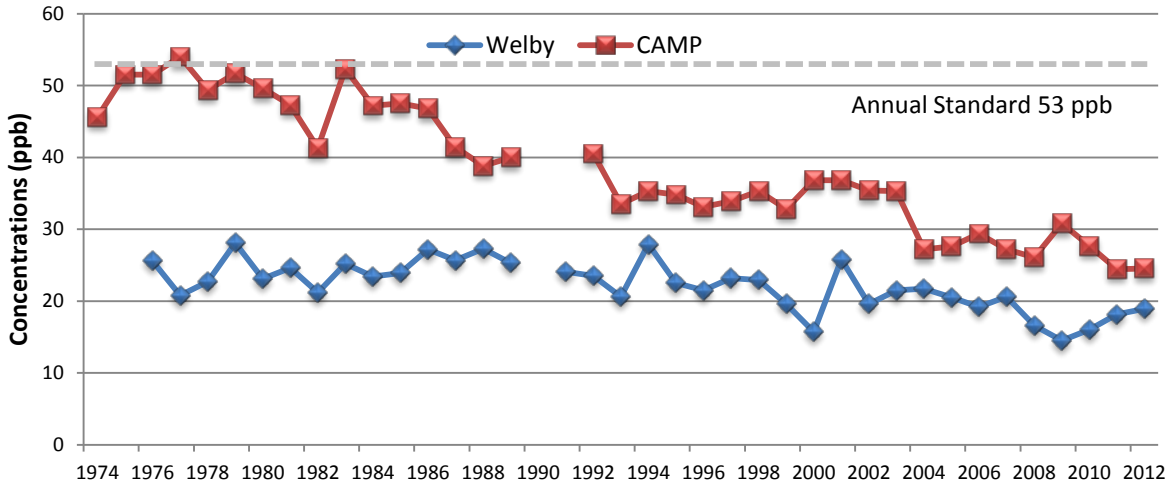


Figure 9. Statewide Ambient Trends for Nitrogen Dioxide

2.2.4.5 Nitrogen Dioxide – National Comparisons

"Nationally, annual mean concentrations of NO_2 decreased 33 percent between 2001 and 2010… In 2010, NO_2 concentrations were the lowest of the ten-year period. All recorded concentrations were well below the level of the annual standard (53 ppb)… Downward trends in annual NO_2, CO, and SO_2 are the result of various national emissions control programs. Even though concentrations of these pollutants are low with respect to the national annual standards, EPA continues to track these pollutants because of their contribution to other air pollutants (e.g., ozone and $PM_{2.5}$) and reduced visibility." (United States Environmental Protection Agency 2010) Table 15 shows national and state ranking for nitrogen dioxide monitors (United States Environmental Protection Agency 2012). The annual mean for all Colorado sites is well below the annual NAAQS of 53 ppb.

Table 15. 2012 National Ranking of Nitrogen Dioxide Monitors by 1-hour Concentration in ppm

Nationwide (411 Monitors)					Colorado (8 Monitors, 2 Operated by the Division)				
National Rank	City/Area	1-hr Max	2nd Max	Annual Mean	National Rank	City/Area	1-hr Max	2nd Max	Annual Mean
1	Brookings, SD	154	134.9	5.8	20	CAMP	85	76	24.5
2	Barstow, CA	146	139	17.1	34	Welby	77	75	18.9
3	Price, UT	138	44	3.8					
4	Houston, TX	134	83	10.7					
5	Oklahoma City, OK	127	80	9.2					

2.2.5 PM_{10}

Particle pollution is a mixture of microscopic solids and liquid droplets suspended in air. This pollution, also known as particulate matter, is made up of a number of components, including acidic aerosols (such as nitrates and sulfates), organic chemicals, metals, soil or dust particles, and allergens (such as fragments of pollen or mold spores). Some of these particles are carcinogenic and others have health effects due to their size, morphology, and composition.

The size of particles is directly linked to their potential for causing health problems. Small particles, less than 10 micrometers (microns) in diameter, pose the greatest problems. Since PM_{10} contains all particles smaller than 10

microns, $PM_{2.5}$ and ultrafine particles which are <0.1 microns are included in the PM_{10} measurement. The smallest particles, like $PM_{2.5}$, can get deep into the lungs, and some, like ultrafine particles, can penetrate all the way into the bloodstream. Exposure to such particles can affect the lungs, the heart, and the cardiovascular system. Larger particles are of less concern, although they can irritate the eyes, nose, and throat (AirNow 2003), and cause serious harm due to inflammation in the airways of people with respiratory diseases such as asthma, chronic obstructive pulmonary disease, and pneumonia (Weinmayr, et al. 2010).

2.2.5.1 An Explanation of Exceptional Events

Sometimes air pollution comes from natural sources that are not preventable and cannot be reasonably controlled by humans. These include things like volcanic eruptions, large regional dust storms, and wildfires. If an exceedance of the NAAQS, or PM_{10} concentrations greater than 150 $\mu g/m^3$ in attainment areas and $\geq$ 98 $\mu g/m^3$ in PM_{10} non-attainment areas, can be shown to have resulted from a natural event and can be documented with scientific evidence, the event can be excluded from NAAQS calculations. For example, one such event was the large wind and dust storm that occurred on March 31, 1999 when monitors from Steamboat Springs to Telluride reported high PM_{10} concentrations. Similar exceptional events have been documented in Lamar and Alamosa. These events are not included in NAAQS determinations, not because they are without any health risk but because they are natural events that cannot be reasonably controlled. The EPA may concur on events that the Division flags and documents as exceptional in the EPA's AQS database. The Exceptional Events Rule was revised on March 22, 2007, with an effective date of May 21, 2007. The EPA has been much more restrictive on concurring natural events since the revision. Table 4 indicates the number of these exceptional events, and more detail can be obtained from the APCD. Concentrations between 98 and 155 $\mu g/m^3$ that are located in State Implementation Plan maintenance areas are also allowed by the Exceptional Events Rule to be flagged and documented as exceptional events.

2.2.5.2 PM_{10} - Standards

The nation's air quality standards for particulate matter were first established in 1971 as total suspended particulates and were not significantly revised until 1987, when EPA changed the indicator of the standards to regulate inhalable particles smaller than, or equal to, 10 micrometers in diameter (about 1/4 the size of a single grain of table salt). In 1997 the EPA revised the particulate matter standards, setting separate standards for fine particles ($PM_{2.5}$) and for PM_{10}. The health data showed that particles in the $PM_{2.5}$ range were linked to more serious health problems ranging from increased symptoms, hospital admissions and emergency room visits to premature death in people with heart or lung disease. They decided to retain the existing 24-hour PM_{10} standard of 150 $\mu g/m^3$. The EPA revoked the annual PM_{10} standard in 2006, because available evidence did not suggest a link between long-term exposure to the coarse fraction of PM_{10} and health problems. The $PM_{2.5}$ standard covers the non-coarse fraction of PM_{10}, and is discussed in Section 2.2.6 below.

2.2.5.3 PM_{10} - Health Effects

Since PM_{10} includes $PM_{2.5}$ and ultrafine particles, health effects associated with $PM_{2.5}$ are also PM_{10} health effects. "…With regard to $PM_{2.5}$, various toxicological and physiological considerations suggest that fine particles may play the largest role in effecting human health. For example, they may be more toxic because they include sulfates, nitrates, acids, metals, and particles with various chemicals adsorbed onto their surfaces. Furthermore, relative to larger particles, particles indicated by $PM_{2.5}$ can be breathed more deeply into the lungs, remain suspended for longer periods of time, penetrate more readily into indoor environments, and are transported over much longer distances. PM_{10}, an indicator for inhalable particles that can penetrate the thoracic region of the lung, consists of particles with an aerodynamic diameter less than or equal to a 10-μm cut point and includes fine particles and a subset of coarse particles. $PM_{10-2.5}$ consists of the PM_{10} coarse fraction defined as the difference between PM_{10} and $PM_{2.5}$ mass concentrations and, for regulatory purposes, serves as an indicator for thoracic coarse particles."(C. A. Pope 2006)

The welfare effects of particulate exposure may be the most widespread of all the pollutants. No place on earth has been spared from the particulate pollution generated by urban and rural sources. This is due to the potential for extremely long-range transport of fine particles and chemical reactions that occur from gasses in the atmosphere to create secondary particulate matter in the form of tiny liquid droplets. The effects of particulates range from

visibility degradation to climate changes and vegetation damage. General soiling, commonly thought to be just a nuisance, can have long-term adverse effects on building paints and other materials. Acid deposition as particulates can be detected in the most remote areas of the world.

2.2.5.4 PM_{10} – Emissions and Sources

The majority of PM_{10} pollution is from miscellaneous sources, which are mainly fugitive dust sources rather than stack emissions or internal engine combustion sources. Fugitive emissions are those not caught by a capture system and are often due to equipment leaks, earth moving, equipment and vehicles, and windblown disturbances. While the amount of miscellaneous emissions isn't broken down specifically, the miscellaneous category contains sources such as agricultural crops, agricultural livestock, paved road re-suspension, unpaved roads, construction activities, and mining and quarrying (United States Environmental Protection Agency 1999). Table 16 (United States Environmental Protection Agency 2013) shows a breakdown of PM_{10} emissions on a national scale in 2012. Figure 10 illustrates the national emissions trends for PM_{10} which has been flat since 2002.

Table 16. PM_{10} National Emissions for 2012

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	400	1.9
Fuel Combustion – Industrial	189	0.9
Fuel Combustion – Other	388	1.8
Chemical Processing/Mfg	26	0.1
Metal Processing	81	0.4
Petroleum Processing	30	0.1
Other Industrial Processes	1,074	5.1
Solvent Utilization	5	0.0
Storage & Transportation	51	0.2
Waste Disposal & Recycling	238	1.1
Highway Vehicles	270	1.3
Off- Highway	188	0.9
Miscellaneous	18,480	87.9
Total	***21,420***	***100.0***

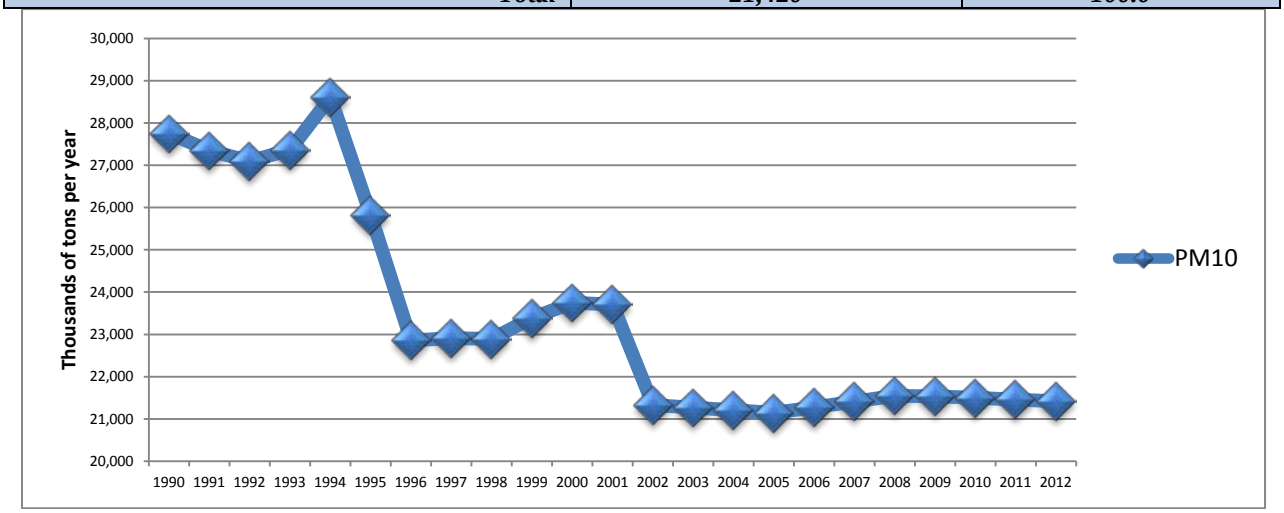


Figure 10. Changes in National PM_{10} Emissions from 1990 to 2012

2.2.5.5 PM_{10} – Statewide Summaries

PM_{10} data have been collected in Colorado since 1985. The samplers were modified in 1987 to conform to the requirements of the new standard when it was established in July of 1987. Therefore, annual trends are only valid back to July 1987. Since 1988, the state has had at least one monitor exceed the level of the 24-hour PM_{10} standard (150 $\mu g/m^3$) every year except 2004. By contrast, no monitor with at least 75 percent data recovery per calendar quarter, which is required for NAAQS comparisons, has exceeded the level of the former standard (50 $\mu g/m^3$ as an annual arithmetic mean averaged over 3 years).

In cases other than exceptional events, and more so than other pollutants, PM_{10} is a localized pollutant where concentrations vary considerably. Thus, local averages and maximum concentrations of PM_{10} are more meaningful than averages covering large regions or the entire state. The APCD has concluded that it is inappropriate to display a state-wide average graph for PM_{10}. Regional averages for all pollutants are discussed in more detail in Section 4 below.

The data contained in Table 17 include those concentrations that are the result of exceptional events (United States Environmental Protection Agency 2012). See Section 2.2.5.1. There have been several of these events documented in Colorado since PM_{10} monitoring began in 1988.

Table 17. Historical Maximum 24-Hour PM_{10} Concentrations

24-Hour Maximum ($\mu g/m^3$)	Monitor	Date
635	Alamosa Municipal	2011
494	Alamosa Municipal	2007
473	Alamosa Adams State College (ASC)	2007
424	Alamosa ASC	2006
412	Alamosa ASC	1991
2012 Maximum PM_{10} Concentration		
389	Alamosa ASC	2012

2.2.5.6 PM_{10} – National Comparisons

In the past several years the top five locations on the list have generally included Keeler, CA; Olancha, CA; the sites around Owens Lake, CA; and sites around Mono Lake, CA. The last two years have seen rankings from Casa Grande in Arizona. All of these levels are associated with hot dry winds. The levels around Owens Lake are associated with the high winds that blow across the large dry lake bed. In the past several years monitors in that area have recorded levels in excess of 20,000 $\mu g/m^3$ as a 24-hour average. Exceedances in Colorado are mainly due to large regional dust storms that usually begin in desert areas to the south and west of the state. These are natural or exceptional events for which the Division is currently analyzing the scientific data and documenting as high wind/blown dust exceptional events. The nationwide and statewide ranking of PM_{10} monitors can be seen in Table 18 (United States Environmental Protection Agency 2012).

Table 18. National Ranking of PM_{10} Monitors by 24-hour Maximum Concentration in $\mu g/m^3$

Nationwide (1,017 Monitors)					Colorado (39 Monitors)				
National Rank	City/Area	1st Max	2nd Max	Annual Mean	National Rank	City/Area	1st Max	2nd Max	Annual Mean
1	Mono Lake, CA	3,972	2,187	69.6	31	Alamosa ASC	389	324	26.9
2	Owens Lake, CA	3,916	880	42.5	46	Lamar Municipal	242	163	24.6
3	Anthony, NM	1,739	751	57.1	48	Alamosa Municipal	239	237	33.1

4	Sunland Park, NM	1,691	961	47.7	62	Lamar Power Plant	220	208	28.1
5	Chaparral, NM	1,606	803	42.8	106	Mt Crested Butte	171	91	14.9

2.2.6 $PM_{2.5}$

EPA generally defines $PM_{2.5}$ as particulate matter with an aerodynamic diameter less than or equal to 2.5 microns in size. According to the Environmental Protection Agency's Our Nation's Air – Status and Trends through 2008:

"The chemical composition of $PM_{2.5}$ is characterized in terms of five major components that generally comprise the mass of $PM_{2.5}$: sulfate, nitrate, organic carbon (OC), elemental carbon (also called black carbon, BC), and crustal material.

…On average, sulfate is the largest component by mass in the eastern U.S. Generally, the largest source of sulfate in the eastern U.S. are electric utilities and industrial boilers. OC is the next largest component in the East. The primary sources of OC are highway vehicles, non-road mobile, waste burning, wildfires, and vegetation. Next is nitrate; the largest sources of nitrate originate from highway vehicles, non-road mobile, electric utilities, and industrial boilers. Elemental carbon is a small component of the overall $PM_{2.5}$ composition (typically 5-10 percent in U.S. cities). Elemental carbon is directly emitted from incomplete combustion processes such as fossil fuel and biomass burning. Crustal material is typically a small fraction of $PM_{2.5}$ mass, although two cities show higher than average values (Birmingham, AL and Detroit, MI). Crustal materials come from suspended soil and metallurgical operations.

In the West, OC is generally the largest estimated component of $PM_{2.5}$ by mass. Fireplaces and woodstoves are important contributors to OC in the West. On an annual average basis, nitrate, sulfate, and crustal material can also represent substantial components of $PM_{2.5}$ for the western U.S. The composition varies from city to city and may vary by geography. For example, in southern California and port cities in the Northwest, emissions from marine vessels also likely contribute a significant portion of $PM_{2.5}$ sulfate."

2.2.6.1 $PM_{2.5}$ - Standards

In 1997, the EPA added 24-hour and annual fine particle standards, $PM_{2.5}$, to the existing PM_{10} standards. EPA added an annual $PM_{2.5}$ standard set at a concentration of 15 $\mu g/m^3$ and a 24-hour $PM_{2.5}$ standard set at 65 $\mu g/m^3$. The annual component of the standard was set to provide protection against typical day-to-day exposures as well as longer-term exposures, while the daily component protects against more extreme short-term events. EPA revised the air quality standards for particle pollution in 2006 to be more protective of human health since recent data showed significant health impacts below the 1997 standards. The 2006 standards tightened the 24-hour fine particle standard from 65 $\mu g/m^3$ to 35 $\mu g/m^3$, and retained the annual fine particle standard at 15 $\mu g/m^3$. On December 14, 2012, EPA lowered the primary annual standard from 15 $\mu g/m^3$ to 12 $\mu g/m^3$ and retained a secondary standard of 15 $\mu g/m^3$.

2.2.6.2 $PM_{2.5}$ - Health Effects

The health effects of $PM_{2.5}$ are not just a function of their size, with the largest fine particles measuring about $1/20^{th}$ the width of an average human hair, which allows them to be breathed deeply into the alveoli of the lungs. It is also a function of their composition. These tiny particles can remain in the lungs for a long time and cause a great deal of damage to lung tissue. They can reduce lung function as well as cause or aggravate respiratory problems. They can increase the long-term risk of lung cancer or lung diseases such as emphysema or pulmonary fibrosis. The smallest range of $PM_{2.5}$ particles, also called ultrafine particles (those with a diameter <0.1 μm) can be transported from the lungs into the blood stream and affect the heart and cardiovascular system.(Cardiovascular Toxicology 2006) Once in the blood stream, ultrafine particles can be transported anywhere in the body. Some of these ultrafine particles are carcinogenic.

2.2.6.3 $PM_{2.5}$ – Emissions and Sources

Figure 11 shows the nationwide changes in emissions of $PM_{2.5}$ particulates from 1990 through 2012. Table 19 lists the national $PM_{2.5}$ emissions for 2012. (United States Environmental Protection Agency 2013) The primary source of fine particles emitted directly into the air is carbonaceous material from combustion sources such as cars, trucks, and industrial boilers. Secondary particles are another large source of "fine" particulates. Secondary particles are those that are created in the atmosphere by chemical reactions of gaseous pollutants and water vapor to form tiny liquid droplets or semi-solid particle. Efficient light scattering and absorption mean that fine particles are the major contributor to visibility problems. As with PM_{10}, the majority of emissions come from the miscellaneous category which includes sources such as agricultural crops, agricultural livestock, paved road re-entrained dust, unpaved roads, construction activities, and mining and quarrying. (United States Environmental Protection Agency 1999)

Table 19. $PM_{2.5}$ National Emissions for 2012

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	304	5.5
Fuel Combustion - Industrial	145	2.6
Fuel Combustion - Other	380	6.9
Chemical Processing/Mfg	20	0.4
Metal Processing	63	1.1
Petroleum Processing	23	0.4
Other Industrial Processes	340	6.1
Solvent Utilization	4	0.1
Storage & Transportation	24	0.4
Waste Disposal & Recycling	205	3.7
Highway Vehicles	154	2.8
Off- Highway	170	3.1
Miscellaneous	4,010	72.4
Total	***5,841***	***100.0***

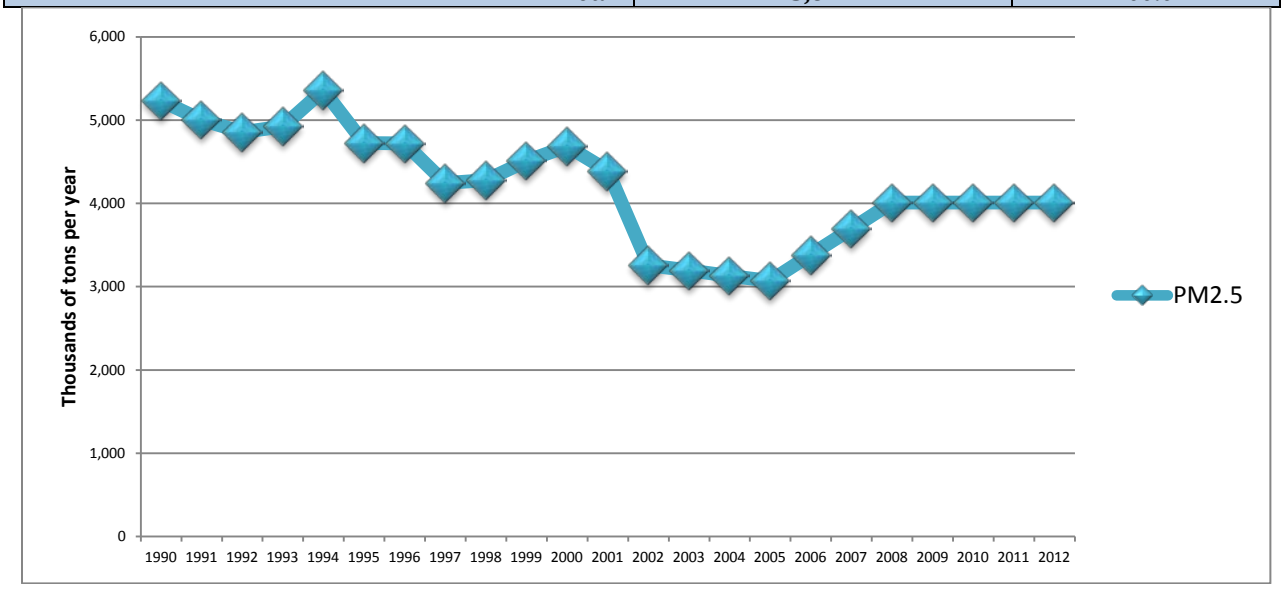


Figure 11. Changes in National $PM_{2.5}$ Emissions from 1990 to 2012

2.2.6.4 $PM_{2.5}$ – Statewide Summaries

Monitoring for $PM_{2.5}$ in Colorado began with the establishment of sites in Denver, Grand Junction, Steamboat Springs, Colorado Springs, Greeley, Fort Collins, Platteville, Boulder, Longmont, and Elbert County in 1999. Additional sites were established nearly every month until full implementation of the base network was achieved in July of 1999. In 2004, there were 20 $PM_{2.5}$ monitoring sites in Colorado. Thirteen of the 20 sites were selected based on the population of the metropolitan statistical areas. This is a federal selection criterion that was developed to protect the public health in the highest population centers. In addition, there were seven special-purpose-monitoring (SPM) sites. These sites were selected due to historically elevated concentrations of PM_{10} or because citizens or local governments had concerns of possible high $PM_{2.5}$ concentrations in their communities. All SPM sites were removed as of December 31, 2006 due to low concentrations and a lack of funding.

Table 20 shows the historical maximum readings for $PM_{2.5}$. (United States Environmental Protection Agency 2012) Though data has only been collected for the past 12 years, the levels of $PM_{2.5}$ appear to be essentially flat. Figure 12 shows the three-year average of the top 98th percentile. Since the standard is based on a three-year average of the top 98th percentile of samples, the 24-hour standard has not been violated at any site[8]. Neither has the three-year average annual standard of 15 $\mu g/m^3$.

Table 20. Historical Maximum $PM_{2.5}$ Concentrations

24-Hour Maximum ($\mu g/m^3$)	Monitor	Date
68.4	Denver CAMP	2001
68.0	Denver CAMP	2001
60.5	Denver CAMP	2007
60.2	Arapahoe Community College	2007
57.3	Commerce City	2001
2012 Maximum $PM_{2.5}$ Concentration		
48.0	Platteville	2012

[8] In 2001, before the current standard went into effect (in 2006), the Adams City monitor showed a three-year 98th percentile average of 35.1 $\mu g/m^3$. Due to rounding conventions, 35.5 $\mu g/m^3$ is needed to violate the 24-hour NAAQS. Data collection at this site began in 1999.

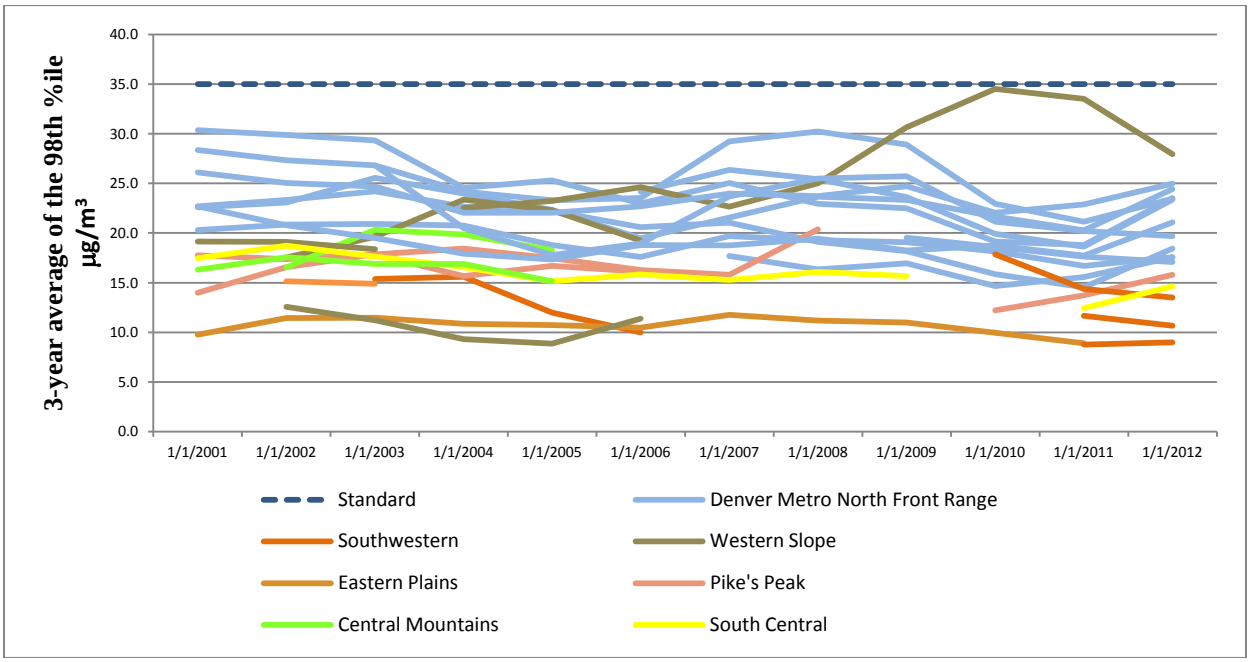


Figure 12. Statewide Ambient Trends for $PM_{2.5}$

2.2.6.5 $PM_{2.5}$ – National Comparisons

National rankings of $PM_{2.5}$ monitors are shown in Table 21. (United States Environmental Protection Agency 2012). Some sites had high 24-hour $PM_{2.5}$ concentrations but low annual $PM_{2.5}$ concentrations, and vice versa. Sites that have high 24-hour concentrations but low or moderate annual concentrations exhibit substantial variability from season to season. (United States Environmental Protection Agency 2013)

Table 21. National Ranking of $PM_{2.5}$ Monitors by Annual Mean Concentrations in $\mu g/m^3$

Nationwide (1,291 Monitors)					Colorado (22 Monitors, 19 operated by the Division)				
National Rank	City/Area	1st Max	2nd Max	Annual Mean	National Rank	City/Area	1st Max	2nd Max	Annual Mean
1	Fresno, CA	86	67	45	779	Alsup	34	29	9
2	Salmon, ID	214	194	22	878	DMAS	35	18	8
3	Mira Loma, CA	48	44	21	914	CAMP	32	32	8
4	Los Angeles, CA	79	59	20	925	Greeley Hospital	44	32	8
5	North Pole, AK	171	158	19	935	Swansea Elementary	33	31	8

2.2.7 Lead

Lead is a metal found naturally in the environment as well as in manufactured products. The major sources of ambient air lead emissions have historically been motor vehicles (such as cars and trucks) and industrial sources (such as lead smelters). Due to the phase out of leaded gasoline for automobiles, piston engine aircraft and metals processing are now the major source of lead emissions to the air today. The highest levels of lead in air are generally found near lead smelters and general aviation airports. Other stationary sources are waste incinerators, utilities, and lead-acid battery manufacturers. (United States Environmental Protection Agency 2007)

2.2.7.1 Lead - Standards

The Clean Air Act requires EPA to review the latest scientific information and standards every five years. Before new standards are established, policy decisions undergo rigorous review by the scientific community, industry, public interest groups, the general public, and the Clean Air Scientific Advisory Committee (CASAC) (http://yosemite.epa.gov/sab/sabpeople.nsf/WebCommittees/CASAC).

On October 15, 2008, EPA strengthened the National Ambient Air Quality Standards for lead. The level for the previous lead standard was 1.5 $\mu g/m^3$, not to be exceeded as an average for a calendar quarter, based on an indicator of lead in total suspended particles (TSP). The new standard, measured in either TSP or low-volume PM_{10} samples, has a level of 0.15 $\mu g/m^3$, not to be exceeded as an average for any rolling three-month period within three years. On December 30, 2009 (effective January 26, 2011), EPA revised the requirements for monitoring for lead (74 FR 69050). In addition to requiring lead monitoring at NCore sites, and removing the CBSA-based monitoring requirement, the EPA lowered the emissions threshold from 1 ton per year to 0.5 ton per year for industrial lead sources, and in urban areas with a population equal to or greater than half a million people. Airports maintain an emission threshold of 1 ton per year, and the EPA is studying the potential need for monitoring at less than 1 ton per year. On December 14, 2010, EPA made final revisions to the ambient monitoring requirements for measuring lead in the air. These amendments expand the nation's lead monitoring network to better assess compliance with the 2008 National Ambient Air Quality Standards for lead.(United States Environmental Protection Agency 2010)

2.2.7.2 Lead - Health Effects

Exposure to lead occurs mainly through inhalation of air and ingestion of lead in food, water, soil, or dust. It accumulates in the blood, bones, and soft tissues and can adversely affect the kidneys, liver, nervous system, and other organs. Excessive exposure to lead may cause neurological impairments such as seizures, intellectual disability[9], and behavioral disorders. Even at low doses, lead exposure is associated with damage to the nervous systems of fetuses and young children, resulting in learning deficits and lowered IQ. Recent studies also show that lead may be a factor in high blood pressure and subsequent heart disease. Lead can also be deposited on the leaves of plants, presenting a hazard to grazing animals and humans through ingestion. (United States Environmental Protection Agency 2009)

2.2.7.3 Lead – Emissions and Sources

The National Emissions Inventory for lead has not been updated since 2005. "Because industrial processes are now responsible for all violations of the lead NAAQS, the lead monitoring strategy currently focuses on emissions from these point sources." (United States Environmental Protection Agency 2009) Since leaded fuel is still used in piston-engine aircraft, airports with general aviation are another significant source of lead emissions. Figure 13 shows the decline in lead emissions between 1975 and 2005. Table 22 shows the emission sources for 2005. (T. G. Pope 2009)

Table 22. Lead National Emissions for 2005

Description	National	
	Tons/Year	Percent
Aviation Gasoline	561	45
Metallurgical Industries	283	23
Manufacturing	171	14
Incineration	94	8
Boilers	70	6
Miscellaneous smaller categories	57	5
Total	***1236***	***100***

9 Referenced material from 2009 contains antiquated terminology, see http://www.opencongress.org/bill/111-s2781/show

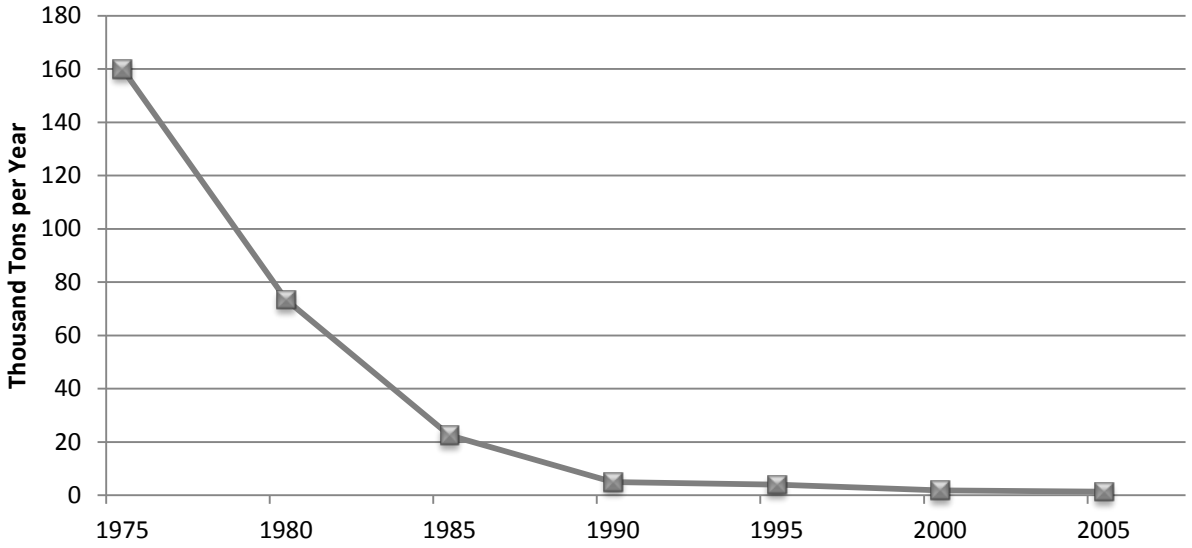


Figure 13. Changes in National Lead Emissions from 1975 to 2005

2.2.7.4 Lead – Statewide Summaries

In Colorado the last violation of the previous 1.5 µg/m^3 lead standard occurred in the first quarter of 1980 at the Denver CAMP monitor. Since then, the concentrations recorded at all monitors showed a steady decline. This decline is the direct result of the use of unleaded gasoline and replacement of older cars with newer ones that do not require leaded gasoline. The reduction in atmospheric lead shows what pollution control strategies can accomplish. In 2006, monitoring for lead by the APCD was reduced from six locations to one. In 2007, that lead monitor was moved from the Denver CAMP location to the Denver Municipal Animal Shelter NCore site at 678 S. Jason St.

Colorado currently operates two lead monitors. Table 23 (United States Environmental Protection Agency 2012) and Figure 14 illustrate the historic statewide lead trends.

Table 23. Historical Maximum Quarterly Lead Concentrations

Quarterly Maximum (µg/m^3)	Monitor	Date
3.47	Denver CAMP, 2105 Broadway	1st Qtr 1979
3.40	Denver, 414 14th St.	4th Qtr 1969
3.03	Denver, 414 14th St.	1st Qtr 1973
3.03	Denver CAMP, 2105 Broadway	4th Qtr 1978
3.02	Denver, 414 14th St.	4th Qtr 1972
2012 Maximum Quarterly Lead Concentration		
0.023	Centennial Airport	4th Qtr 2012

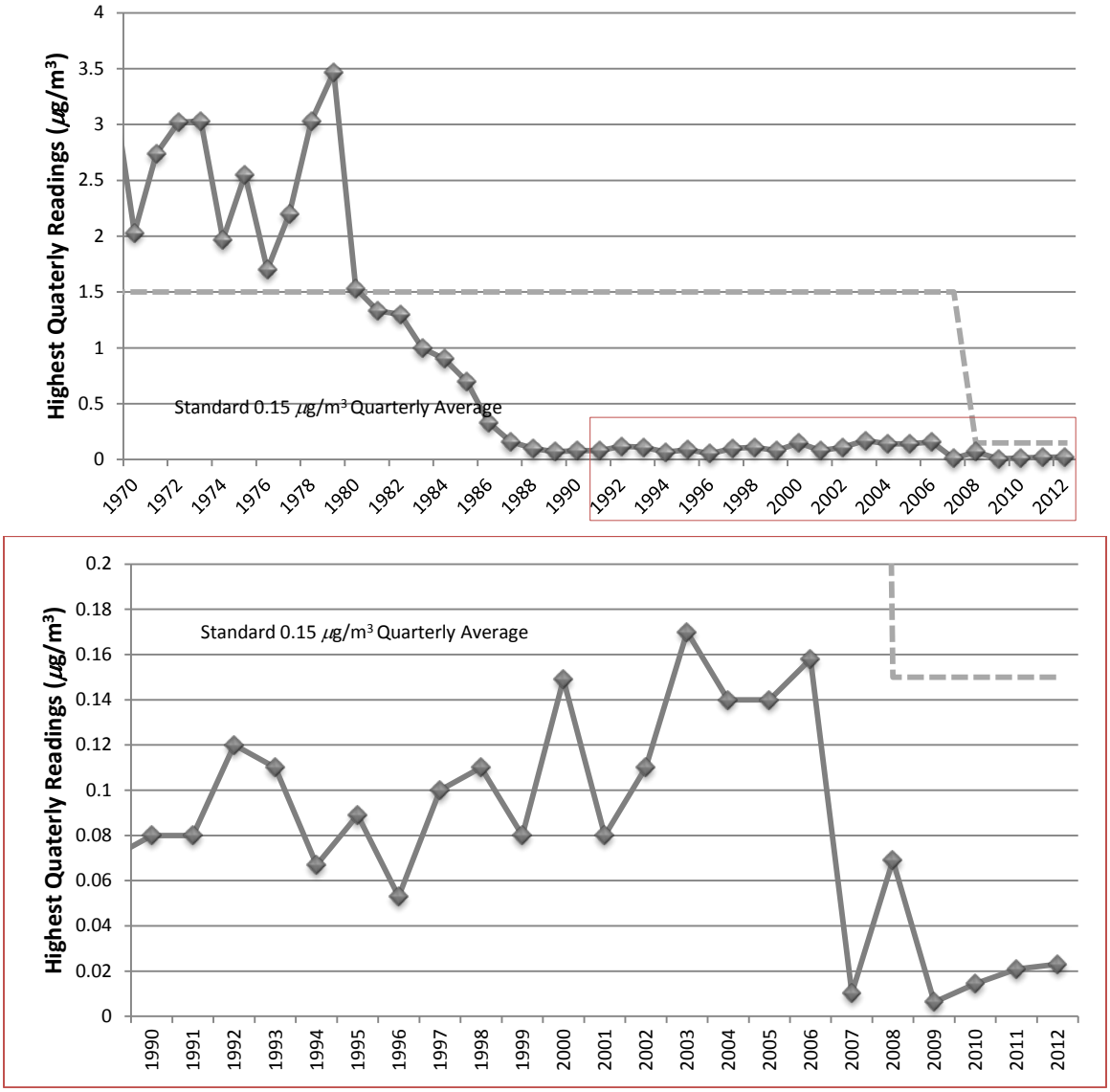


Figure 14. Statewide Ambient Trends for Lead

2.2.7.5 Lead – National Comparisons

Table 24. National Ranking of Lead Monitors by 24-hour Maximum Concentration in µg/m^3

Nationwide (260 Monitors)			Colorado (2 Monitors)		
National Rank	**City/Area**	**24-hr Max**	**National Rank**	**City/Area**	**24-hr Max**
1	Herculaneum, MO	7.7	186	Centennial	0.08
2	Richmond, KY	6.0	358	DMAS	0.02
3	Troy, AL	5.7			
4	Reading, PA	4.7			
5	Granite City, IL	3.2			

Table 24 lists the nationwide comparisons of lead concentrations. (United States Environmental Protection Agency 2012)[10]

3. NON-CRITERIA POLLUTANTS

Non-criteria pollutants are those pollutants for which there are no current national ambient air quality standards. These include but are not limited to the pollutants that impair visibility, certain oxides of nitrogen species, total suspended particulates, and air toxics. Meteorological measurements of wind speed, wind direction, temperature, and humidity are also included in this group, as is chemical speciation of $PM_{2.5}$ analyses.

3.1. Visibility

Visibility is unique among air pollution effects in that it involves human perception and judgment. It has been described as the maximum distance that an object can be perceived against the background sky. Visibility also refers to the clarity with which the form and texture of distant, middle and near details can be seen as well as the sense of the trueness of their apparent coloration. As a result, measures of visibility serve as surrogates of human perception. There are several ways to measure visibility but none of them tell the whole story or completely measure visibility as we experience it.

3.1.1 Visibility - Standards

The Colorado Air Quality Control Commission established a visibility standard in 1990 for the Denver Metropolitan "AIR Program" area. The standard, an atmospheric extinction of 0.076 per inverse kilometer, was based on the public's definition of unacceptable amounts of haze as judged from slides of different haze levels taken in the Denver area. At the standard, 7.6 percent of the light in a kilometer of air is blocked, and the standard is violated when the four-hour average extinction exceeds 7.6 percent. The standard applies from 8 A.M. to 4 P.M. each day, during those hours when the relative humidity is less than 70 percent. Visibility, along with meteorology and concentrations of other pollutants for which National Ambient Air Quality Standards exist, is used to determine the need for mandatory wood burning and voluntary driving restrictions.

There is no quantitative visibility standard for Colorado's pristine and scenic rural areas. However, in the 1977 amendments to the Federal Clean Air Act, Congress added Section 169a (Clean Air Act as ammended in 1977, Section 169a 1977) and established a national visibility goal that created a qualitative standard of "the prevention of any future and the remedying of any existing, impairment of visibility in mandatory Class I federal areas which impairment results from manmade air pollution." The implementation of Section 169a has led to federal requirements to protect visual air quality in large national parks and wilderness areas (Visibility Protection for Federal Class 1 Areas n.d.). Colorado has 12 of these Class I areas. Federal and state law prohibits visibility impairment in national parks and wildernesses due to large stationary sources of air pollution.

3.1.2 Visibility - Health Effects

Visual air quality is an element of public welfare. Specifically, it is an important aesthetic, natural, and economic resource of the State of Colorado. EPA, the US Forest Service, and the US National Park Service have conducted studies that show that good visibility is something that people undeniably value. They have also shown that impaired visibility affects the enjoyment of a recreational visit to a scenic mountain area.

The APCD believes although the worth of visibility is difficult to measure, people prefer to have clear views from their homes and offices. These concerns are reflected in residential property values and office rents. Any loss in visual air quality may contribute to corresponding losses in tourism and usually make an area less attractive to residents, potential newcomers, and industry. Researchers have found this link strongest with concentrations of fine

10 Herculaneum, MO sites near the Doe Run lead smelter, constituting 22 of the top 40 concentrations, were collected as one site for this comparison.

particles, which also contribute to visibility impairment. In July 1997, the EPA developed a NAAQS for $PM_{2.5}$ (more detail is in Section 2.2.6). Any control strategies to lower ambient concentrations of fine particulate matter for health reasons will also improve visibility.

3.1.3 Visibility - Sources

The cause of visibility impairment in Colorado is most often fine particles in the 0.1 to 2.5 micrometer size range. Light passing from a vista to an observer is either scattered away from the sight path or absorbed by the atmospheric fine particulates. Sunlight entering the pollution cloud may be scattered into the sight path adding brightness to the view and making it difficult to see elements of the vista. Sulfate, nitrate, elemental carbon, and organic carbon are the types of particulate matter most effective at scattering and/or absorbing light. The man-made sources of these particulates include wood burning, electric power generation, industrial combustion of coal or oil, and emissions from cars, trucks, and buses.

Visibility conditions vary considerably across the state. Usually, visibility in Colorado is among the best in the country. Our prized western vistas exist due to unique combinations of topography and scenic features. Air in much of the West contains low humidity and minimal levels of visibility-degrading pollution. Nevertheless, visibility problems occur periodically throughout the state. Wood burning haze is a concern in several mountain communities each winter. Denver has its "Brown Cloud." Even the national parks, monuments, and wilderness areas show pollution related visibility impairment on occasion due to regional haze, the interstate or even regional-scale transport of visibility-degrading pollution. The visibility problems across the state have raised public concern and spurred research. The goal of Colorado's visibility program is to protect visual air quality where it is presently good and improve visibility where it is degraded.

3.1.4 Visibility - Class I Areas in Colorado

Phase 1 of the visibility program, also known as Reasonably Attributable Visibility Impairment (RAVI), addresses impacts in Class I areas by establishing a process to evaluate source specific visibility impacts, or *plume blight*, from individual sources or small groups of sources. Figure 15 illustrates these areas in Colorado.

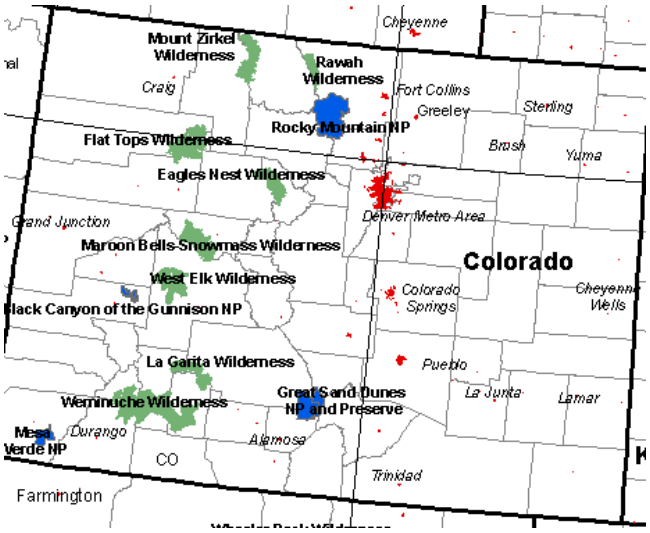


Figure 15. Class I areas in Colorado

Section 169B was added to the Clean Air Act Amendments of 1990 to address Regional Haze. Since Regional Haze and visibility problems do not respect state and tribal boundaries, the amendments authorized EPA to establish visibility transport regions as a way to combat regional haze.

Phase 2 of the visibility program addresses Regional Haze. This form of visibility impairment focuses on overall decreases in visual range, clarity, color, and ability to discern texture and details in Class I areas. The responsible air pollutants can be generated in the local vicinity or carried by the wind often many hundreds or even thousands of miles from where they originated.

The APCD developed a Regional Haze State Implementation Plan (SIP) in 2010 illustrating how Colorado intends to meet the requirements of EPA's Regional rules for the period ending in 2018 (the first planning period in the rule), while also establishing enforceable controls that will help address the long term national visibility goals targeted to be achieved by the year 2064.

Colorado's Regional Haze SIP was approved by the Colorado Air Quality Control Commission on January 7, 2011. This plan will lead to less haze and improved visibility in some of Colorado's most treasured and scenic areas,

including Rocky Mountain National Park, Mesa Verde, Maroon Bells, and the Great Sand Dunes. By 2018, the plan will result in more than 70,000 tons of pollutant reductions annually, including 35,000 tons of nitrogen oxides, which leads to ground-level ozone formation. In total, the plan covers 30 industrial emitters at 16 facilities throughout Colorado, including coal-fired power plants and cement kilns.

3.1.5 Visibility - Monitoring

There are several ways to measure visibility. The APCD uses camera systems to provide qualitative visual documentation of a view. Transmissometers and nephelometers are used to measure the atmosphere's ability to attenuate light quantitatively.

A visibility site was installed in Denver in late 1990 using a long-path transmissometer. Visibility in the downtown area is monitored using a receiver located near Cheesman Park at 1901 E. 13th Avenue, and a transmitter located on the roof of the Federal Building at 1929 Stout Street (Figure 16). Renovations at the Federal Building forced the transmissometer to temporarily move to 1255 19th Street in 2010, and quality control measurements showed no meaningful difference between old and new locations. This instrument directly measures light extinction, which is proportional to the ability of atmospheric particles and gases to attenuate image-forming light as it travels from an object to an observer. The visibility standard is stated in units of atmospheric extinction. Days when the visibility is affected by rain, snow, or relative humidity above 70% are termed "excluded" (as shown in Figure 28) and are not counted as violations of the visibility standard.

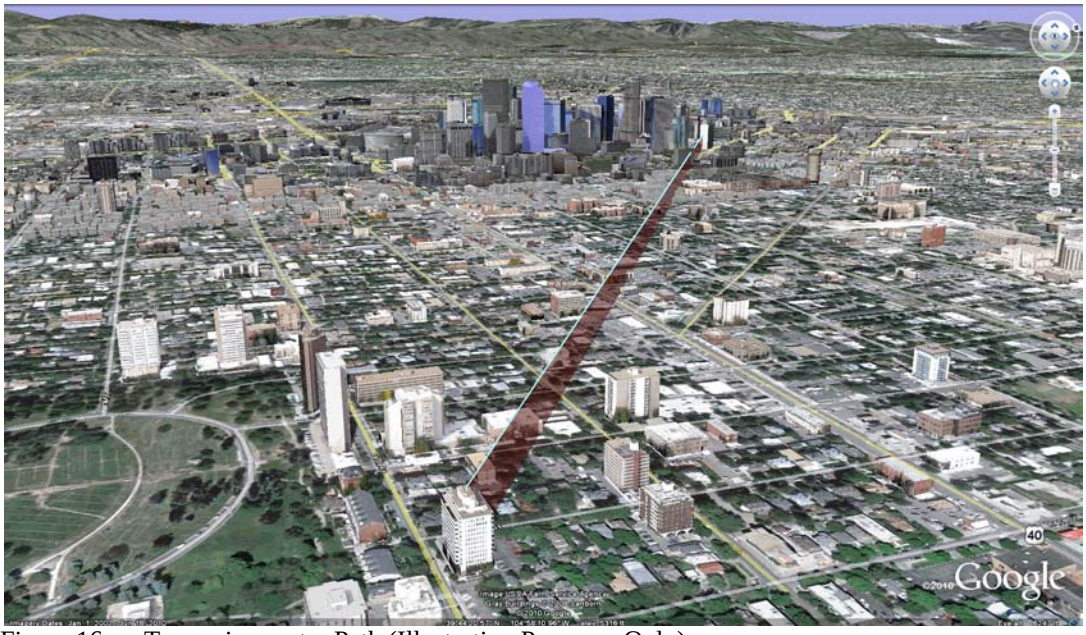


Figure 16. Transmissometer Path (Illustration Purposes Only)

In September 1993, a transmissometer and nephelometer were purchased by the City of Fort Collins to monitor visibility in that community. Elsewhere in Colorado, several agencies of the federal government, in cooperation with regional and nationwide state air pollution organizations, also monitor visibility in a number of national parks and wilderness Class I areas, either individually or jointly through the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. The goals of the monitoring programs are to establish background visibility levels, identify trends of deterioration or improvement, identify suspected sources of visibility impairment, and to track regional haze. Visibility and the atmospheric constituents that cause visibility degradation are characterized with camera systems, transmissometers, and extensive fine particle chemical composition measurements by the monitoring network. There are currently IMPROVE monitoring sites in Rocky Mountain National Park, Mesa Verde National Park, Weminuche Wilderness, Mount Zirkel Wilderness, Great Sand Dunes National Monument, and White River National Forest. These data are not contained in this report, but are available at: http://vista.cira.colostate.edu/improve/

3.1.6 Visibility - Denver Camera

The APCD operates a web-based camera that can be viewed on the Live Image of Denver icon on the bottom left side of the screen at the APCD web site http://www.colorado.gov/airquality. There is a great deal of other information available from this site in addition to the image from the visibility camera, including the Front Range Air Quality Forecast, Air Quality Advisory, Monitoring Reports, this report, and Open Burning Forecast.

The images in Figure 17 show the visibility on one of the best and worst days for the year. The best visibility day was April 27, 2012. The worst visibility day was July 4, 2012.

Figure 17. Best (left) and Worst (right) Visibility Days in Denver

These two pictures are images made by the web camera at the visibility monitor located at 1901 E. 13th Avenue in Denver, and are centered on the Federal Building at 1929 Stout Street (see Figure 16, the camera follows the transmissometer path). The difference in these two pictures is not just the brightness but the detail that can be seen between the two images. On the best day, buildings can be clearly resolved, and the Front Range is visible. On the worst day, however, contrast between buildings is lower, and the Front Range is almost entirely obscured.

3.2. Nitric Oxide

Nitric oxide is the most abundant of the oxides of nitrogen emitted from combustion sources. There are no known adverse health effects at normal ambient concentrations. However, nitric oxide is a precursor to nitrogen dioxide, nitric acid, particulate nitrates, and ozone, all of which have demonstrated adverse health effects. (United States Environmental Protection Agency 1982) There are no federal or state standards for nitric oxide.

Site	1st Maximum Value (PPB)	Annual Arithmetic Mean (ppb)
CAMP	516	20.2
Welby	285	16.8
DMAS	213	10.3

Table 25. Nitric Oxide Summary

Nitric oxide was sampled simultaneously with NO_2 at Welby, CAMP, and DMAS. Table 25 shows the maximum and average NO concentrations in Colorado. Without national standards with which to compare these numbers, they are only here for informational purposes, and are considered by the APCD to be consistent with recent historical nitric oxide concentrations.

3.3. Total Suspended Particulates

Total suspended particulates (TSP) were first monitored in Colorado in 1960 at 414 14th Street in Denver. This location monitored TSP until 1988. The Adams City and Gates TSP monitors began operation in 1964 and the Denver CAMP monitor at 2105 Broadway began operating in 1965. Either the EPA or the City of Denver operated

these monitors until the mid-1970s, when daily operation was taken over by the Colorado Department of Public Health and Environment. None of these monitors are in operation today.

Particulate monitoring expanded to more than 70 locations around the state by the early 1980s. The primary standards for total suspended particulates were 260 $\mu g/m^3$ as a 24-hour sample and 75 $\mu g/m^3$ as an annual geometric mean. On July 1, 1987, with the promulgation of the PM_{10} standards, the old TSP standards were eliminated. Until December 2006 the Division operated six TSP samplers to measure lead. On January 1, 2007 the number of lead monitoring sites was reduced to one, at the Denver Municipal Animal Shelter located at 678 S. Jason Street. The reason for the change in the number of TSP monitors is that the ambient concentrations of lead have been reduced dramatically.

In October of 2008 the lead standard changed again. With this change, a TSP sampler was installed near the Centennial Airport in Arapahoe County. The location was selected to more closely monitor lead from small aircraft that still use leaded fuel. The maximum TSP concentration recorded in 2012 was 169 $\mu g/m^3$ at DMAS, and the maximum TSP recorded in 2012 at the Centennial Airport was 69 $\mu g/m^3$. A more detailed explanation of the lead standard and measurements can be found in Section 2.2.7 and 4.2 respectively.

3.4. Air Toxics

Toxic air pollutants, or air toxics, are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects. Air toxics may also cause adverse environmental and ecological effects. EPA is required to reduce air emissions of 188 air toxics listed in the Clean Air Act. Examples of air toxics include benzene (found in gasoline), perchloroethylene (emitted from some dry cleaning facilities), and methylene chloride (used as a solvent by a number of industries). Most air toxics originate from man-made sources, including mobile sources like cars, trucks, and construction equipment, and stationary sources like factories, refineries, and power plants, as well as indoor sources (some building materials and cleaning solvents). Some air toxics are also released from natural sources such as volcanic eruptions and forest fires. (United States Environmental Protection Agency 2009)

People exposed to air toxics at sufficient concentrations may experience various health effects including cancer and damage to the immune system, as well as neurological, reproductive (including reduced fertility), developmental, respiratory, and other health problems. In addition to exposure from breathing air toxics, risks are also associated with the deposition of toxic pollutants onto soils or surface waters, where they are taken up by plants and ingested by animals and eventually magnified up through the food chain. Like humans, animals may experience health problems due to air toxics exposure.

The APCD currently monitors for air toxics in Grand Junction as part of EPA's National Air Toxics Trend Stations project. Monitoring for ozone precursors, which are a subset of air toxics, also began at CAMP and Platteville in December of 2011. The data from the Grand Junction study are available in a separate report, available at http://www.colorado.gov/airquality/tech.aspx#misc.

3.5. Meteorology

The APCD takes a limited set of meteorological measurements at 18 locations around the state. These measurements include wind speed, wind direction, temperature, standard deviation of horizontal wind direction, and select monitoring of relative humidity. Relative humidity measurements are also taken in conjunction with the two visibility monitors. The humidity data are not summarized in this report since they are used primarily to validate the visibility measurements taken at the specific locations. The Division does not collect precipitation measurements. The wind speed, wind direction, and temperature measurements are collected primarily for air quality forecasting and air quality modeling. These instruments are installed on ten-meter towers and the data are collected as hourly averages and sent along with other air quality data to be stored on the EPA's Air Quality Systems database. The wind speed and wind direction data are shown as wind roses at the end of each monitoring area in Section 4 below.

The wind roses displayed in this report are based on the direction that the wind is blowing from. Another way of visualizing a wind rose is to picture you standing in the center of the plot and facing into the wind. The wind direction is divided into the 16 cardinal directions (ESE, for example). The wind speed is divided into six ranges. The roses in Section 4 below use 1-3 mph, 4-6 mph, 7-11 mph, 12-14 mph, 15-38 mph, and greater than 38 mph. The length of each arm of the wind rose represents the percentage of time the wind was blowing from that direction at that speed. The longer the arm, the greater the percentage of time the wind is blowing from that direction.

3.6. $PM_{2.5}$ Chemical Speciation

Numerous health effects studies have correlated negative health effects to the total mass concentration of $PM_{2.5}$ in ambient air. (AirNow 2003) However, it has not yet been completely determined if the health correlation is to total mass concentration, or to concentrations of specific chemical species in the $PM_{2.5}$ mix. When the EPA promulgated the NAAQS for $PM_{2.5}$ in 1997, a compliance monitoring network based on total $PM_{2.5}$ mass was established. Mass concentrations from the compliance network are used to determine attainment of the NAAQS. EPA soon supplemented the $PM_{2.5}$ network with the Speciation Trends Network (STN) monitoring to provide information on the chemical composition of $PM_{2.5}$. The main purpose of the STN is to identify sources, develop implementation plans to reduce $PM_{2.5}$ pollution, and support health effects research.

Colorado began chemical speciation monitoring at the Commerce City site in February 2001 at the state's only STN site. Four other chemical speciation sites were established in 2001 in Colorado Springs, Durango, Grand Junction, and Platteville. The Durango site was closed in September 2003. The Colorado Springs site was closed in December, 2006. These sites were eliminated when concentrations were found to trend low and when funding was reduced for the project. The Grand Junction site was closed in December 2009 and moved to DMAS NCore where it began sampling in January of 2010 to comply with the requirement from EPA to monitor $PM_{2.5}$ speciation at NCore sites.

Chemical speciation monitoring is conducted for 47 elemental metals, five ionic species, and elemental and organic carbon. Selected filters can also be analyzed for semi-volatile organics and microscopic analyses. The results of these samples can be obtained from the APCD upon request. Some of these chemical species and compounds can cause serious health effects, premature deaths, visibility degradation, and regional haze. The chemical speciation data for $PM_{2.5}$ is used in many ways, such as to determine which general source categories are likely responsible for the $PM_{2.5}$ pollution at a given monitoring site on a given day, and how much pollution comes from each source category. There are two broad categories of $PM_{2.5}$ – primary and secondary particles. Primary $PM_{2.5}$ particles include those emitted directly to the air from carbonaceous particles from incomplete combustion of internal combustion engines, wood burning, waste burning, and crushed geologic materials. Secondary $PM_{2.5}$ is formed from gases that combine in the atmosphere through chemical processes and form liquid aerosol droplets. Ammonium nitrates and ammonium sulfates are generally the two largest types of secondary $PM_{2.5}$ in Colorado. If $PM_{2.5}$ pollution needs to be controlled, it is important to know the composition of $PM_{2.5}$ particles so that the appropriate sources can be targeted for control (see Section 2.2.6.3 above for more information on $PM_{2.5}$ sources).

4. MONITORING RESULTS BY AREA IN COLORADO

Please refer to section 1.2 for a brief description of the monitoring areas below.

4.1. Eastern Plains Counties

Currently, there are two PM_{10} monitoring sites and one meteorological site in Lamar. The Lamar monitors have recorded exceedances of the 24-hour PM_{10} standard in the past three years. These have been associated with high winds and blowing dust from large regional dust storms and dry conditions. The background $PM_{2.5}$ monitor in Elbert County has been discontinued due to a change in land ownership and is being relocated. Table 26 lists the 2012 concentration values for the Eastern Plains particulate monitors, while Figure 18 is an illustration of the wind rose overlain on a map of the monitoring site.

Table 26. Eastern Plains Particulate Values

Site Name	PM_{10} (µg/m^3)		
	Annual Average	24-hour Max	3-Year Avg. Exceedance
Prowers			
Lamar Power Plant	28	220	1.7
Lamar Municipal	25	242	0.7

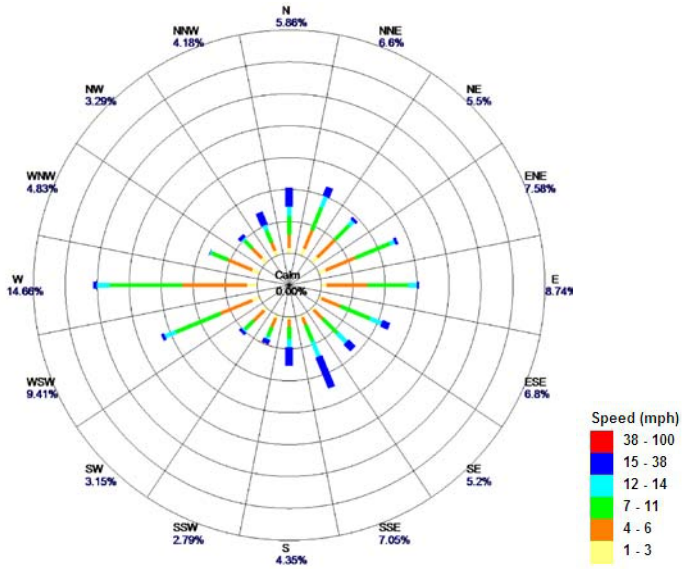


Figure 18. Eastern Plains Wind Rose, Lamar Port of Entry, 7100 US Hwy 50

The Lamar Power Plant station has had an average of 1.7 exceedances per year over the last 3 years (3, 2, and 0 exceedances for 2012, 2011, and 2010 respectively), which is in violation of the annual average primary standard, if exceptional events are not excluded (United States Environmental Protection Agency 2010). See Section 2.2.5.1. However, the Lamar Power Plant site is inappropriately sited and does not represent ambient air exposure. It is located on the roof of the old power plant near an obstructing wall which may bias the results. APCD has sent a request to EPA that the site be closed.

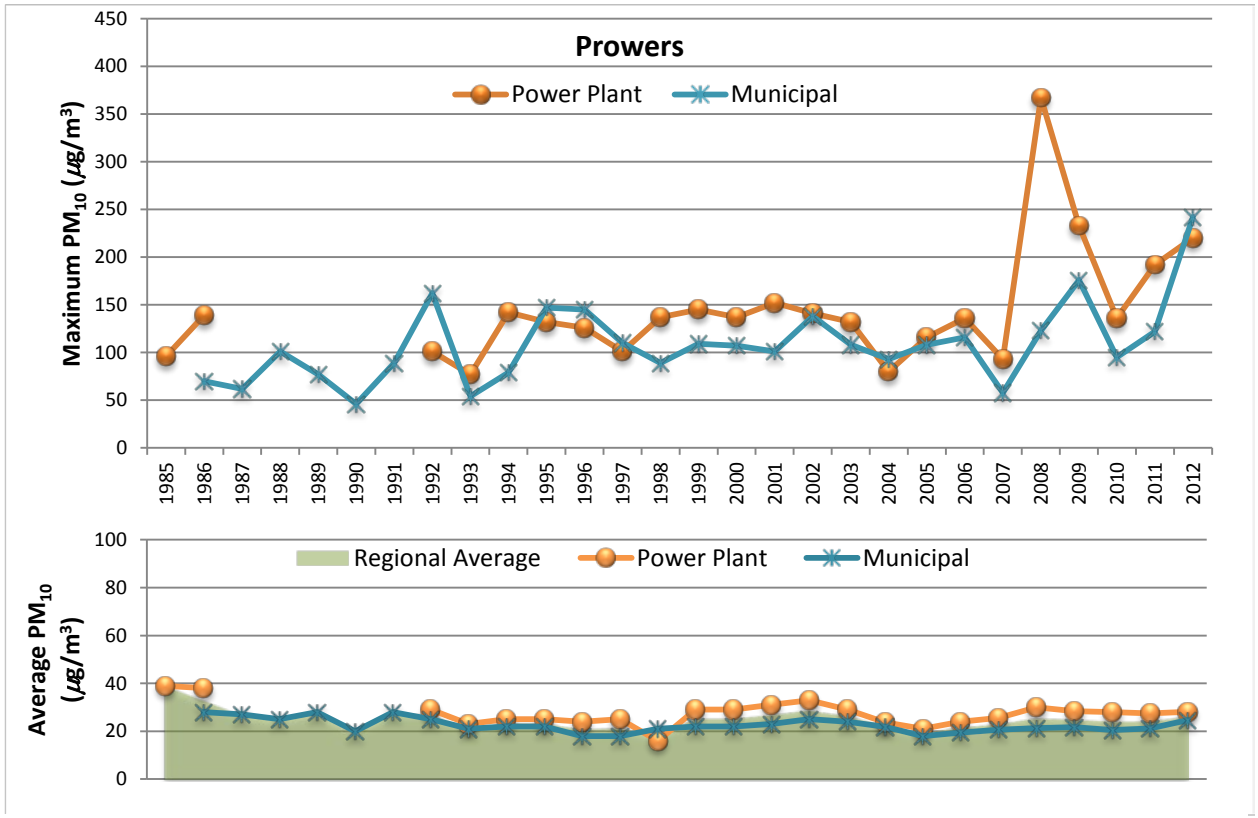


Figure 19. Average and Maximum PM_{10} Concentrations for the Eastern Plains Counties

4.2. Denver Metro/Northern Front Range

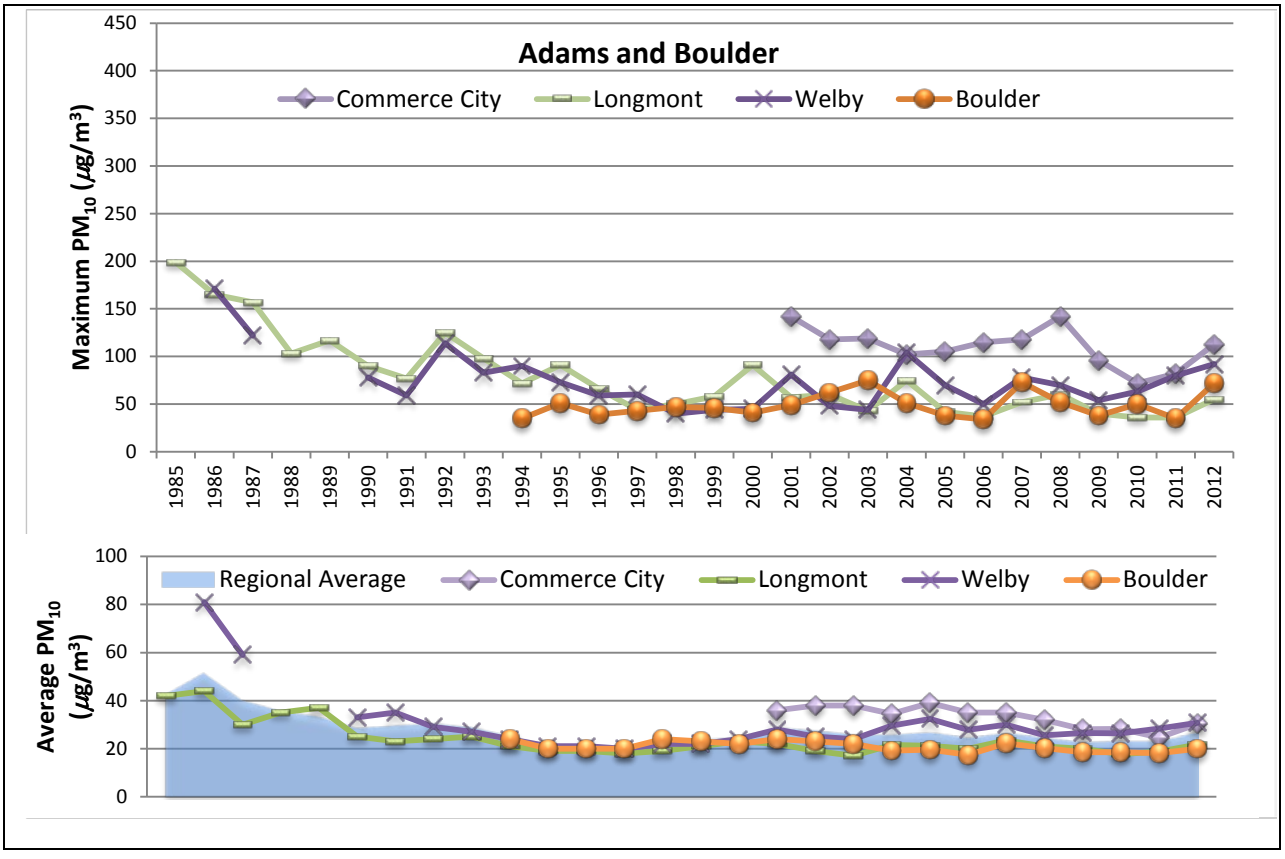
Table 27 shows there were no violations of the $PM_{2.5}$ or PM_{10} NAAQS in the northern Front Range counties. Data below may include exceptional events. See Section 2.2.5.1.

Table 27. Northern Front Range Particulate Values[11]

Site Name	PM_{10} (µg/m^3)			$PM_{2.5}$ (µg/m^3)	
	Annual Average	24-hour Maximum	3-Year Average Exceedance	3-Year Weighted Average	3-Year Average of 98th %ile
Adams					
Commerce City	29.5	113	0	8.2	22.4
Welby	31.3	91	0		
(Continuous)	22.8	92			
Arapahoe					
Arapahoe Com. College				6.4	18.4
Boulder					
Longmont	21.7	55	0	6.9	24.4

11 Continuous monitors report hourly averages of particulate matter 365 days of the year. Other monitors sample particulate matter on filters on a fixed but non-continuous schedule.

Boulder, 2440 Pearl St.	19.9	72	0	6.3	17.6
Denver					
Denver CAMP (Continuous)	30.9	79	0	7.8	19.1
	31.4	115			
Visitor Center	27.2	87	0		
Swansea School				7.6	19.8
DMAS (Continuous)	25.6	56	0	7.6	17.1
	28.0	93			
Douglas					
Chatfield Res				5.8	16.1
Larimer					
Fort Collins - Edison (Continuous)	23.7	72	0	6.4	20.9
	23.9	104			
Weld					
Greeley	25.7	102	0	7.3	25.0
Platteville				7.6	19.7



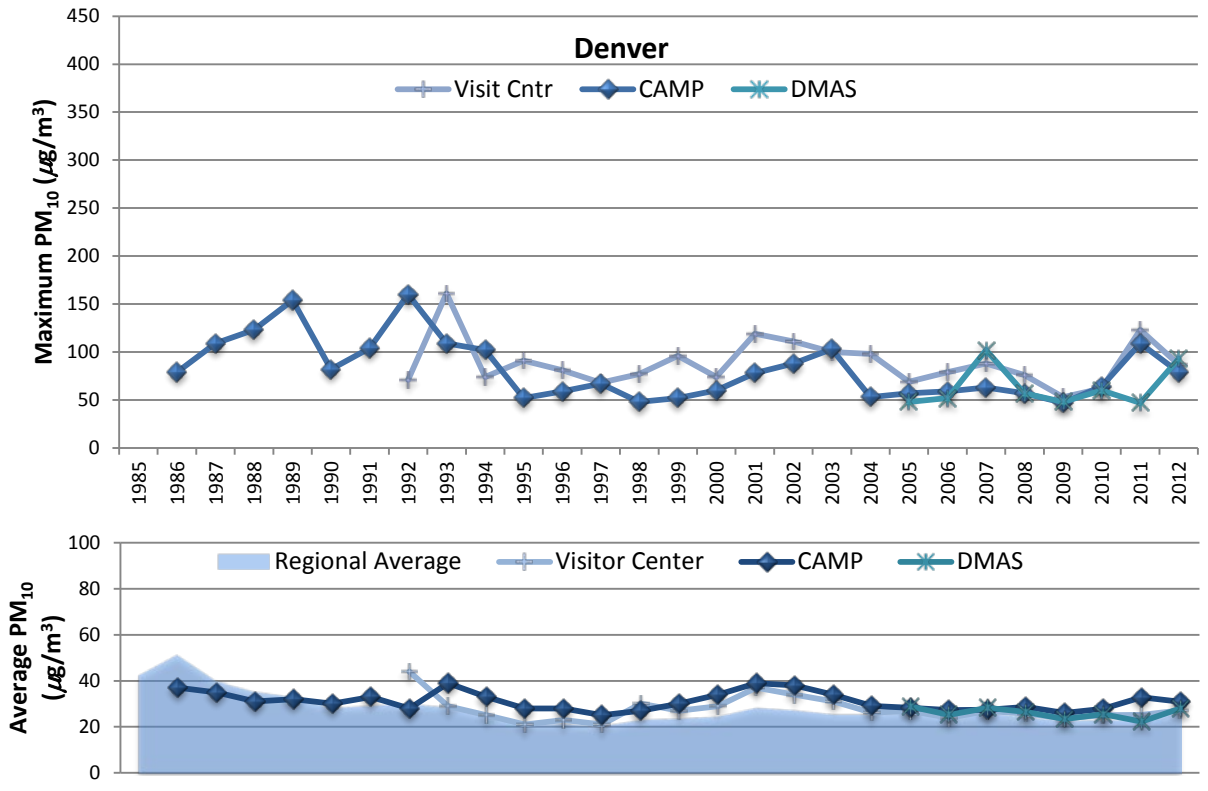
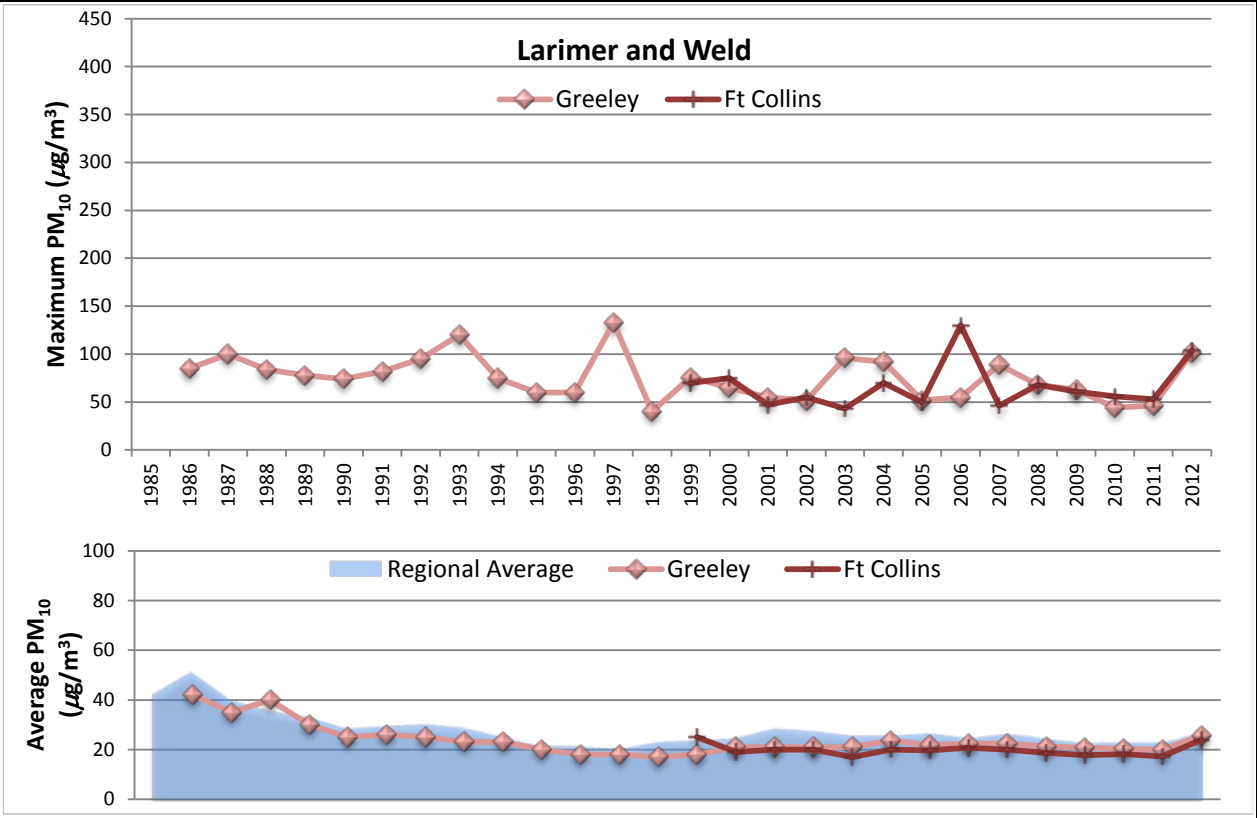
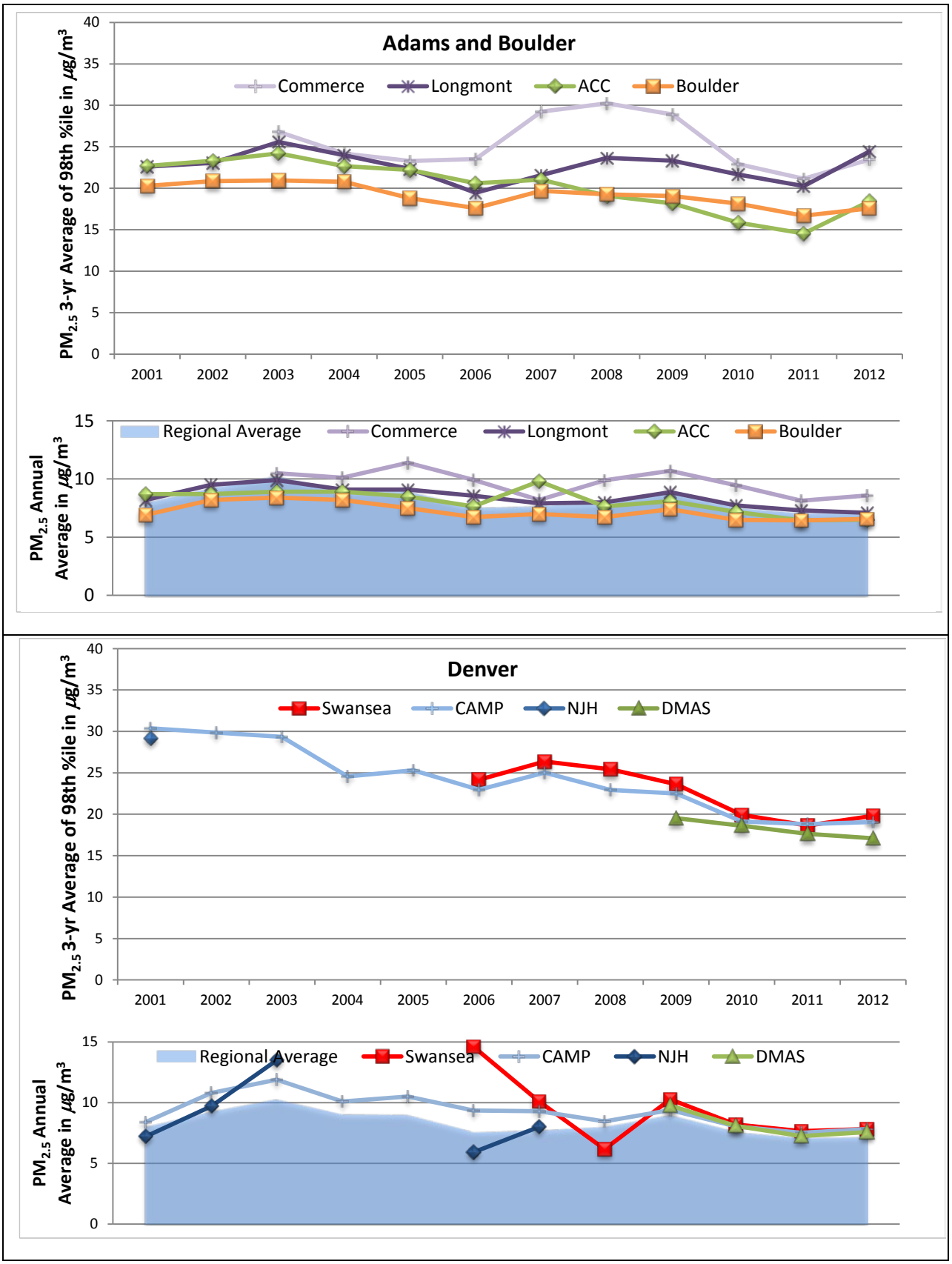


Figure 20. Average and Maximum PM_{10} Concentrations for the Northern Front Range Counties




Adams and Boulder
PM2.5 3-yr Average of 98th %ile in µg/m3
Commerce
Longmont
ACC
Boulder
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
PM2.5 Annual Average in µg/m3
Regional Average
Commerce
Longmont
ACC
Boulder
Denver
PM2.5 3-yr Average of 98th %ile in µg/m3
Swansea
CAMP
NJH
DMAS
PM2.5 Annual Average in µg/m3
Regional Average
Swansea
CAMP
NJH
DMAS

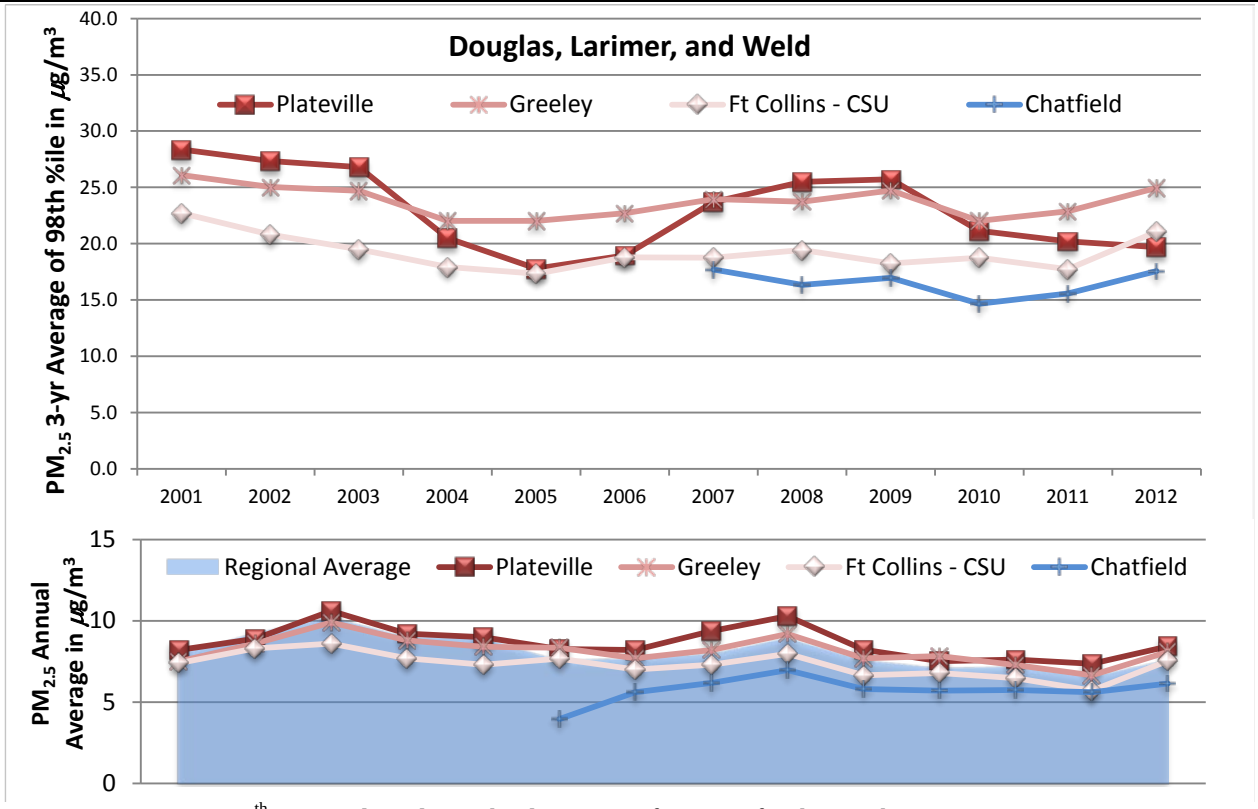


Figure 21. 3-Year 98th Percentile and Weighted Averages for $PM_{2.5}$ for the Northern Front Range Counties

Table 28. Northern Front Range TSP and Lead Values

Site Name	TSP (µg/m^3)		Lead (µg/m^3)	
	Annual Mean	24-hour Maximum	Maximum Quarter	24-hour Maximum
Denver				
DMAS	67.8	169	0.0068	0.014
Centennial	29.3	69	0.0780	0.017

() indicates less than 75 percent data for one or more quarters.

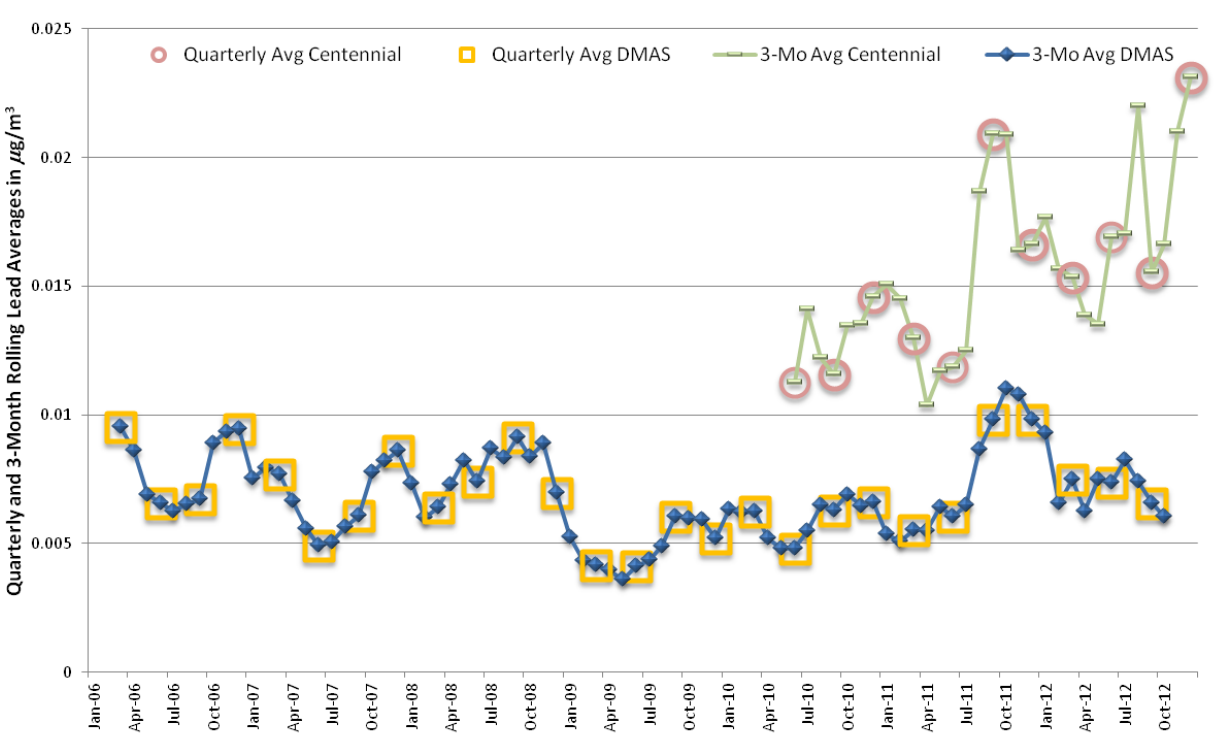


Figure 22. Quarterly Lead Averages for the Northern Front Range Counties

Table 29. Northern Front Range Carbon Monoxide Values

Site Name	Location	CO 1-hour Avg. (ppm)		CO 8-hour Avg. (ppm)	
		1st Maximum	2nd Maximum	1st Maximum	2nd Maximum
Adams					
Welby	3174 E. 78th Ave.	2.2	2.2	1.7	1.3
Denver					
Denver-CAMP	2105 Broadway	4.2	4.0	2.7	2.0
DMAS	678 S. Jason St	2.1	2.1	1.5	1.2
Larimer					
Fort Collins	708 S. Mason St	2.7	2.5	1.8	1.7
Weld					
Greeley	905 10th Ave.	3.2	3.2	2.3	1.6

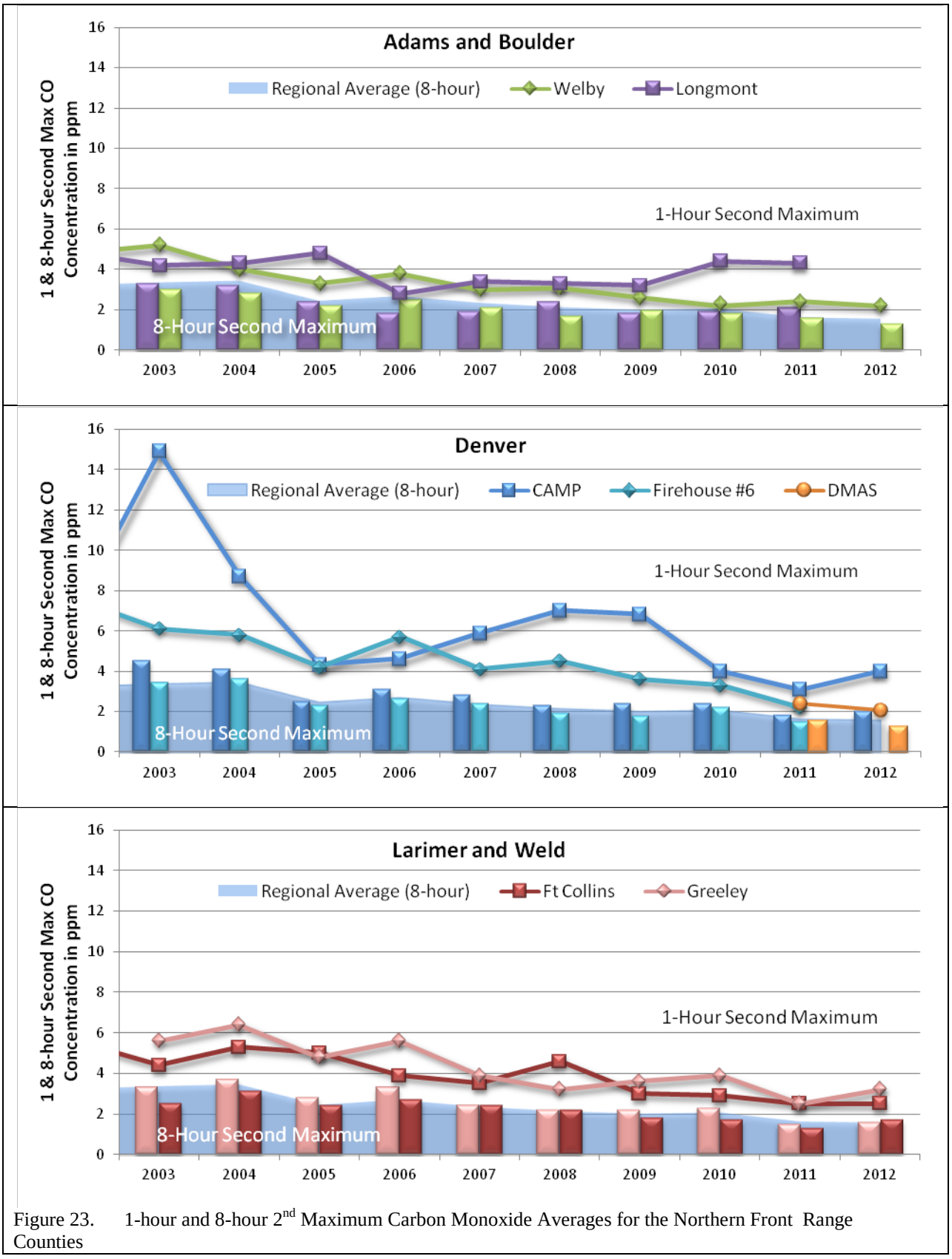


Figure 23. 1-hour and 8-hour 2nd Maximum Carbon Monoxide Averages for the Northern Front Range Counties

Table 30. Northern Front Range Ozone Values

Site Name	Location	Ozone 8-hour Avg. (ppm)		
		1st Maximum	4th Maximum	3-year Average of 4th Maximum
Adams				
Welby	3174 E. 78th Ave.	0.087	0.077	0.071
Arapahoe				
Highland Reservoir	8100 S. University Blvd	0.094	0.080	0.077
Aurora East	36001 E. Quincy Ave.	0.085	0.077	0.073
Boulder				
Boulder	1405½ S. Foothills Highway	0.094	0.076	0.074
Denver				
Denver Carriage	2325 Irving St.	0.092	0.077	0.073
DMAS	678 S. Jason St.	0.090	0.073	0.069
Douglas				
Chatfield Reservoir	11500 N. Roxborough Park Rd.	0.098	0.086	0.082
Jefferson				
Welch	12400 W. Hwy 285	0.090	0.079	0.076
Rocky Flats-N	16600 W. Colorado 128	0.101	0.084	0.080
NREL	2054 Quaker St.	0.095	0.081	0.079
Aspen Park	26137 Conifer Rd.	0.090	0.077	0.074
Larimer				
Fort Collins-W	3416 La Porte Ave.	0.093	0.080	0.078
Rist Canyon	11835 Rist Canyon Rd.	0.077	0.071	0.071
Fort Collins-Mason	708 S. Mason St.	0.094	0.074	0.069
Weld				
Weld County Tower	3101 35th Ave.	0.090	0.080	0.076

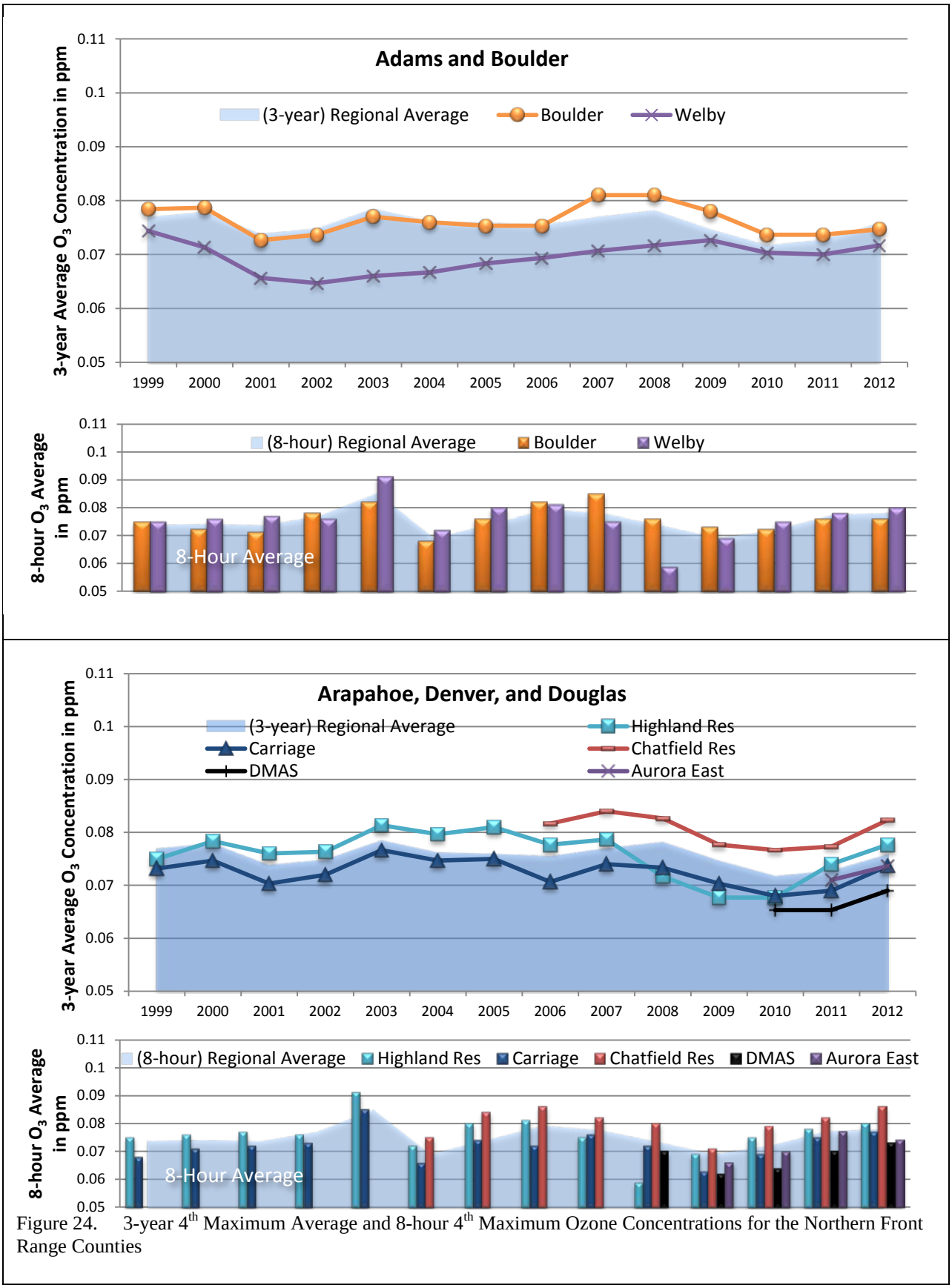


Figure 24. 3-year 4th Maximum Average and 8-hour 4th Maximum Ozone Concentrations for the Northern Front Range Counties

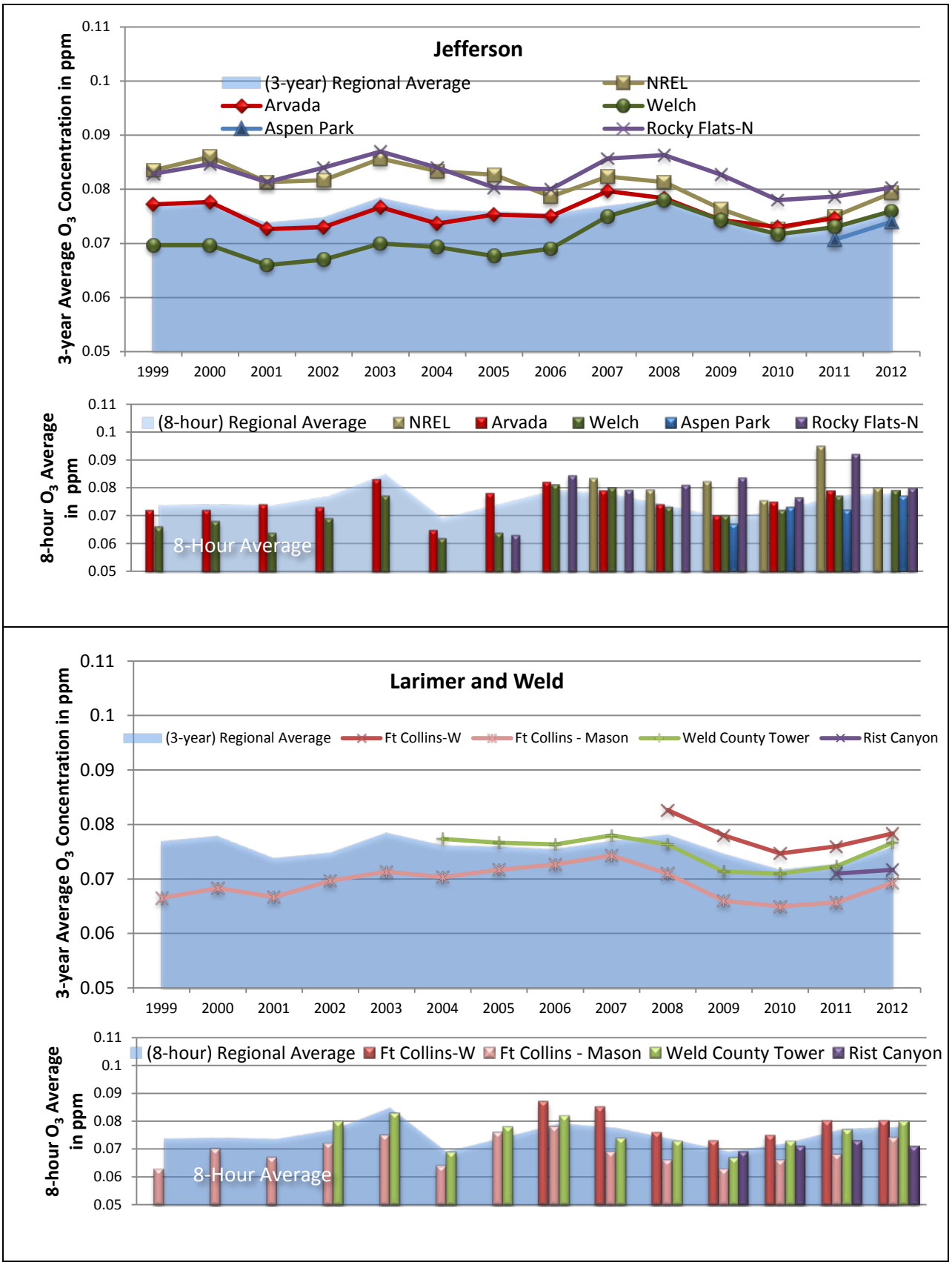

Jefferson
3-year Average O_3 Concentration in ppm
0.11
0.1
0.09
0.08
0.07
0.06
0.05
(3-year) Regional Average
NREL
Arvada
Welch
Aspen Park
Rocky Flats-N
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
8-hour O_3 Average in ppm
(8-hour) Regional Average
NREL
Arvada
Welch
Aspen Park
Rocky Flats-N
8-Hour Average
Larimer and Weld
3-year Average O_3 Concentration in ppm
(3-year) Regional Average
Ft Collins-W
Ft Collins - Mason
Weld County Tower
Rist Canyon
8-hour O_3 Average in ppm
(8-hour) Regional Average
Ft Collins-W
Ft Collins - Mason
Weld County Tower
Rist Canyon
8-Hour Average

Table 31. Northern Front Range Oxides of Nitrogen and Sulfur Dioxide Values

Site Name	Nitrogen Dioxide (ppb)		Sulfur Dioxide (ppb)			
	Annual Mean	3-year Avg 98th %ile	3-hour 2nd Max	1-hour 99th %ile	Annual Mean	3-year Avg 1-hr 99th %ile
Welby	18.9	61	17	46	0.88	32
CAMP	24.5	82	34	43	2.01	35
DMAS			23	32	1.53	<3 Years

() indicates <75% data recovery

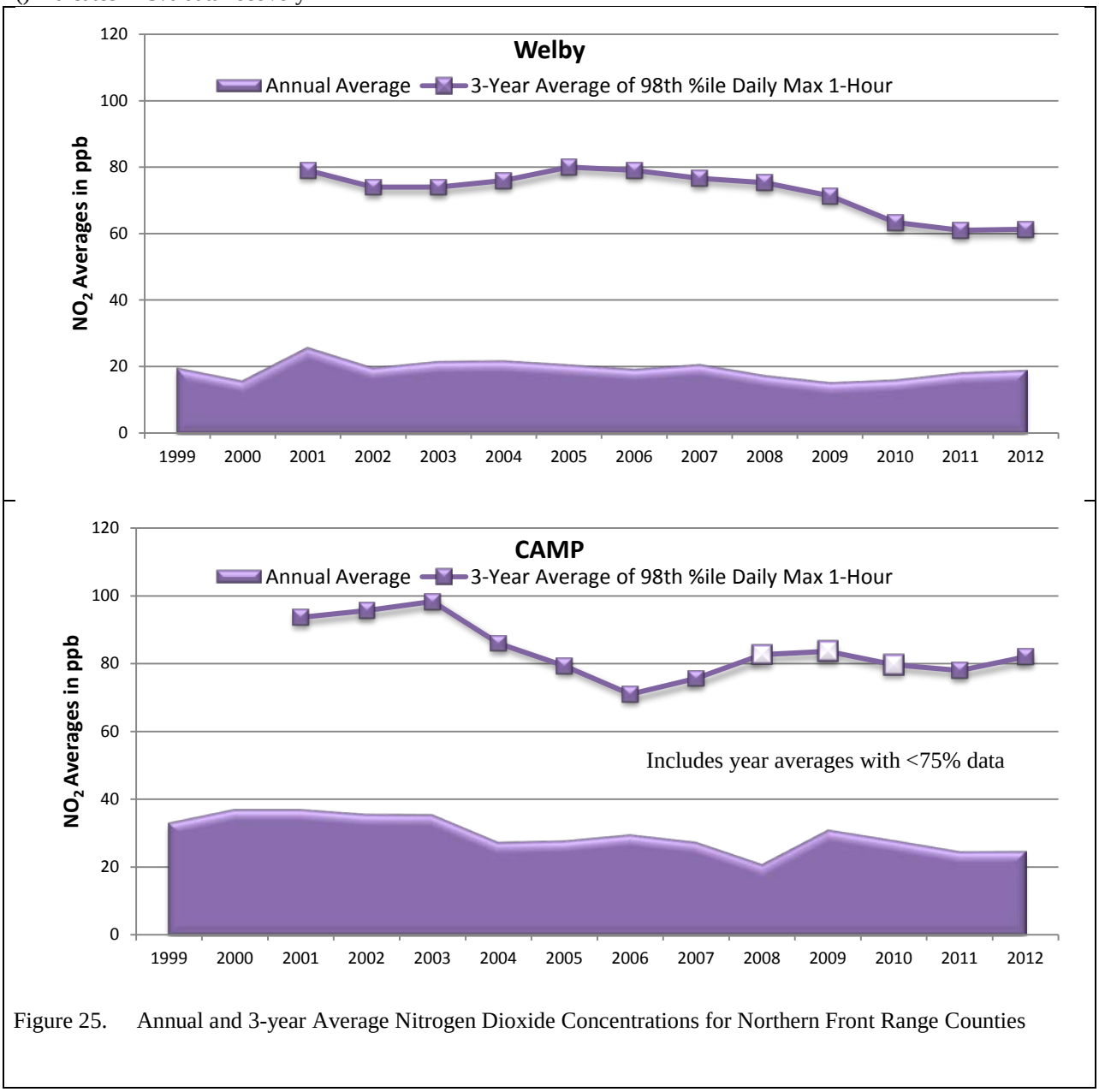
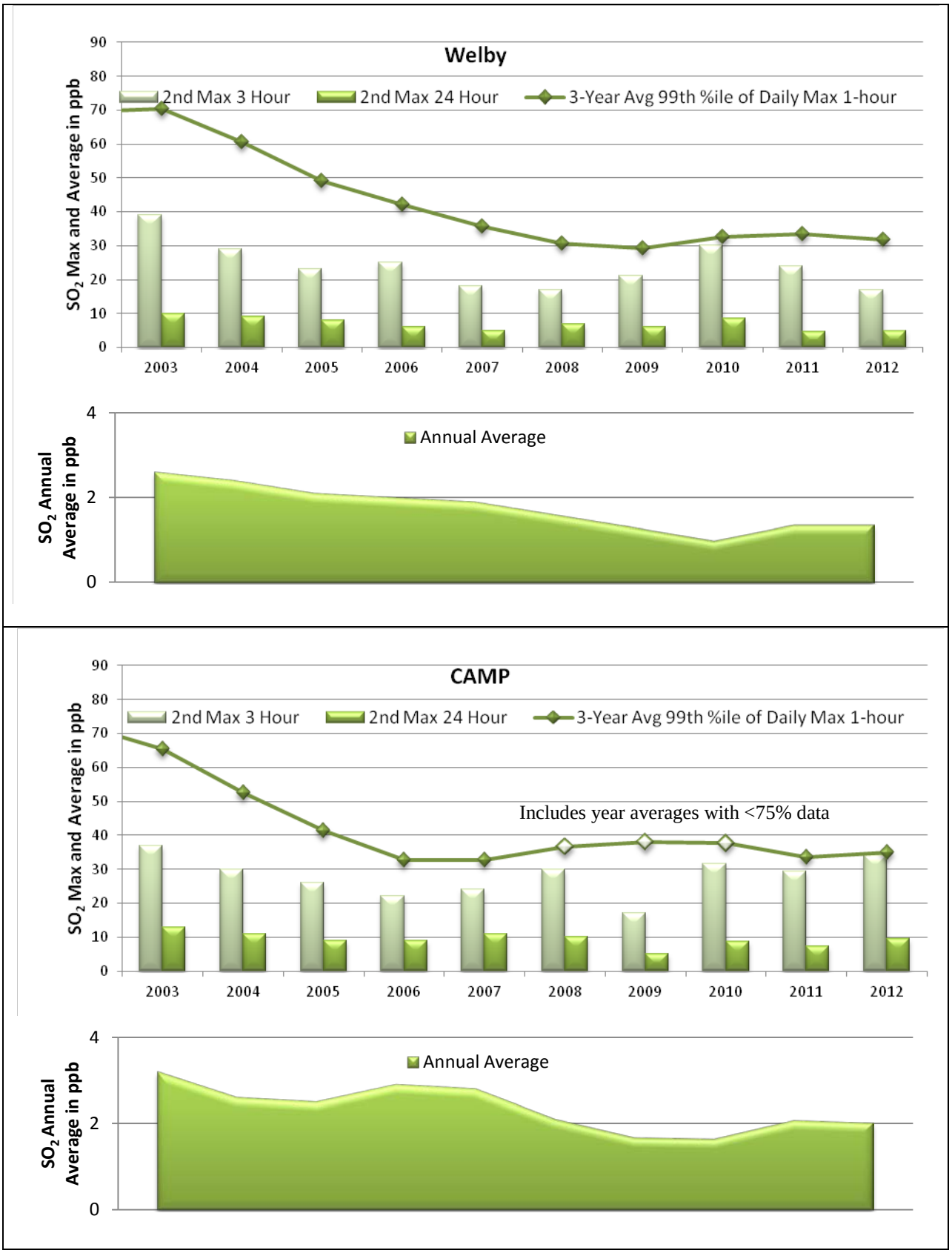


Figure 25. Annual and 3-year Average Nitrogen Dioxide Concentrations for Northern Front Range Counties


Welby
2nd Max 3 Hour
2nd Max 24 Hour
3-Year Avg 99th %ile of Daily Max 1-hour
SO2 Max and Average in ppb
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Annual Average
SO2 Annual Average in ppb
4
2
0
CAMP
2nd Max 3 Hour
2nd Max 24 Hour
3-Year Avg 99th %ile of Daily Max 1-hour
Includes year averages with <75% data
SO2 Max and Average in ppb
Annual Average
SO2 Annual Average in ppb

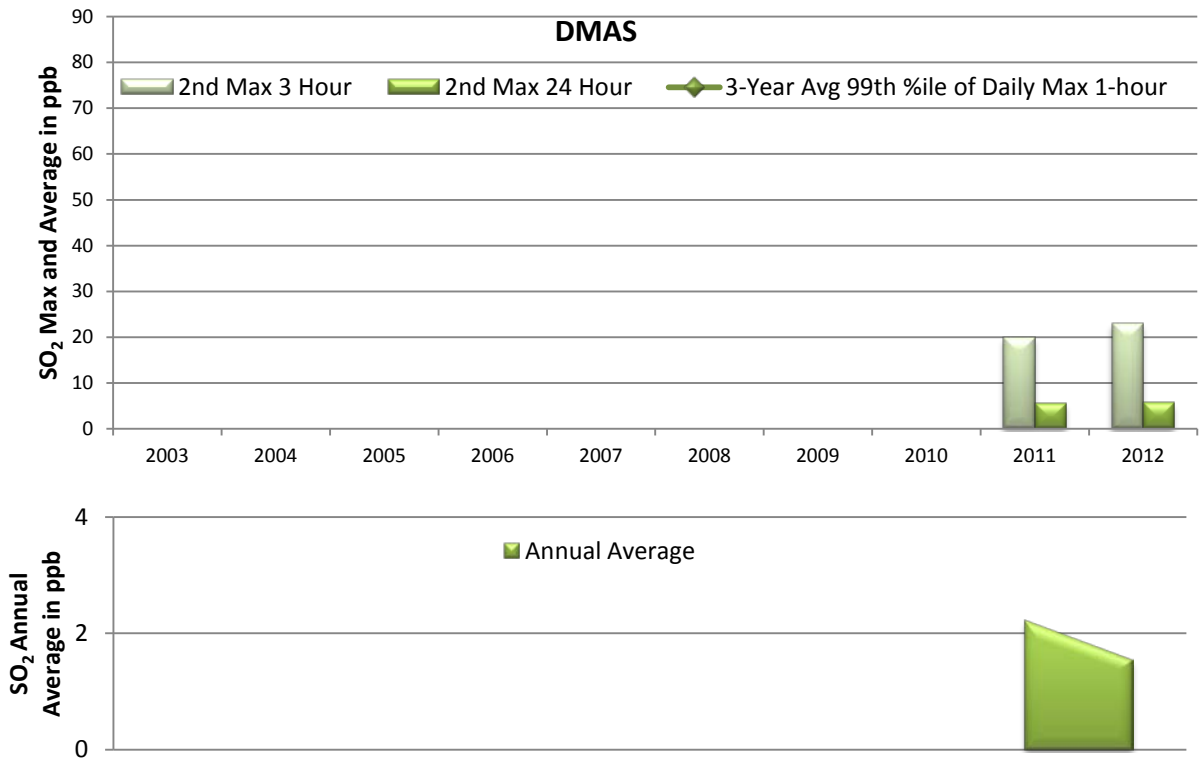


Figure 26. Sulfur Dioxide Maximums and Averages for Northern Front Range Counties

Table 32. Denver Visibility Standard Exceedance Days (Transmissometer Data)

Month	Days	EX POOR	POOR	FAIR	GOOD	Missing	(>70% RH)
January	31			16	12		3
February	29	3	5	9	7		5
March	31		3	17	10		1
April	30		2	8	14	5	1
May	31		4	16	8	1	2
June	30		5	18	7		
July	31	1	6	15	8		1
August	31		5	15	1	10	
September	30					30	
October	31					31	
November	30					30	
December	31					31	
Totals							
	366	4	30	114	67	138	13

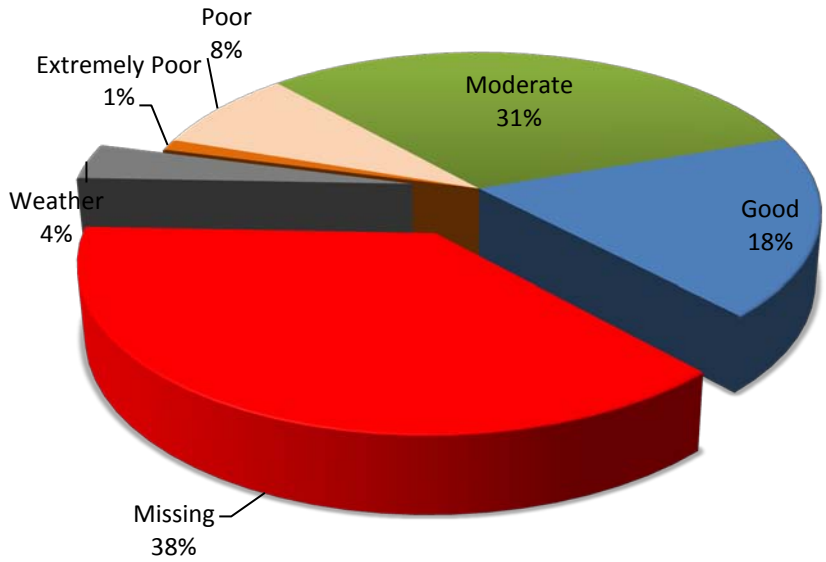


Figure 27. Denver Visibility Data

In Figure 28 and 29, days above the standard are shown as positive numbers and days below the standard are shown as negative numbers. In addition, error bars in the positive direction indicate the number of days where data is missing, and error bars in the negative direction indicate the number of days with data excluded for weather (only tracked at Ft. Collins since 2009).

In mid-August of 2012 construction along the Transmissometer path used a crane that would occasionally block the light source. Because of the erratic timing of the interruption, data were invalidated for the remainder of the year.

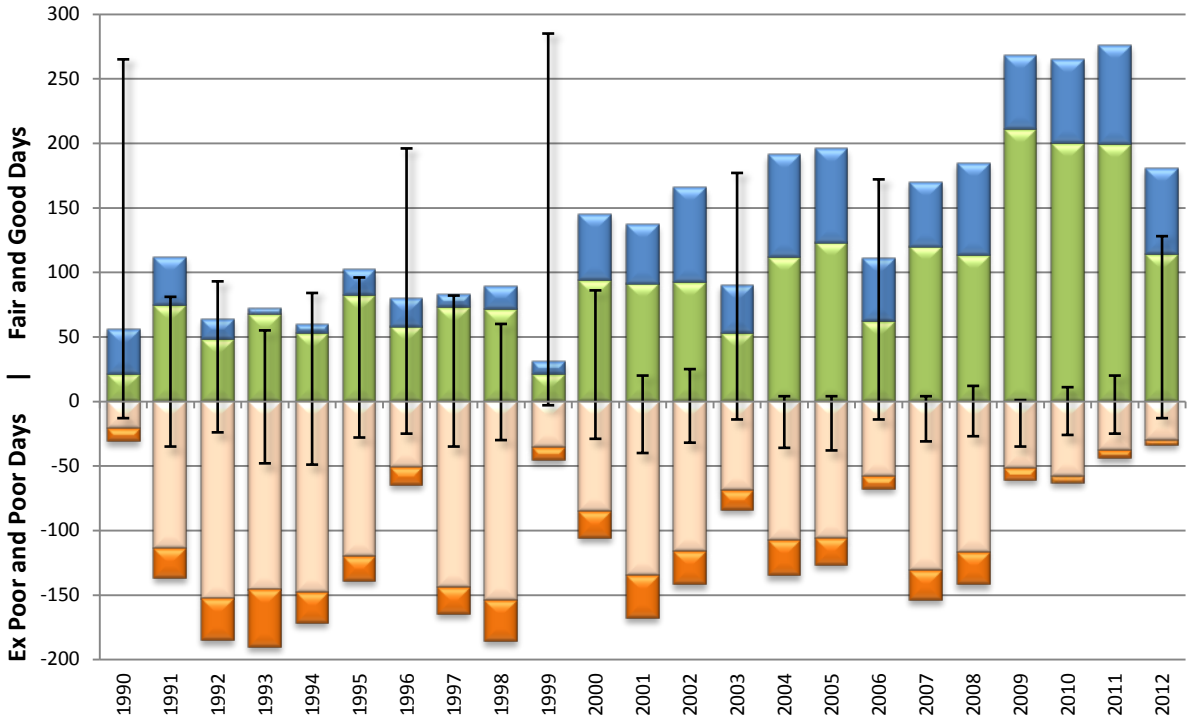


Figure 28. Annual Comparison of Visibility Data in Denver Between 1990 and 2012

Table 33. Fort Collins Visibility Standard Exceedance Days (Transmissometer Data)

Month	Days	EX POOR	POOR	FAIR	GOOD	EX GOOD	Missing	(>70% RH)
January	31		9	3	17		1	1
February	29		4	9	10		2	4
March	31		10	3	16		2	
April	30		5	3	20		2	
May	31		18	4	3	1	5	
June	30		9	2	5		14	
July	31		12	4	9	1	5	
August	31		10	1	1	3	16	
September	30		2	4		2	22	
October	31		12	5	2		12	
November	30		13	3	3	1	10	
December	31		12	3	4		11	1
Totals								
	366	0	116	44	90	8	102	6

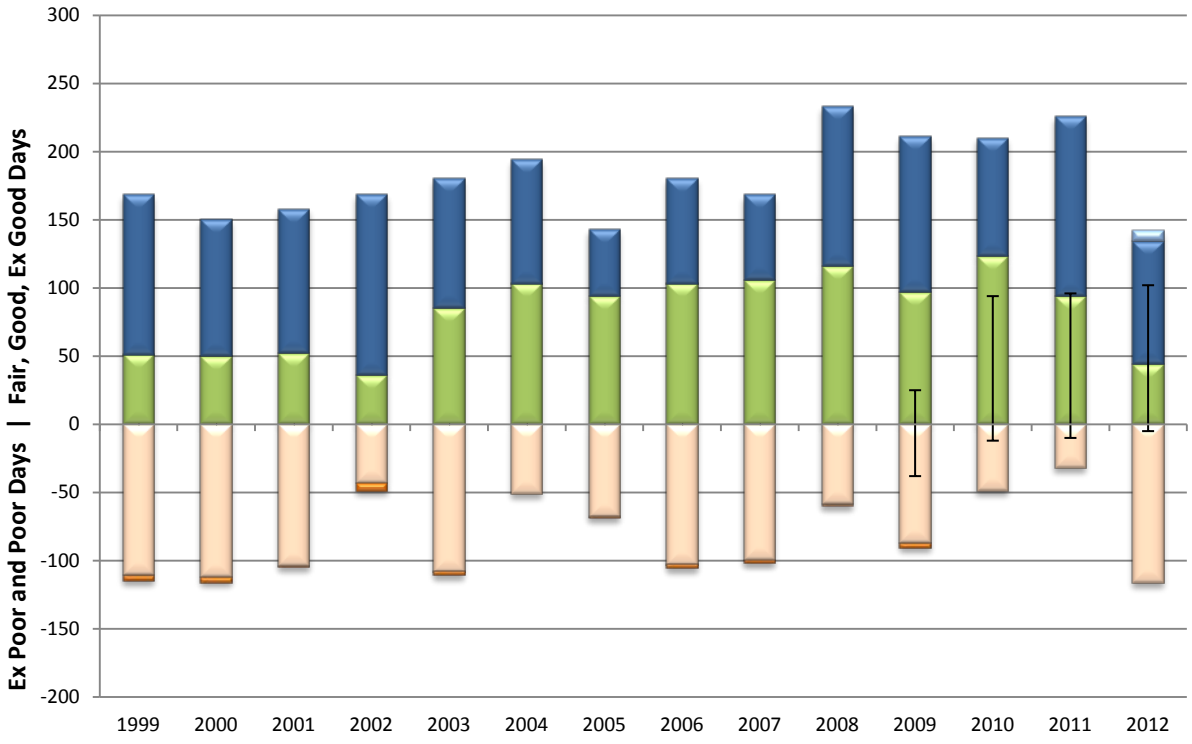


Figure 29. Annual Comparison of Visibility Data in Ft. Collins between 1999 and 2012

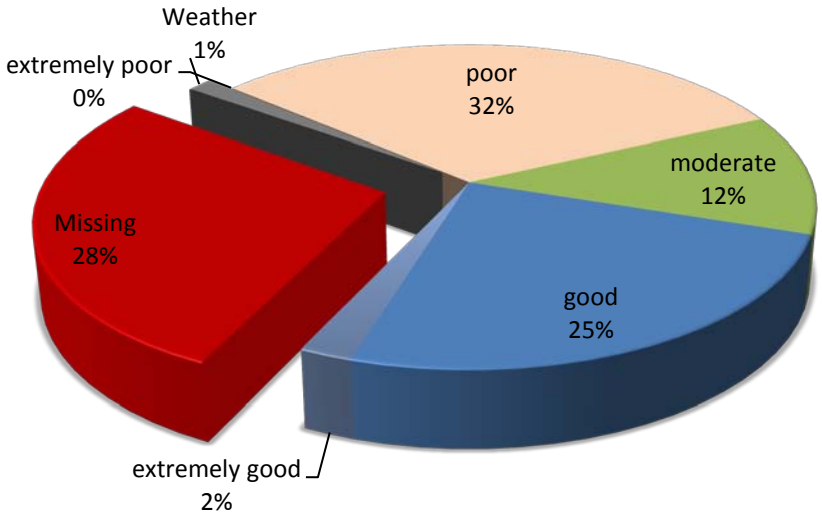
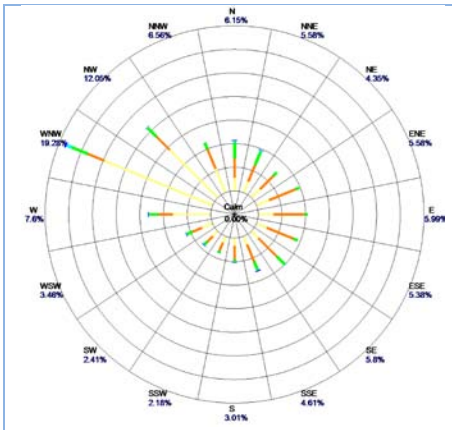


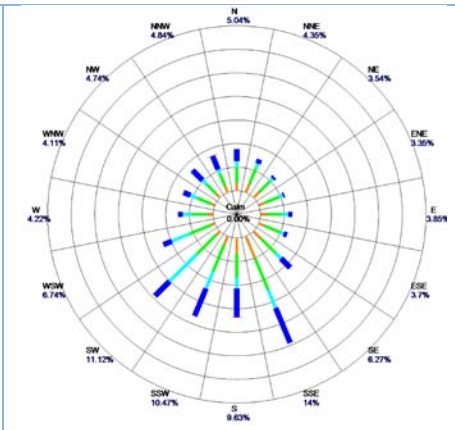
Figure 30. Ft. Collins Visibility Data

Figure 29 shows that since 1999, Fort Collins has averaged 90 days per year where the visibility was either “Fair” or “Good” and only 42 days where the visibility was either “Poor” or “Ex Poor.” The missing days are lost due to either high relative humidity (greater than 70 percent) or machine maintenance.

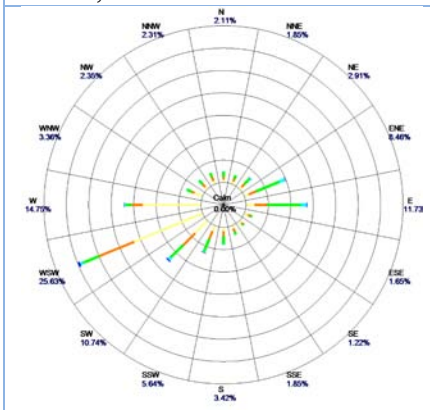
Figure 31. Northern Front Range Wind Roses (Pages 53-55)



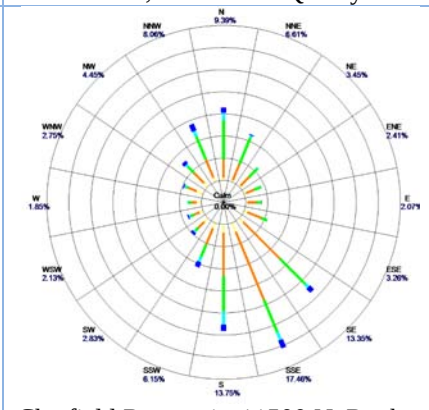
Arvada, 9101 W. 57th Ave.



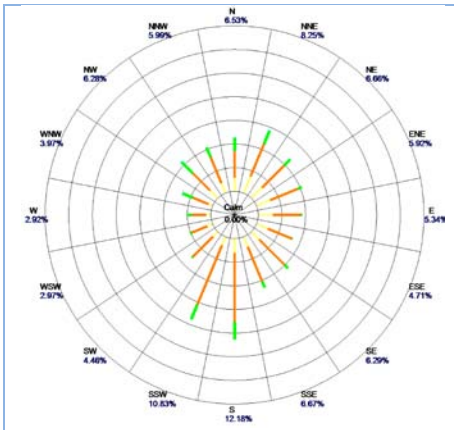
Aurora East, 36001 East Quincy Ave.



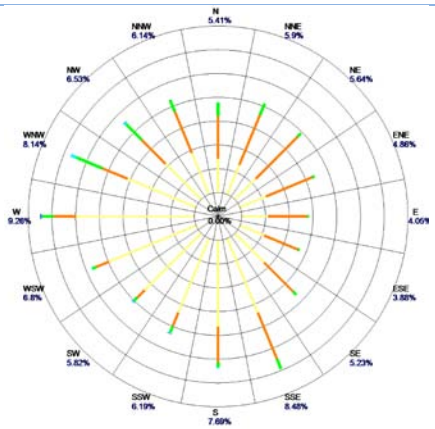
Aspen Park, 26137 Conifer Rd.



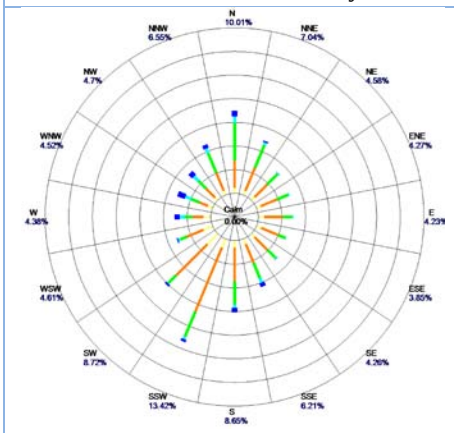
Chatfield Reservoir, 11500 N. Roxborough Pk. Rd.



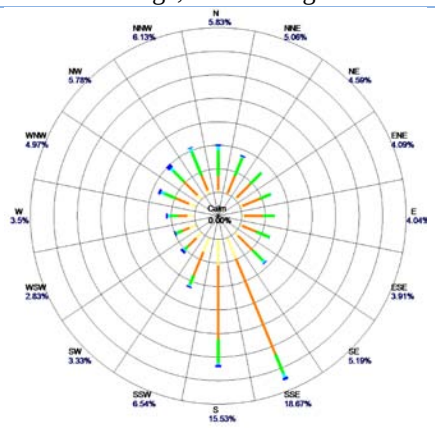
Denver CAMP, 2105 Broadway



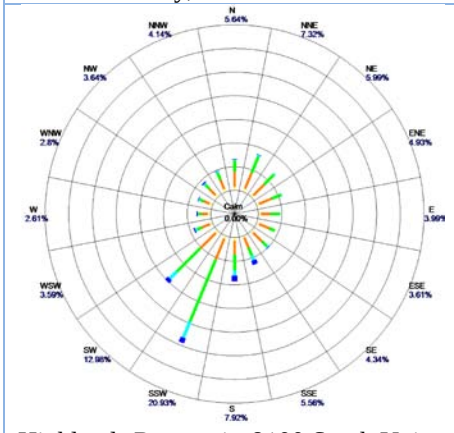
Denver Carriage, 2325 Irving St.



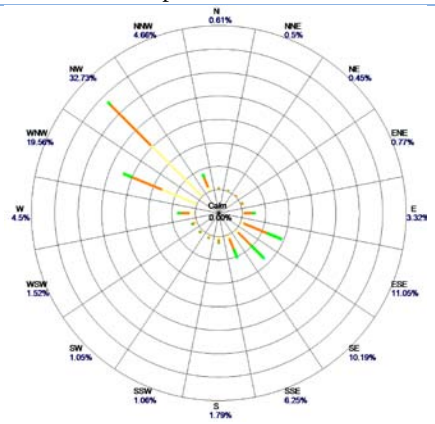
Commerce City, 7101 Birch St.



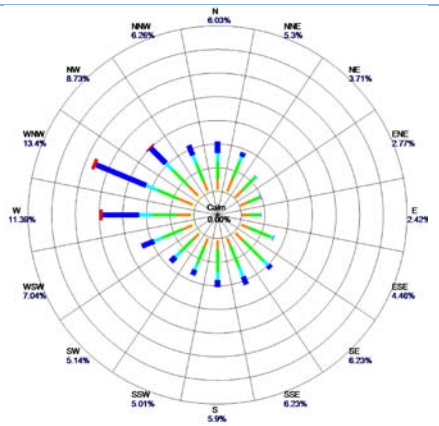
Denver Municipal Animal Shelter, 678 S. Jason St.



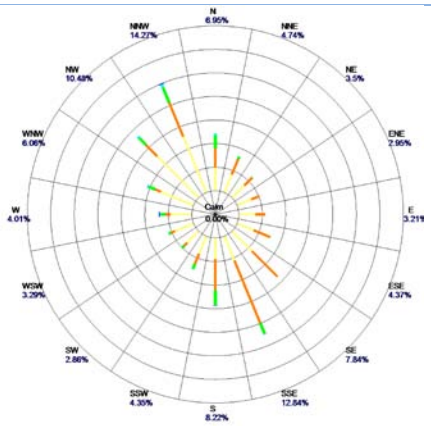
Highlands Reservoir, 8100 South University Blvd.



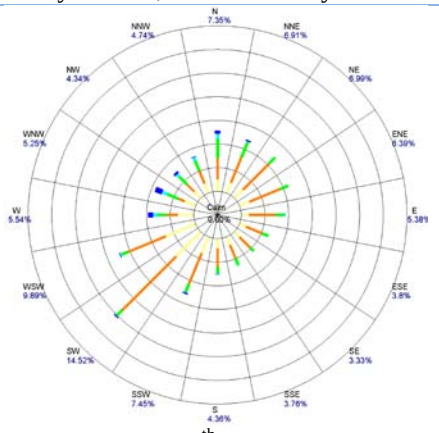
Rist Canyon and 708 S. Mason St.



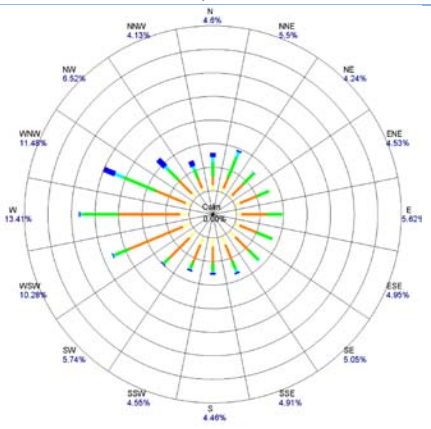
Rocky Flats-N, 16600 W. Hwy. 128



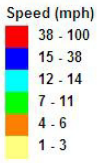
Fort Collins – CSU, 251 Edison Dr.



Welby, 3174 E. 78th Ave.



Welch, 12400 W. Hwy. 285



4.3. Pikes Peak

Data below may include exceptional events. See Section 2.2.5.1.

Table 34. Pikes Peak Particulate Values

Site Name	Location	PM_{10} (µg/m^3)			$PM_{2.5}$ (µg/m^3)	
		Annual Avg.	24-hour Max	3-Year Avg. Exceedance	3-Year Weighted Avg.	3-Year Average of 98th %ile
El Paso						
Colorado Springs	130 W. Cache la Poudre	25.5	64	0	6.3	15.6

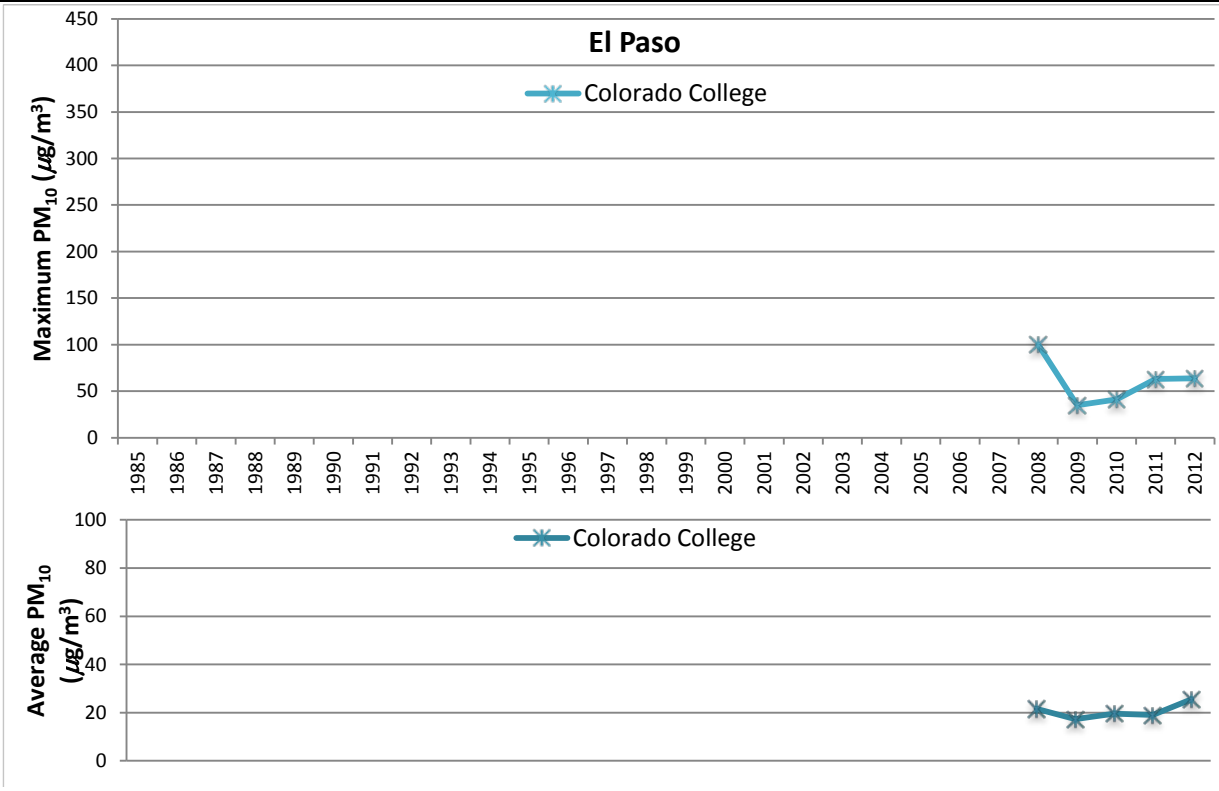


Figure 32. Average and Maximum PM10 Concentrations for Pikes Peak

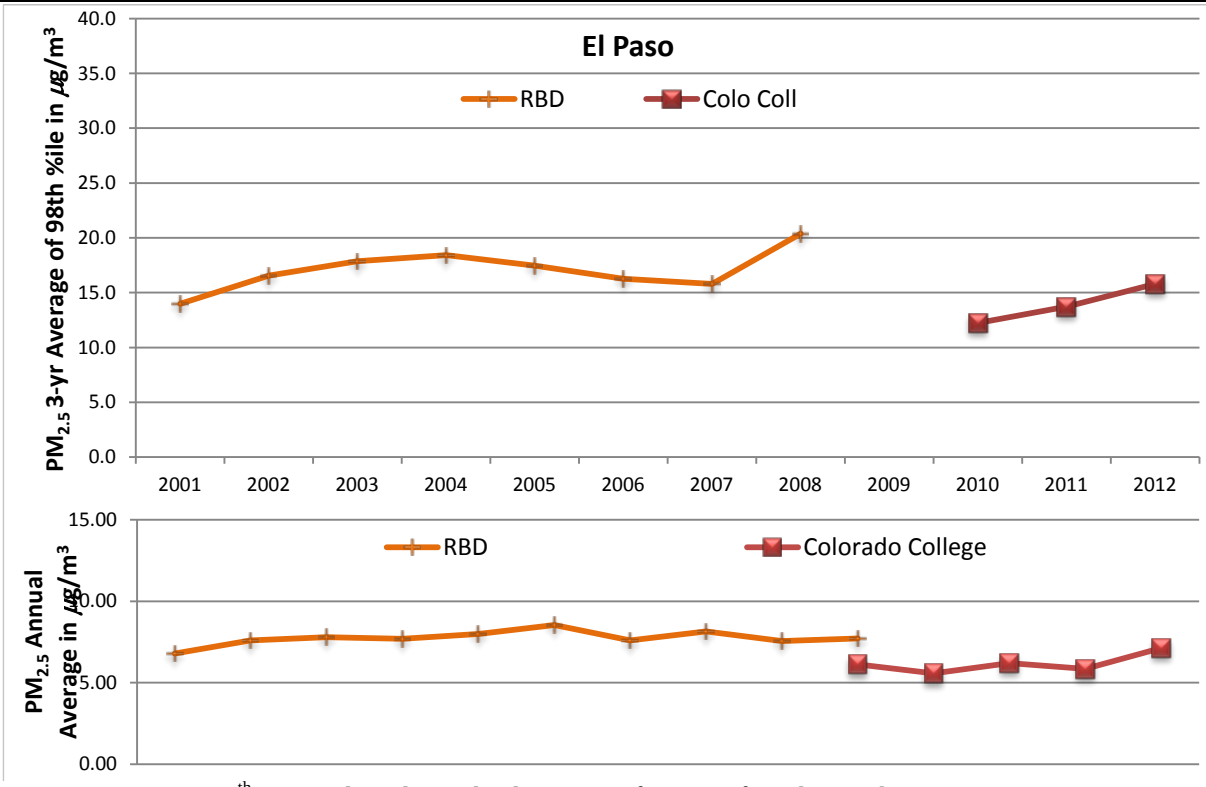


Figure 33. 3-Year 98th Percentile and Weighted Averages for $PM_{2.5}$ for Pikes Peak

Table 35. Southern Front Range Carbon Monoxide Values

Site Name	Location	CO 1-hour Avg. (ppm)		CO 8-hour Avg. (ppm)	
		1st Maximum	2nd Maximum	1st Maximum	2nd Maximum
El Paso					
Colorado Springs	690 W. Hwy 24	2.7	2.7	2.0	1.4

Table 36. Southern Front Range Ozone Values

Site Name	Location	Ozone 8-hour Avg. (ppm)		
		1st Maximum	4th Maximum	3-year Average of 4th Maximum
El Paso				
USAFA	USAFA Rd 640	0.078	0.075	0.072
Manitou Springs	101 Banks Pl.	0.079	0.075	0.074

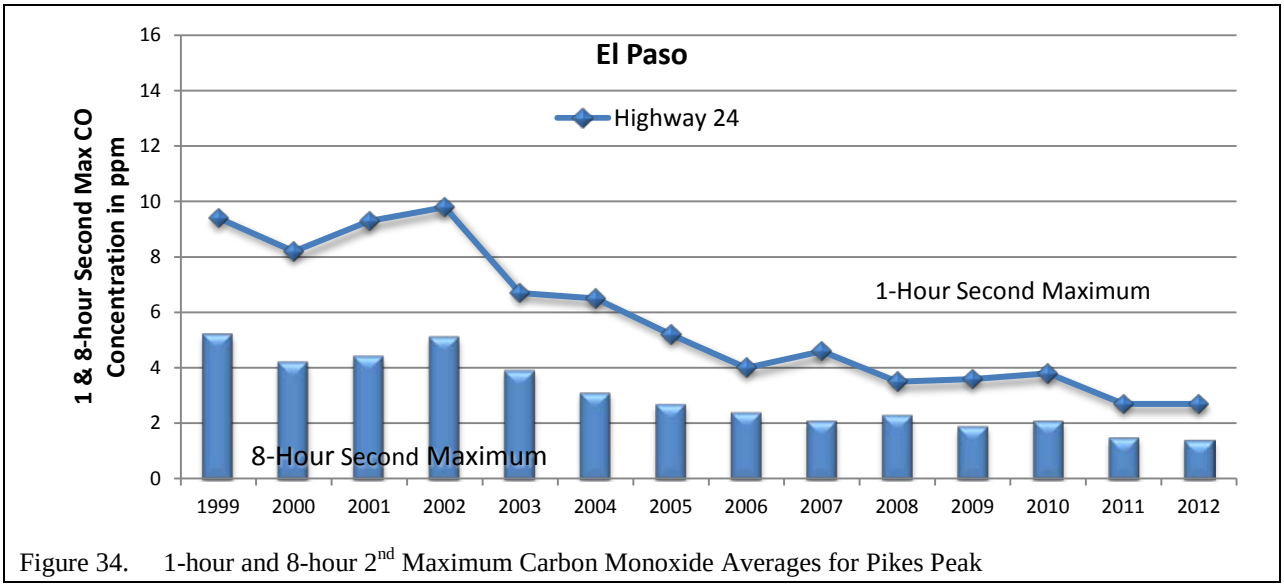


Figure 34. 1-hour and 8-hour 2nd Maximum Carbon Monoxide Averages for Pikes Peak

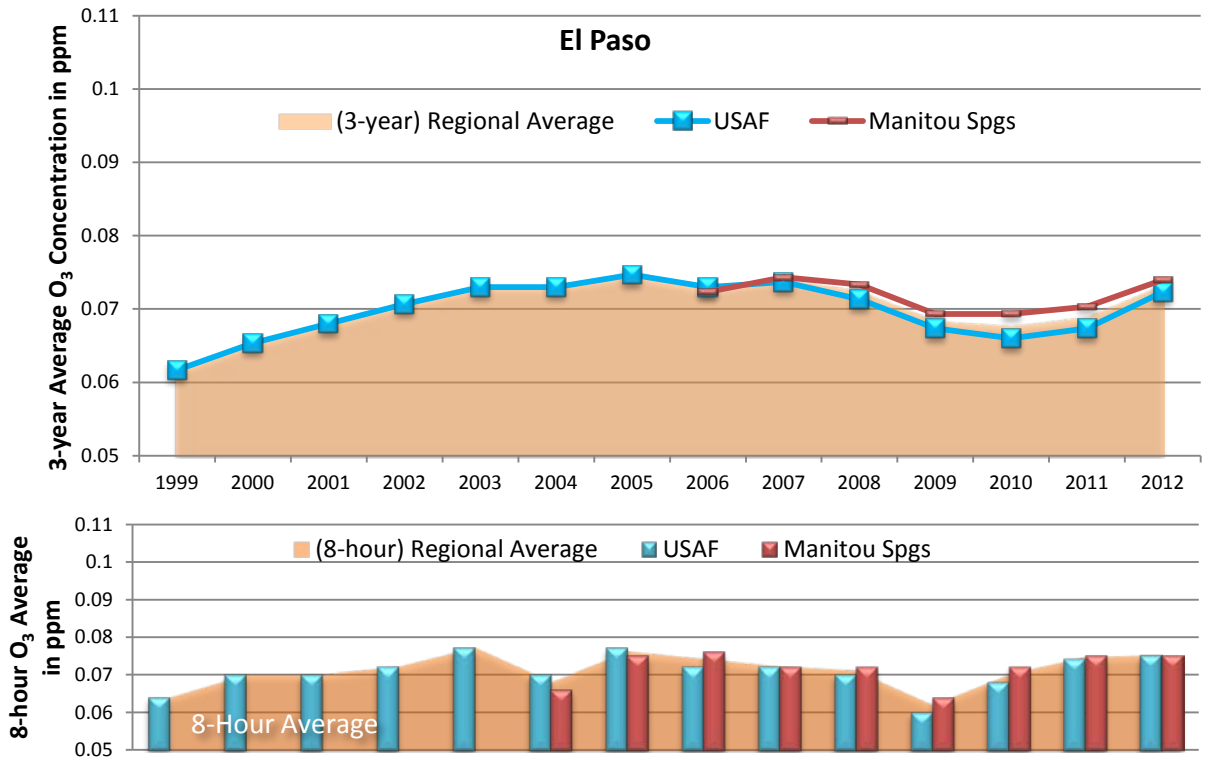


Figure 35. 3-year 4th Maximum Average and 8-hour 4th Maximum Ozone Concentrations for Pikes Peak

4.4. Central Mountains

The data below may include exceptional events. See Section 2.2.5.1.

Table 37. Mountain Counties Particulate Values

Site Name	Location	PM_{10} (µg/m^3)		
		Annual Avg.	24-Hr Max	3-Year Avg. Exceedances
Fremont				
Canyon City	128 Main St.	19.8	61	0
Gunnison				
Crested Butte	603 6th St.	20.4	50	0
Mt. Crested Butte	19 Emmons Loop	14.9	171	0.7
Pitkin				
Aspen	120 Mill St.	16.4	87	0
Routt				
Steamboat Springs	136 6th St.	19.8	124	0
Summit				
Breckenridge	501 N. Park Ave.	16.9	82	0

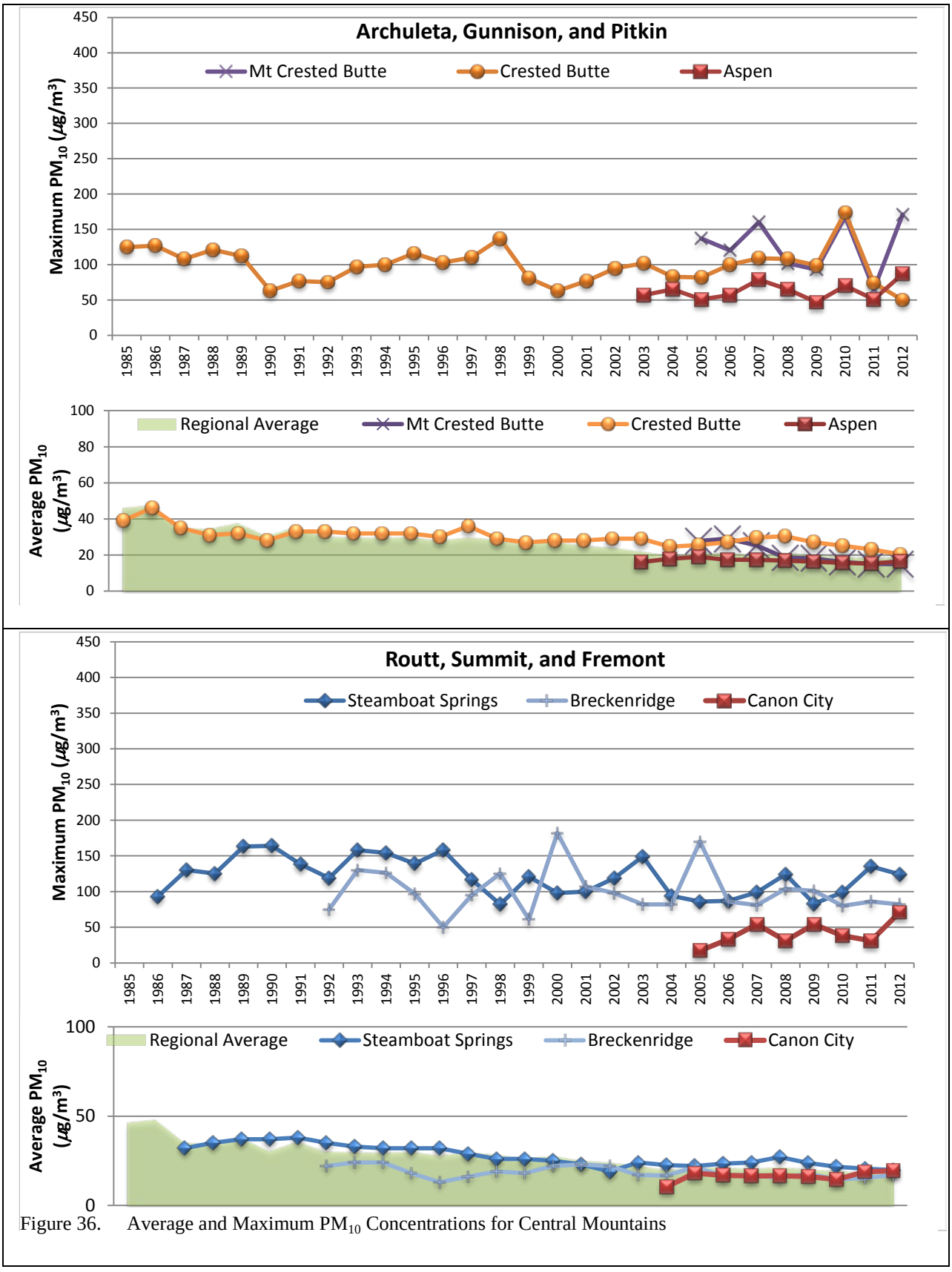


Figure 36. Average and Maximum PM_{10} Concentrations for Central Mountains

4.5. San Luis Valley

The data below may include exceptional events. See Section 2.2.5.1.

Table 38. Mountain Counties Particulate Values

Site Name	Location	PM_{10} ($\mu g/m^3$)		
		Annual Avg.	24-Hr Max	3-Year Avg. Exceedances
Alamosa				
ASC	208 Edgemont Blvd.	26.9	389	2.8
Alamosa Municipal	425 4th St.	33.1	239	3.9

The San Luis Valley is somewhat unique in Colorado in that there isn't a predominant wind direction. While a majority of the winds in the area come from the south they are generally calmer, and dispersed between all southerly directions. Synoptic dust transportation may come from northwestern New Mexico or northeastern Arizona. Local particulate matter comes from farming activity and arid land. The Alamosa Municipal station has had an average of 4 exceedances per year over the last 3 years (3, 4, and 5 exceedances for 2010, 2010, and 2012 respectively), and the ASC site had an average of 5 exceedances (4, 5, and 6 respectively), which is in violation of the annual average primary standard. Not including exceptional events awaiting EPA concurrence, neither site is in violation of this standard (United States Environmental Protection Agency 2010).

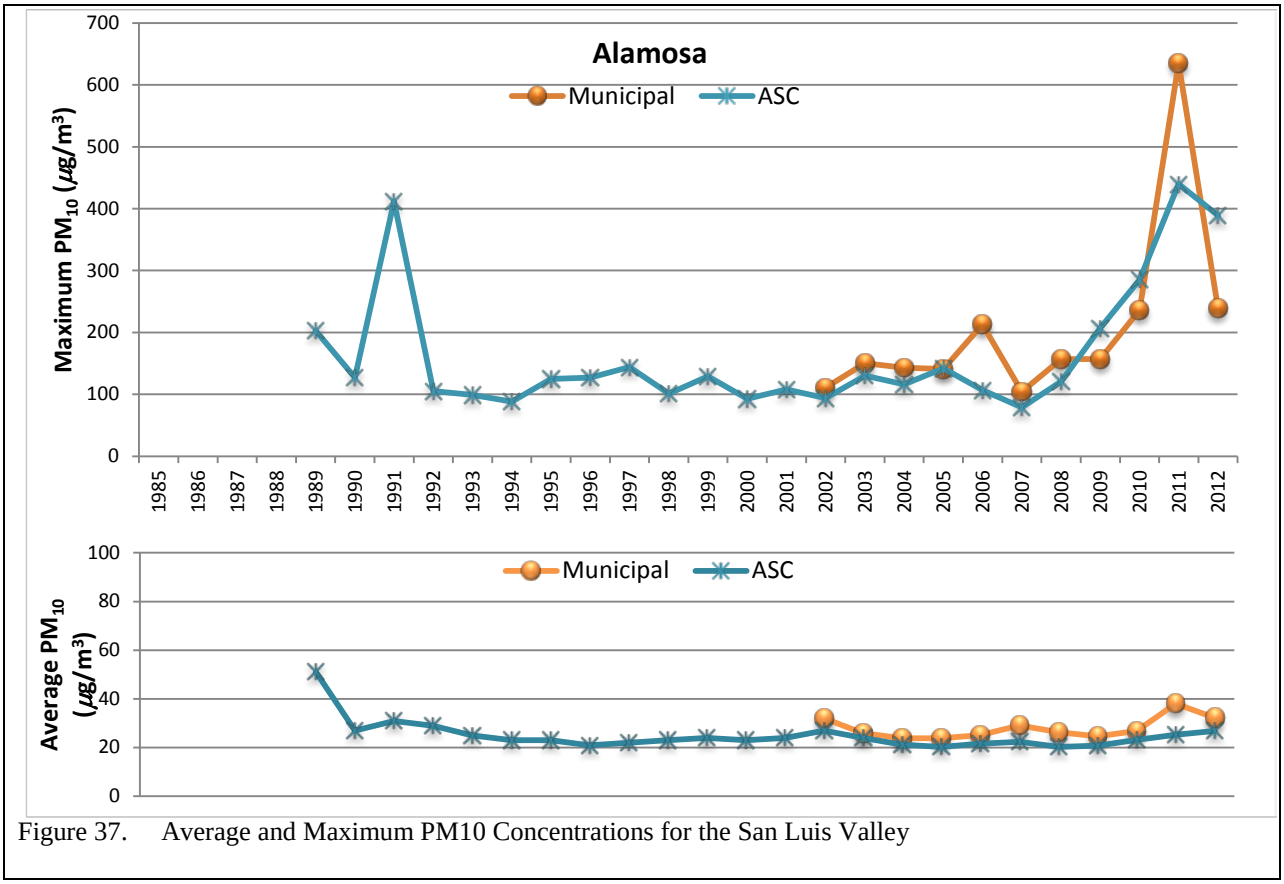


Figure 37. Average and Maximum PM10 Concentrations for the San Luis Valley

4.6. South Central

The data below may include exceptional events. See Section 2.2.5.1.

Table 39. South Central Particulate Values

Site Name	Location	PM_{10} (µg/m^3)			$PM_{2.5}$ (µg/m^3)	
		Annual Avg.	24-hour Max	3-Year Avg. Exceedance	3-Year Weighted Avg.	3-Year Average of 98th %ile
Pueblo						
Fountain Magnet School	925 N. Glendale Ave.	20.8	62	0	6.3	14.6

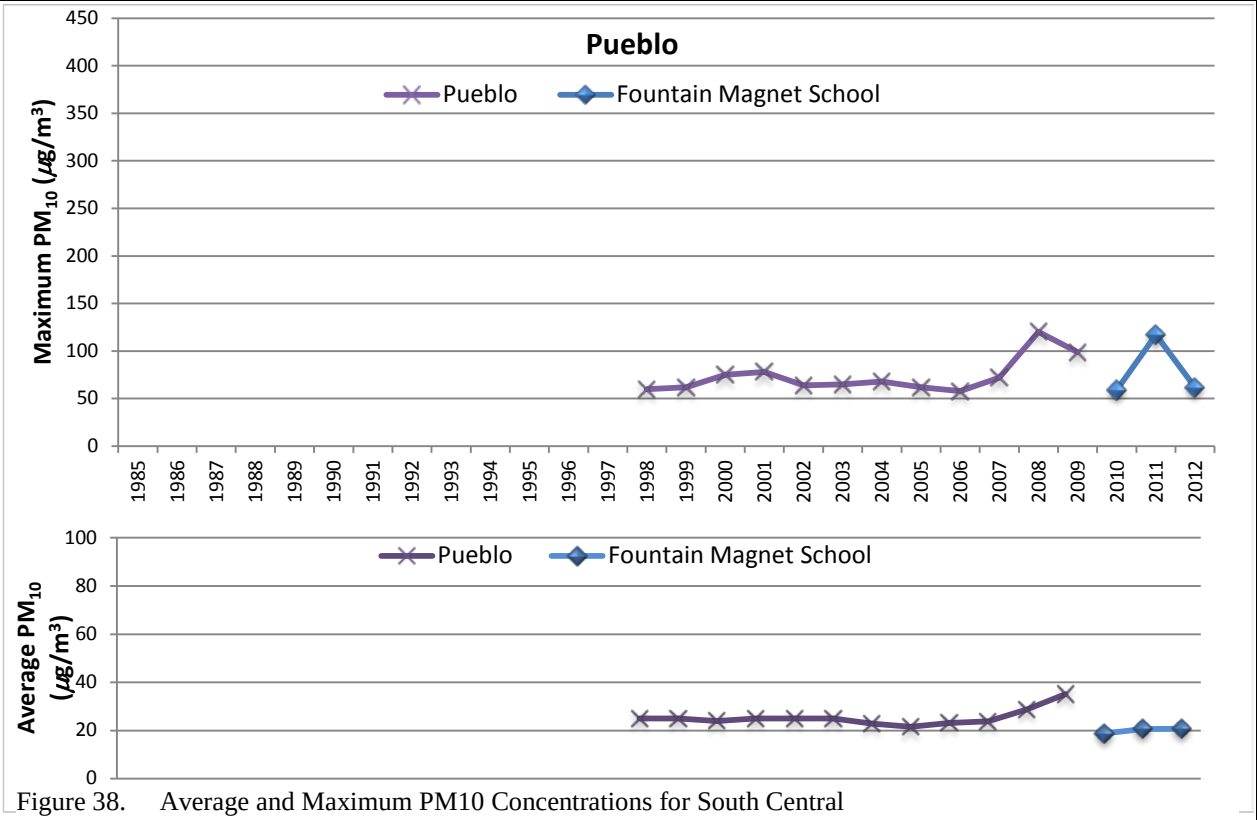


Figure 38. Average and Maximum PM10 Concentrations for South Central

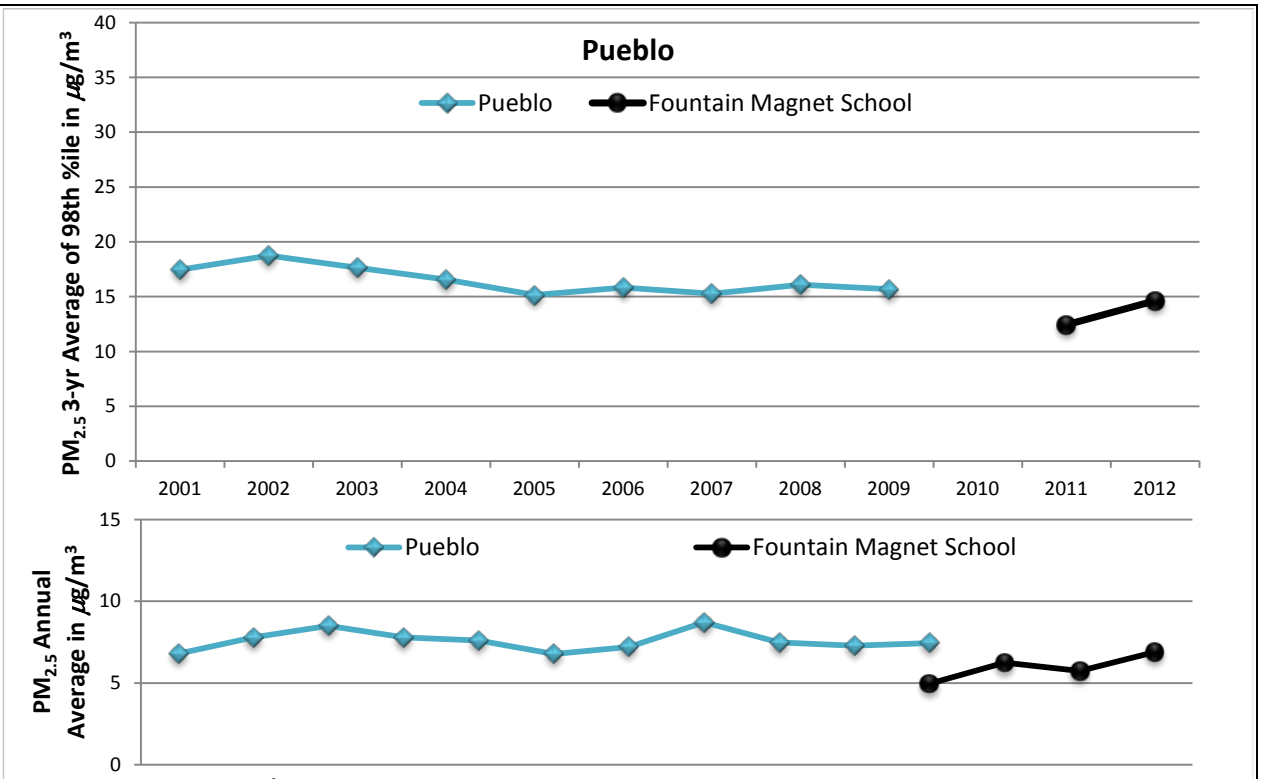


Figure 39. 3-Year 98th Percentile and Weighted Averages for $PM_{2.5}$ for South Central

4.7. Southwestern

The data below may include exceptional events. See Section 2.2.5.1.

Table 40. Southwestern Particulate Values

Site Name	Location	PM_{10} (µg/m^3)			$PM_{2.5}$ (µg/m^3)	
		Annual Avg.	24-hour Max	3-Year Avg. Exceedance	3-Year Weighted Avg.	3-Year Average of 98th %ile
Pueblo						
Pagosa Springs	309 Lewis St.	23.1	147	0		
Durango	1235 Camino del Rio	19.4	80	0		
Montezuma						
Cortez	106 W. North St.				5.9	13.5

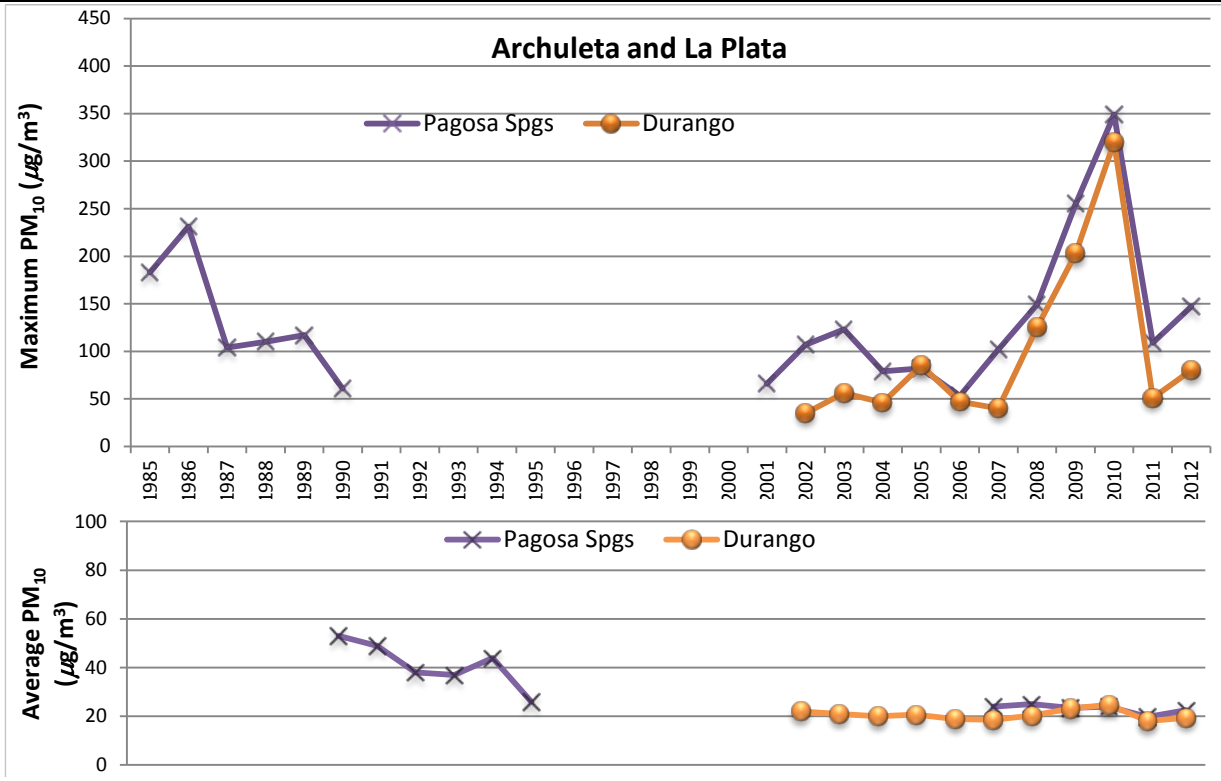


Figure 40. Average and Maximum PM_{10} Concentrations for Southwestern

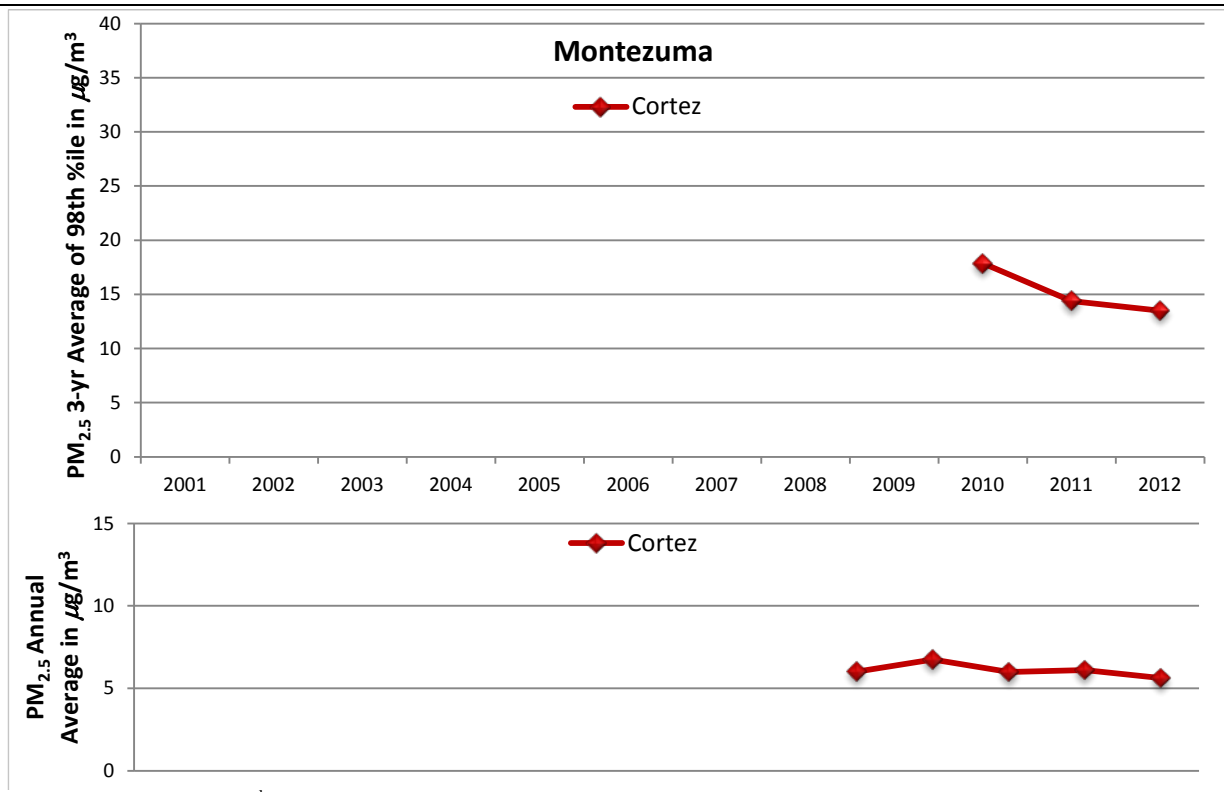


Figure 41. 3-Year 98th Percentile and Weighted Averages for $PM_{2.5}$ for Southwestern

Table 41. Southwestern Ozone Values

Site Name	Location	Ozone 8-hour Avg. (ppm)		
		1st Maximum	4th Maximum	3-year Average of 4th Maximum
Montezuma				
Cortez	106 W. North Ave.	0.072	0.069	0.068

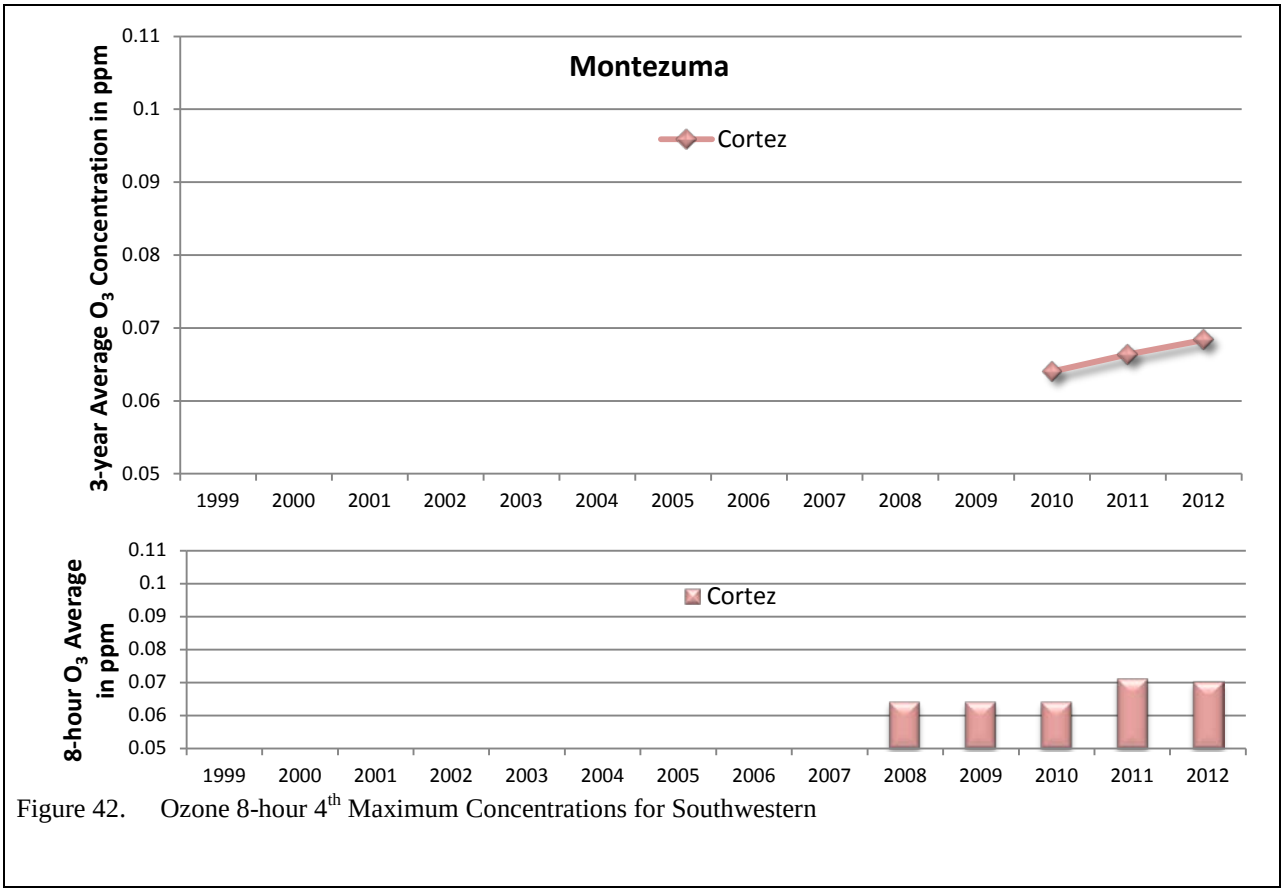


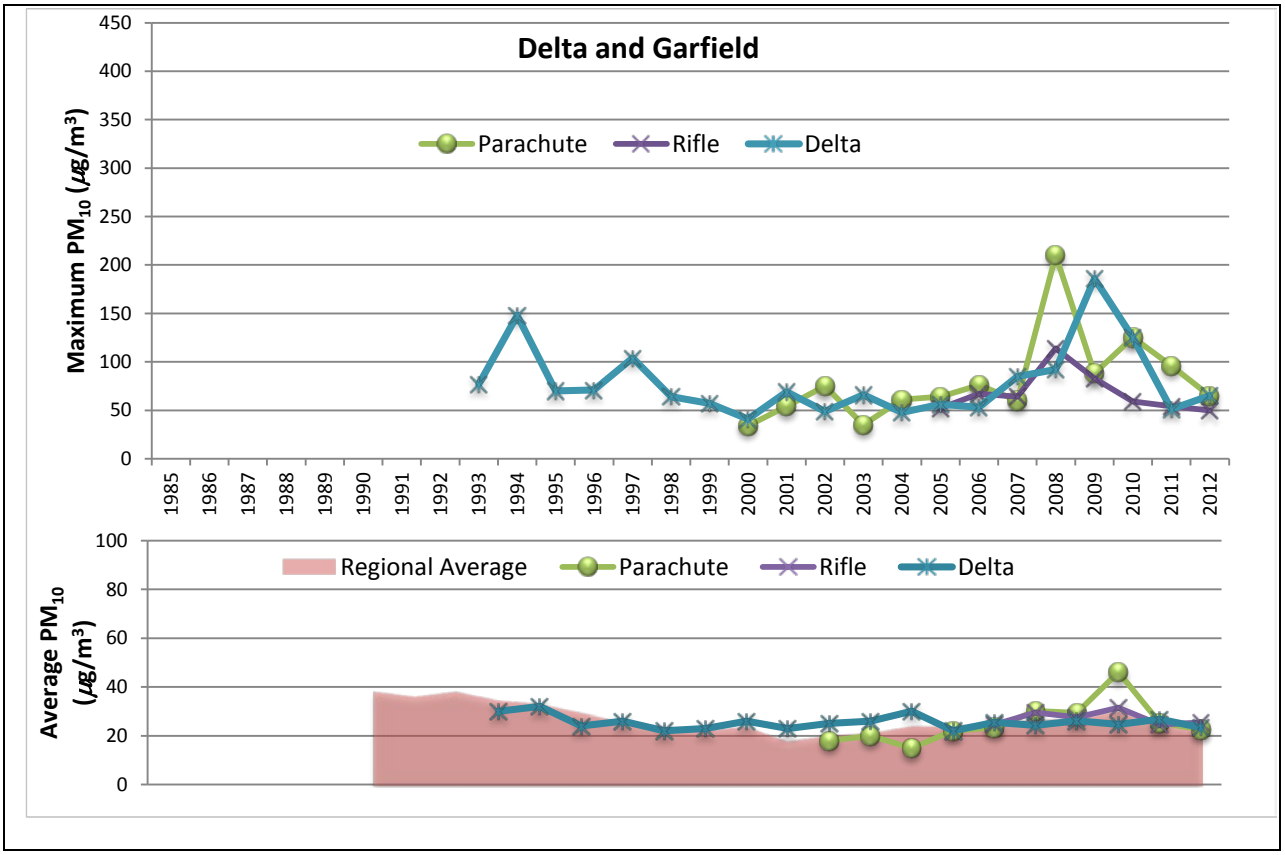
Figure 42. Ozone 8-hour 4th Maximum Concentrations for Southwestern

4.8. Western Slope

The data below may include exceptional events. See Section 2.2.5.1.

Table 42. Western Slope Particulate Values

Site Name	Location	PM_{10} (µg/m^3)			$PM_{2.5}$ (µg/m^3)	
		Annual Avg.	24-hour Max	3-Year Avg. Exceedances	3-Year Weighted Avg.	3-Year Average of 98th %ile
Delta						
Delta	560 Dodge St.	24.4	65	0		
Garfield						
Parachute	100 E. 2nd Ave.	18.7	65	0		
Rifle	144 E. 3rd St.	19.5	50	0		
Mesa						
Powell	650 South Ave.	22.7	176	0	7.8	27.9
Clifton	141 & D St.	19.5	74	0		
San Miguel						
Telluride	333 W. Colorado Ave.	16.9	80	0		



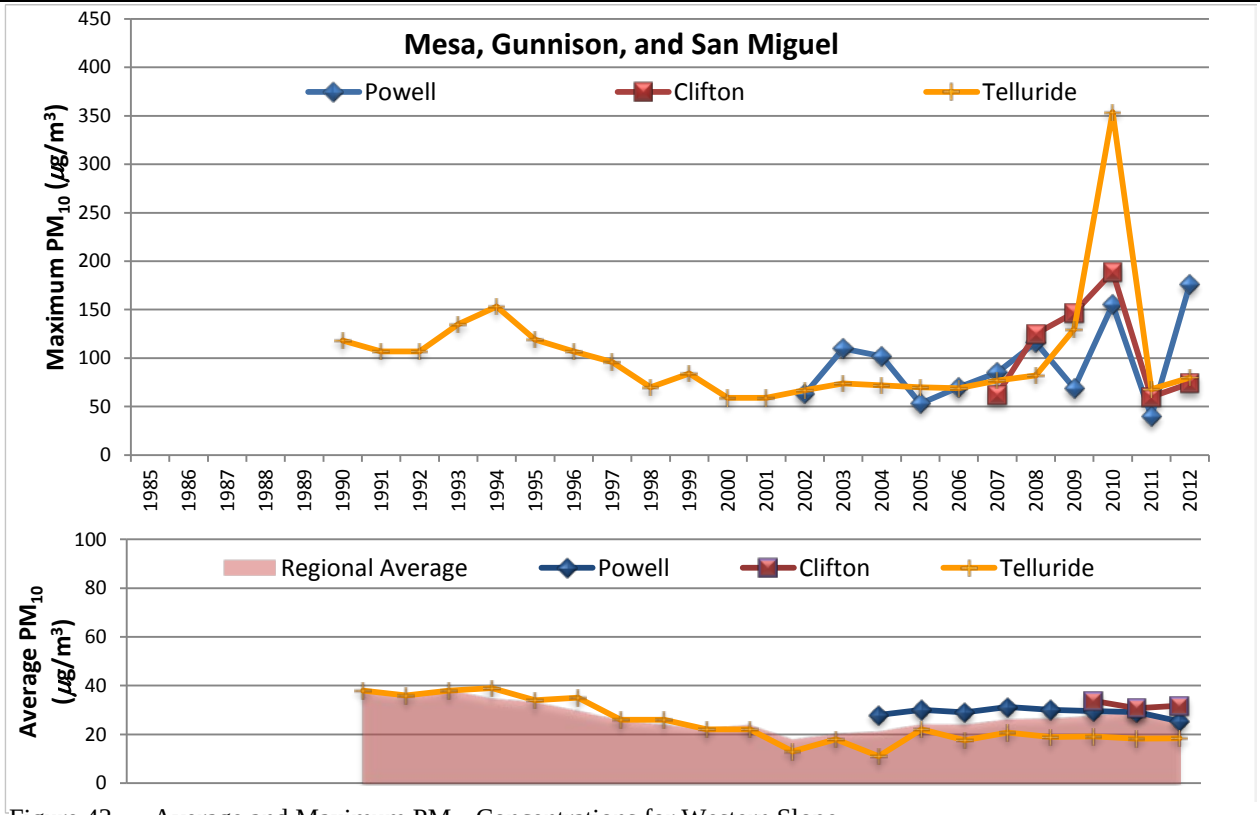


Figure 43. Average and Maximum PM_{10} Concentrations for Western Slope

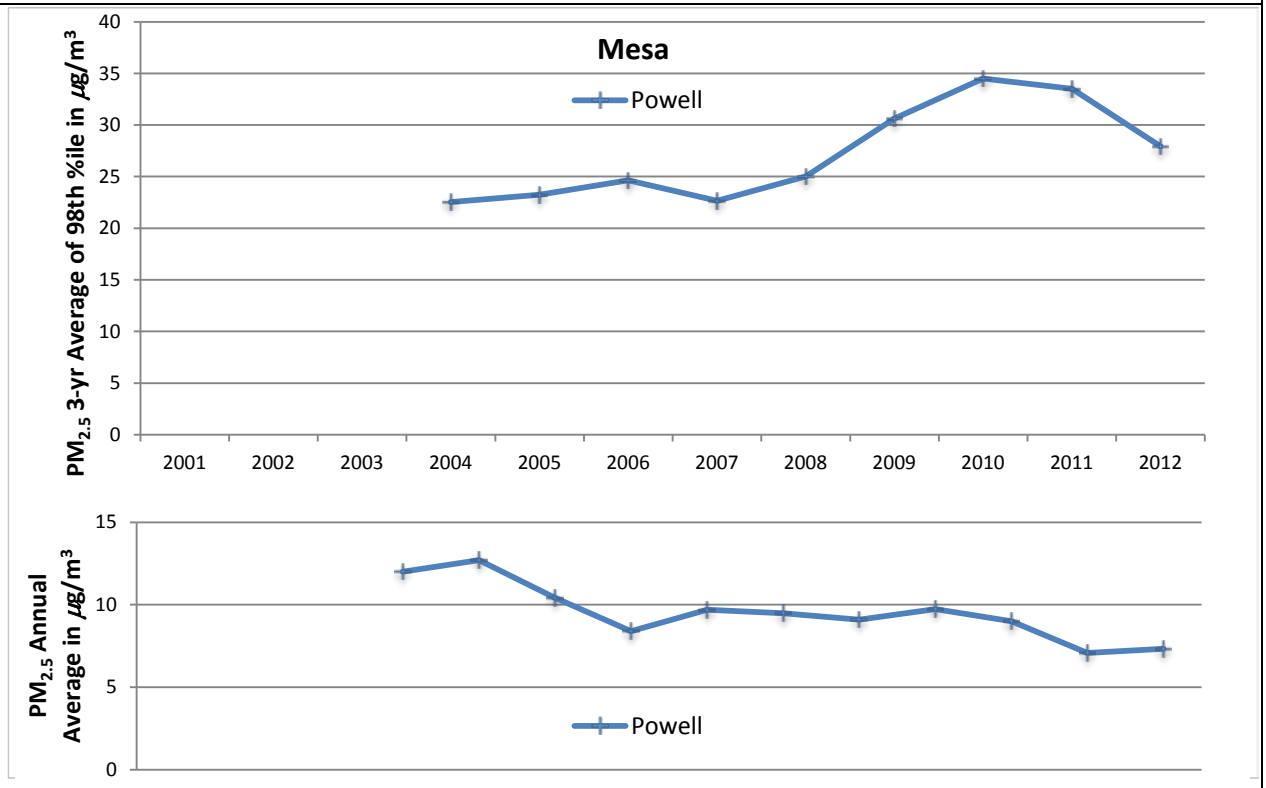


Figure 44. 3-Year 98th Percentile and Weighted Averages for $PM_{2.5}$ for Western Slope

Table 43. Western Slope Carbon Monoxide Values

Site Name	Location	CO 1-hour Avg. (ppm)		CO 8-hour Avg. (ppm)	
		1st Maximum	2nd Maximum	1st Maximum	2nd Maximum
Mesa					
Pitkin	645 ½ Pitkin Ave.	2.0	1.6	1.1	1.0

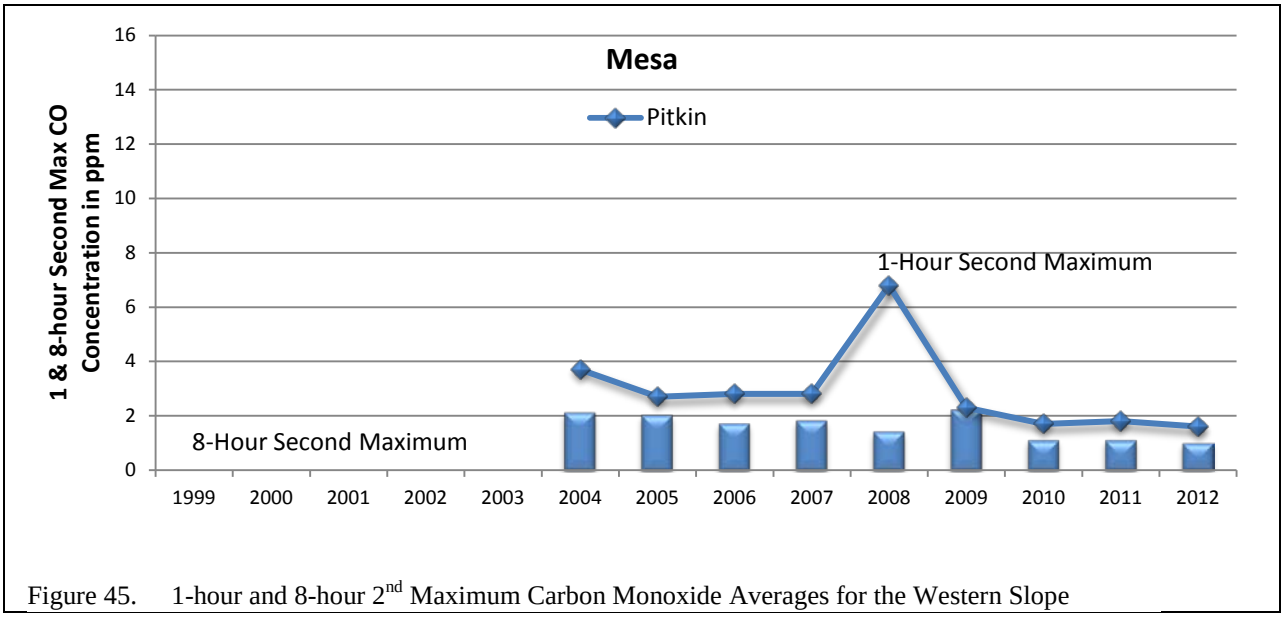


Figure 45. 1-hour and 8-hour 2nd Maximum Carbon Monoxide Averages for the Western Slope

Table 44. Western Slope Ozone Values

Site Name	Location	Ozone 8-hour Avg. (ppm)		
		1st Maximum	4th Maximum	3-year Average of 4th Maximum
Garfield				
Rifle	195 W. 14th St.	0.078	0.068	0.066
Mesa				
Palisade Water Treatment Plant	865 Rapid Creek Dr.	0.075	0.072	0.068
Moffat				
Lay Peak	17820 CR 17	0.072	0.066	<3 years data

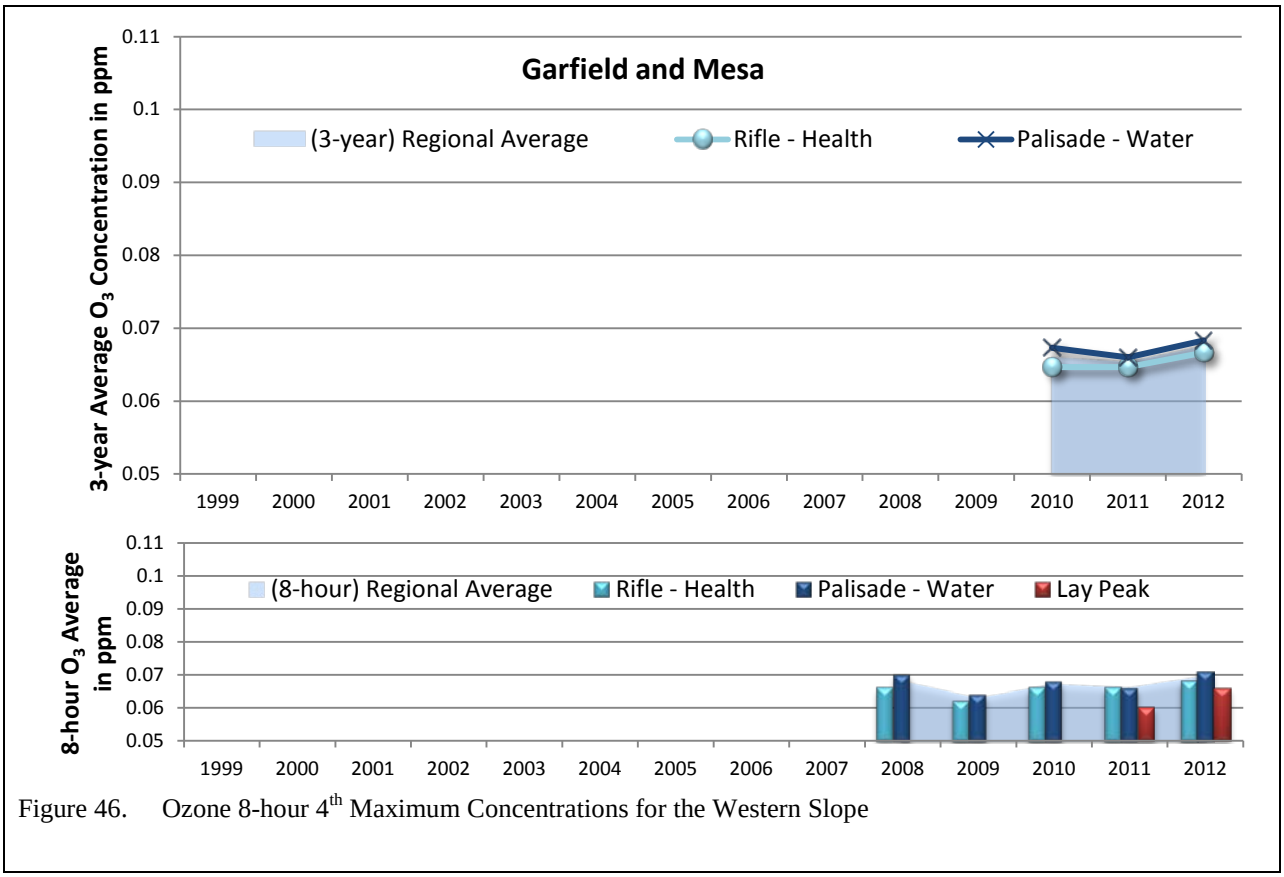
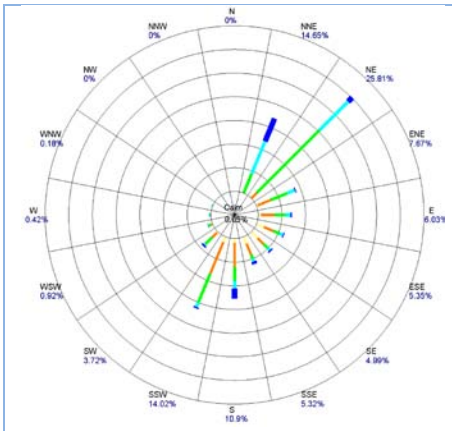
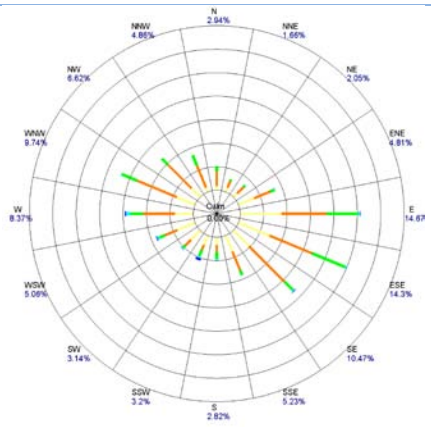


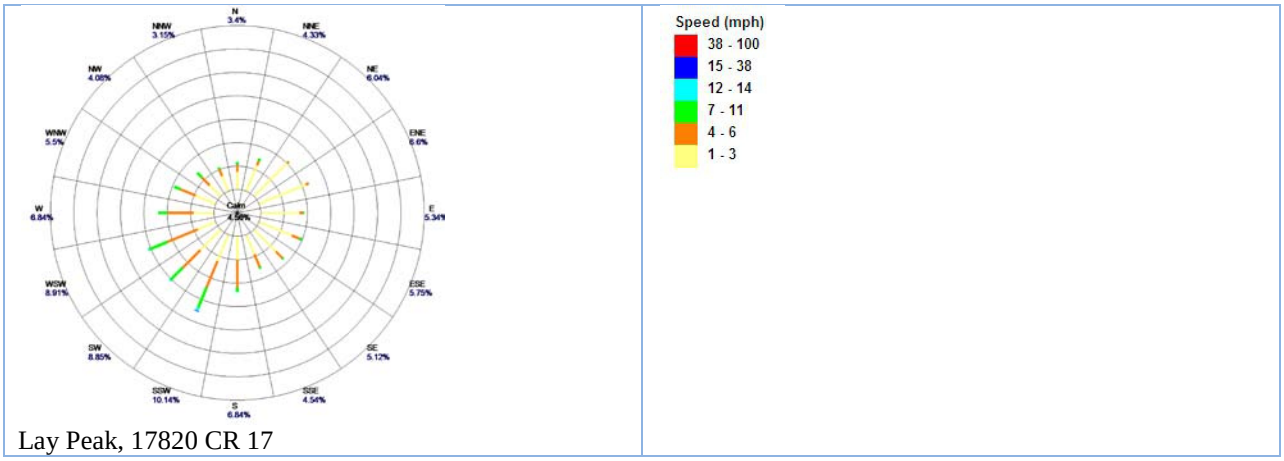
Figure 46. Ozone 8-hour 4th Maximum Concentrations for the Western Slope



Palisade Water Treatment Plant



Pitkin, 645¼ Pitkin Ave



Lay Peak, 17820 CR 17

Figure 47. Western Slope Wind Roses

5. RESULTS THROUGH THE YEAR

In the previous sections, summary data has been presented to give an overall picture of the progress of air quality through the years and to compare measured concentrations against NAAQS, in Sections 2 and 4 respectively. However, the APCD collects data on hourly averages (which are themselves the result of even more brief intervals being averaged together) for select criteria pollutants at each site. In this section, monthly averages will be presented for each site, and compared against the state-wide range of averages.

In some sense, there is little interpretation to be done concerning the air quality information presented in this section. It is not intended to compare Colorado's air quality against the standards, other states, or past air quality. This section is only to suggest a more detailed picture of the air quality in our state throughout the year.

In all of the graphs in this section, the minimum and maximum average ranges are illustrated as blue shading in the background. This is the range for the entire state. The sites are not grouped in a geographic fashion, rather they are presented in order of their Air Quality Site ID, which is an EPA designated code derived from the state and county where the site is located, along with a unique site number. Each graph has been limited in the number of sites it presents for clarity sake, but for each pollutant set, the minimum and maximum state-wide range is the same. Data in the graphs below may include exceptional events, see Section 2.2.5.1.

5.1. Carbon Monoxide

CO can generally be considered an indicator of overall air quality. High CO concentrations indicate poor air quality, and low concentrations mean generally good air quality (except for O_3). CO is normally higher in the winter months and lower in the summer, for reasons discussed in Section 2. This notion of low summer concentrations and higher winter concentrations holds true throughout Colorado. Figure 48 shows the monthly average concentrations for CO across the state.

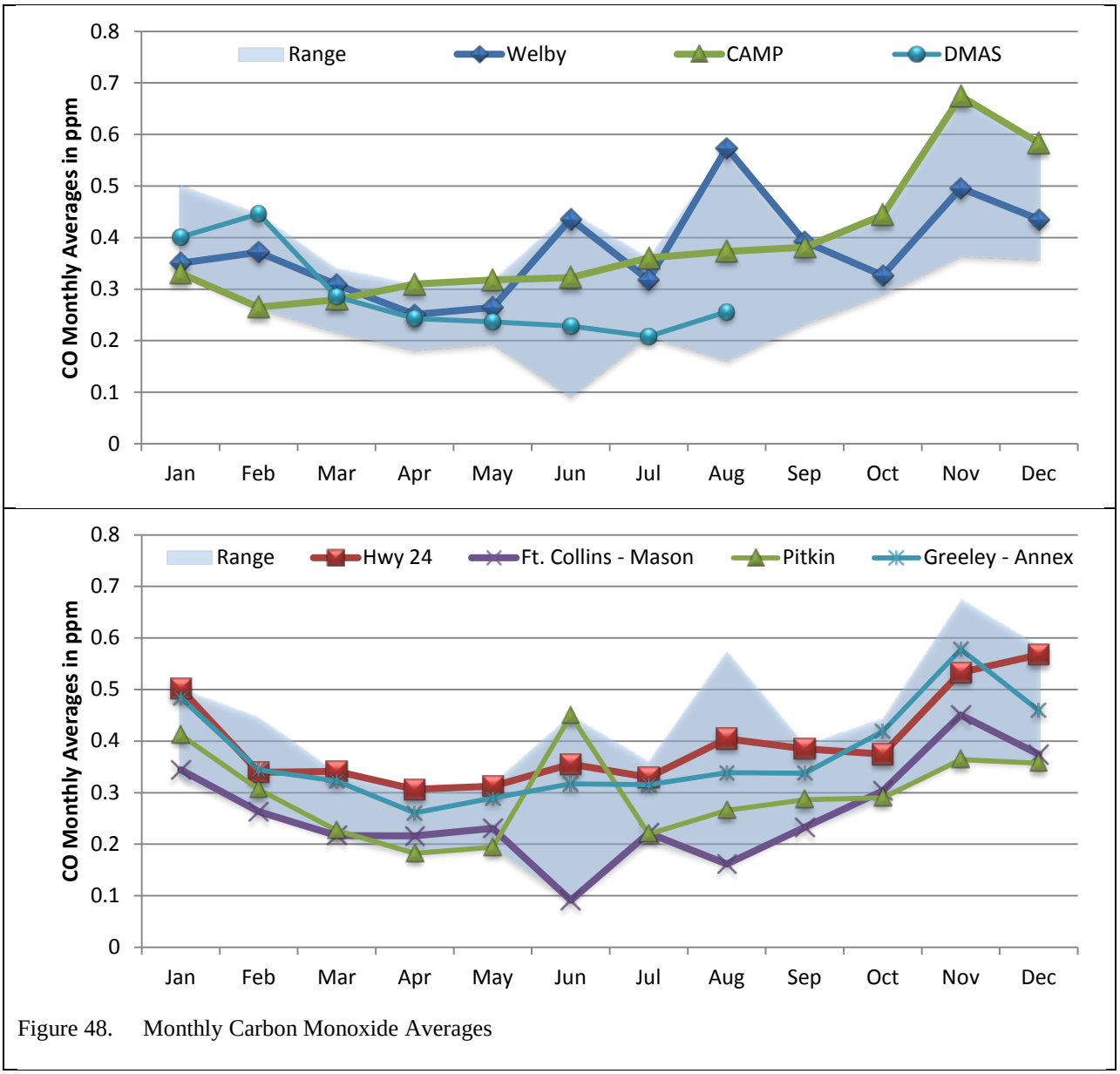


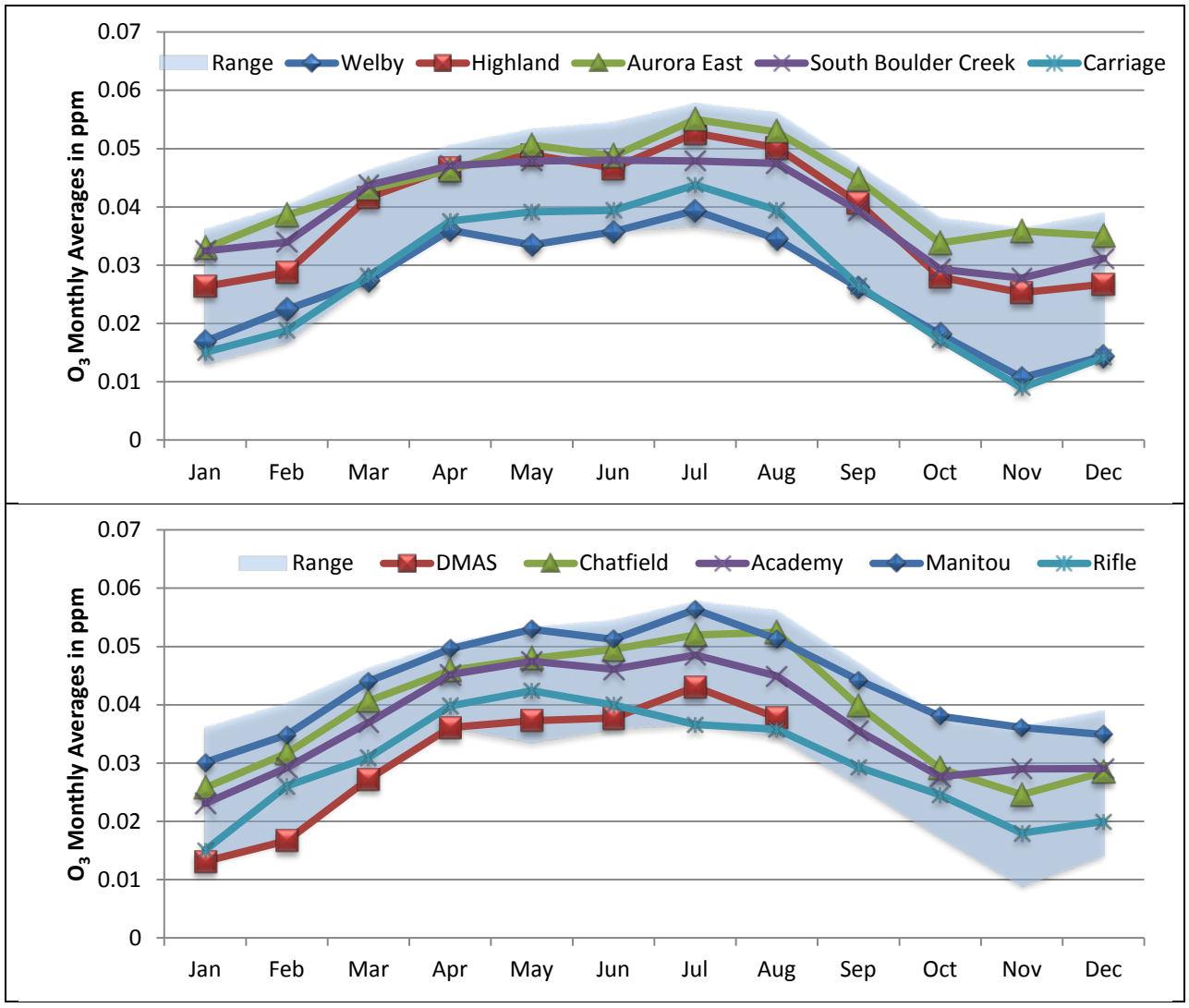
Figure 48. Monthly Carbon Monoxide Averages

5.2. Ozone

Ozone follows an opposite pattern than that of CO. The summer months see high ozone and the winter shows lower levels in part because of the length of daytime and the angle of the sun relative to the ground. Remember that ozone may be indicative of ground-level smog or the "Denver Brown Cloud". Generally speaking, sites in the Northern Front Range counties fared worse than other areas (especially sites directly west of, and at higher elevation than, metro Denver), though sites outside the Front Range occasionally had the highest averages.

It is important to note here, and in Sections 2 and 4, and Figure 5, that O_3 on average is higher everywhere it is measured in the state than it was last year, and has been increasing since 2010. Weather patterns through 2012 could be argued as ideal for production of ground-level ozone, and it is directly coincident with an increase in oil and natural gas exploration and development.

Recent studies are finding that high ozone concentrations within closed basins that have a lot of industrial activity and emissions may occur during the winter (see Section 2.2.2). Atmospheric inversions combined with snow cover in closed basins may lead to more ozone being created and retained within the basin. This condition has been observed on monitors operated by other agencies where the Uinta Basin, primarily in Utah, intrudes into northwest Colorado.



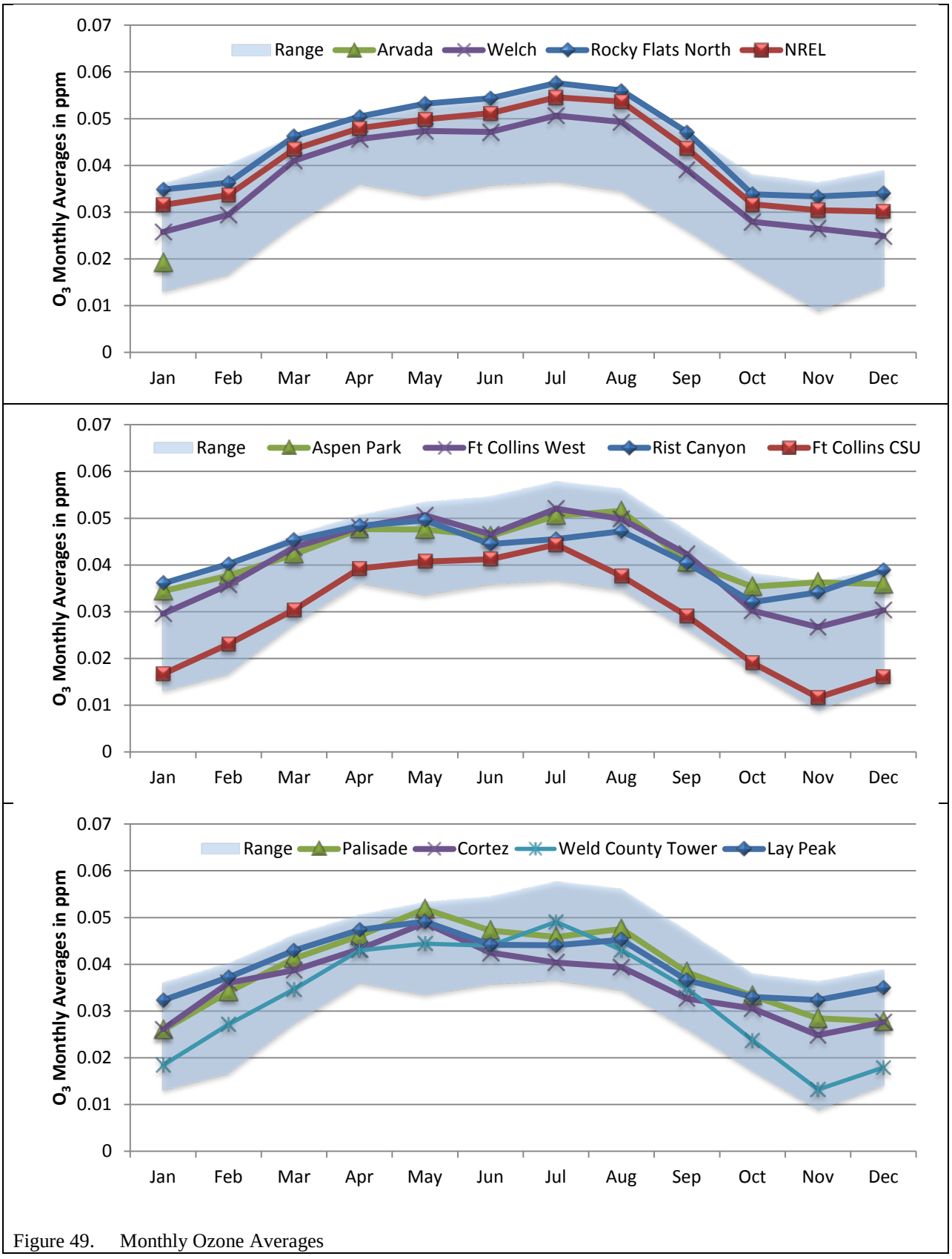


Figure 49. Monthly Ozone Averages

5.3. Sulfur Dioxide

Sulfur dioxide is measured at three stations in Colorado: Welby, DMAS, and CAMP, in the metro Denver area. At times concentrations between the stations appear to track well with each other, except for June through August where no correlation appears to exist. DMAS data were only valid from the beginning of the year until August.

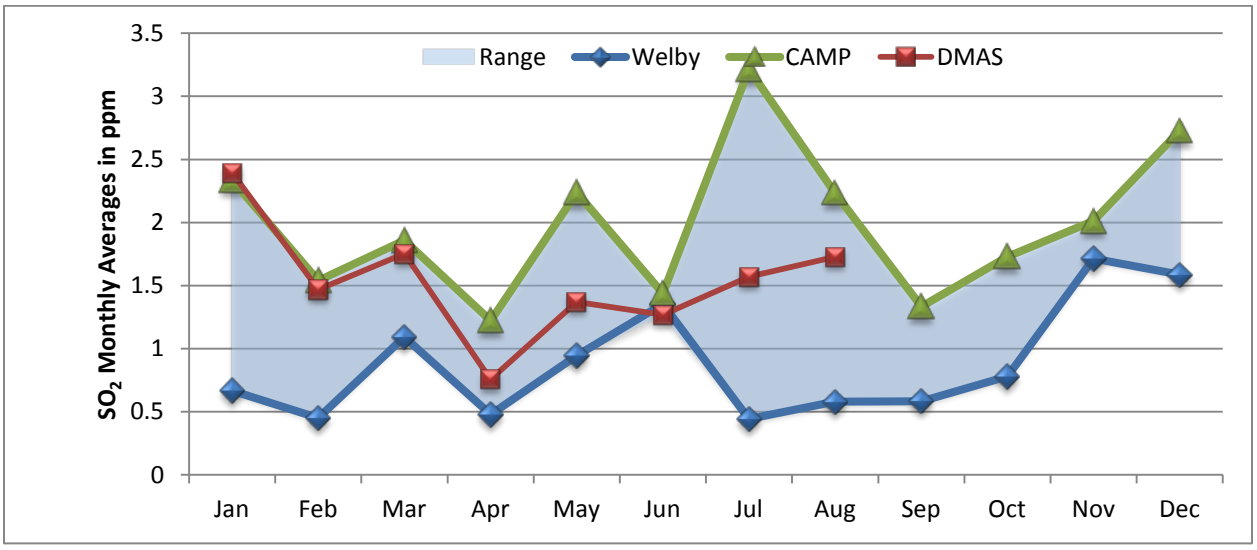


Figure 50. Monthly Sulfur Dioxide Averages

5.4. Nitrogen Dioxide

Nitrogen dioxide seems to follow the same pattern of CO, generally lower concentrations in the warmer months and higher in the colder months. NO_2 at sites in fairly close proximity appear to track with each other well.

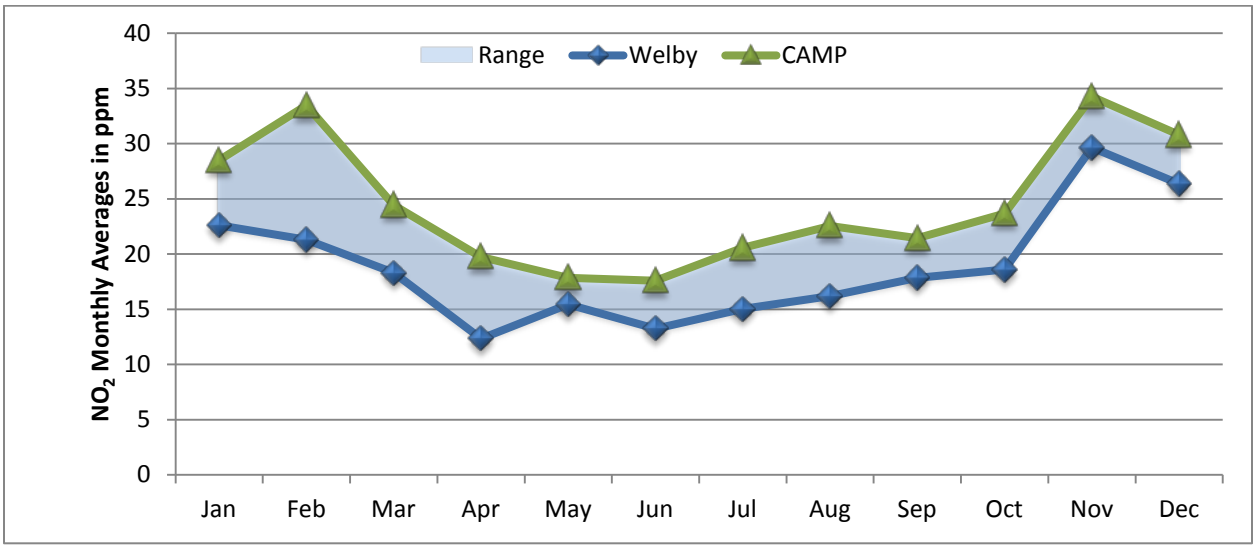
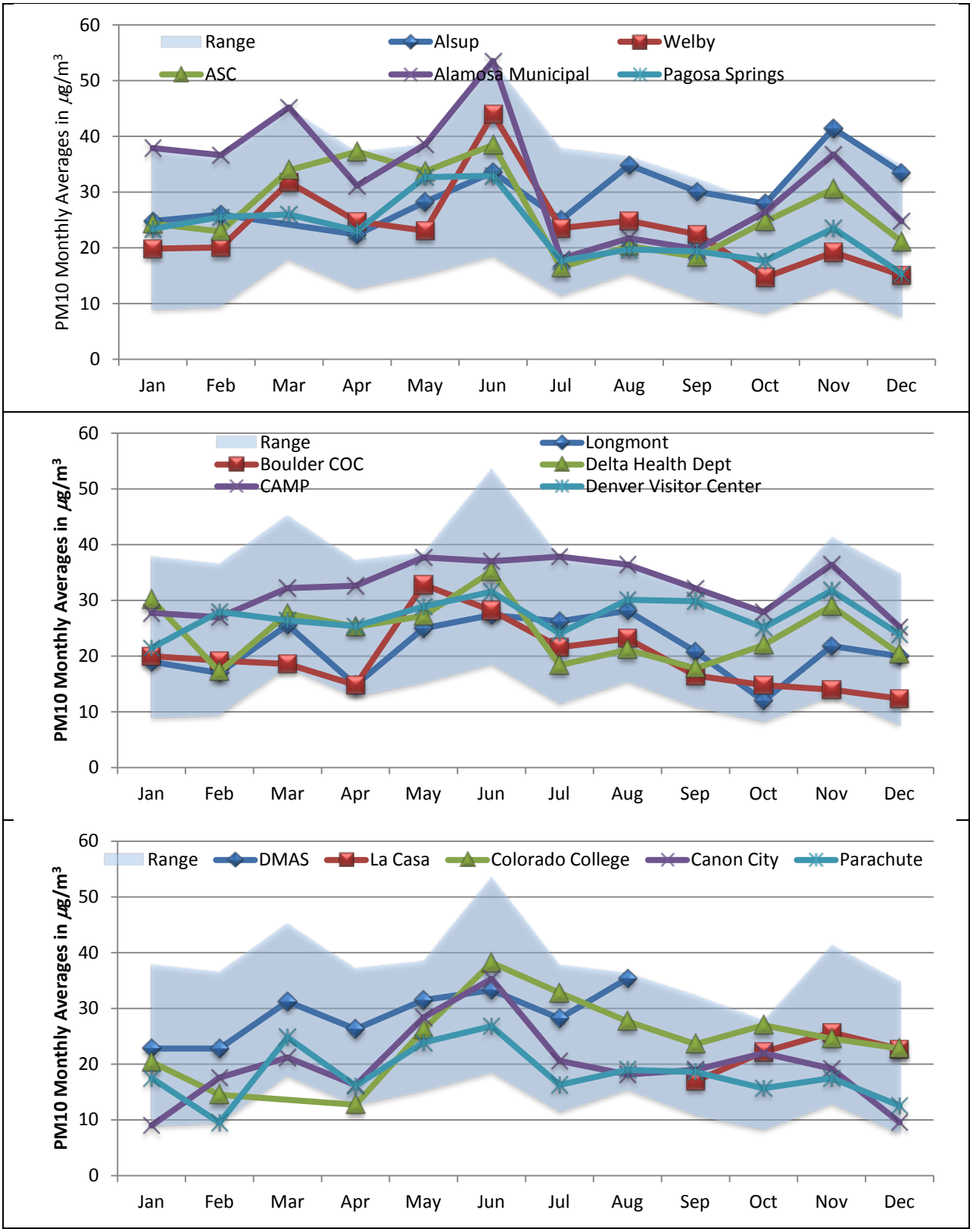


Figure 51. Monthly Nitrogen Dioxide Averages

5.5. Particulate Matter – PM_{10}

PM_{10} can be high for a variety of reasons including anthropogenic and natural occurrences. Higher PM_{10} concentrations might be expected during dry months, since the soil has a chance to dry out and be picked up by the winds. This can be somewhat seen in the range of PM_{10} concentrations found in the following graphs, but the peaks in concentrations are often due to single-point high-concentration events. The data below may contain exceptional events. See Section 2.2.5.1.


PM10 Monthly Averages in µg/m³
Range
Alsup
Welby
ASC
Alamosa Municipal
Pagosa Springs
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
PM10 Monthly Averages in µg/m³
Range
Longmont
Boulder COC
Delta Health Dept
CAMP
Denver Visitor Center
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
PM10 Monthly Averages in µg/m³
Range
DMAS
La Casa
Colorado College
Canon City
Parachute
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

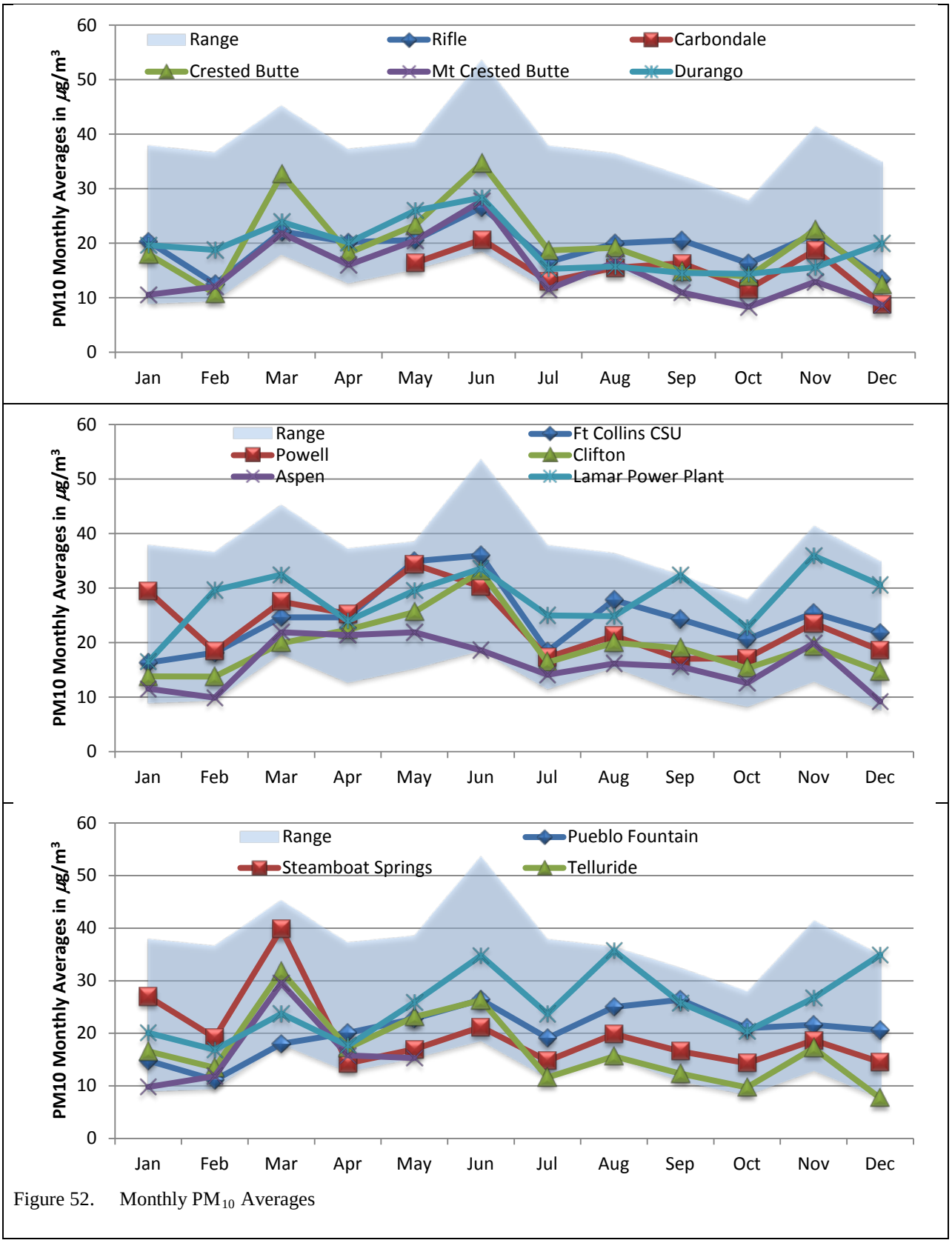
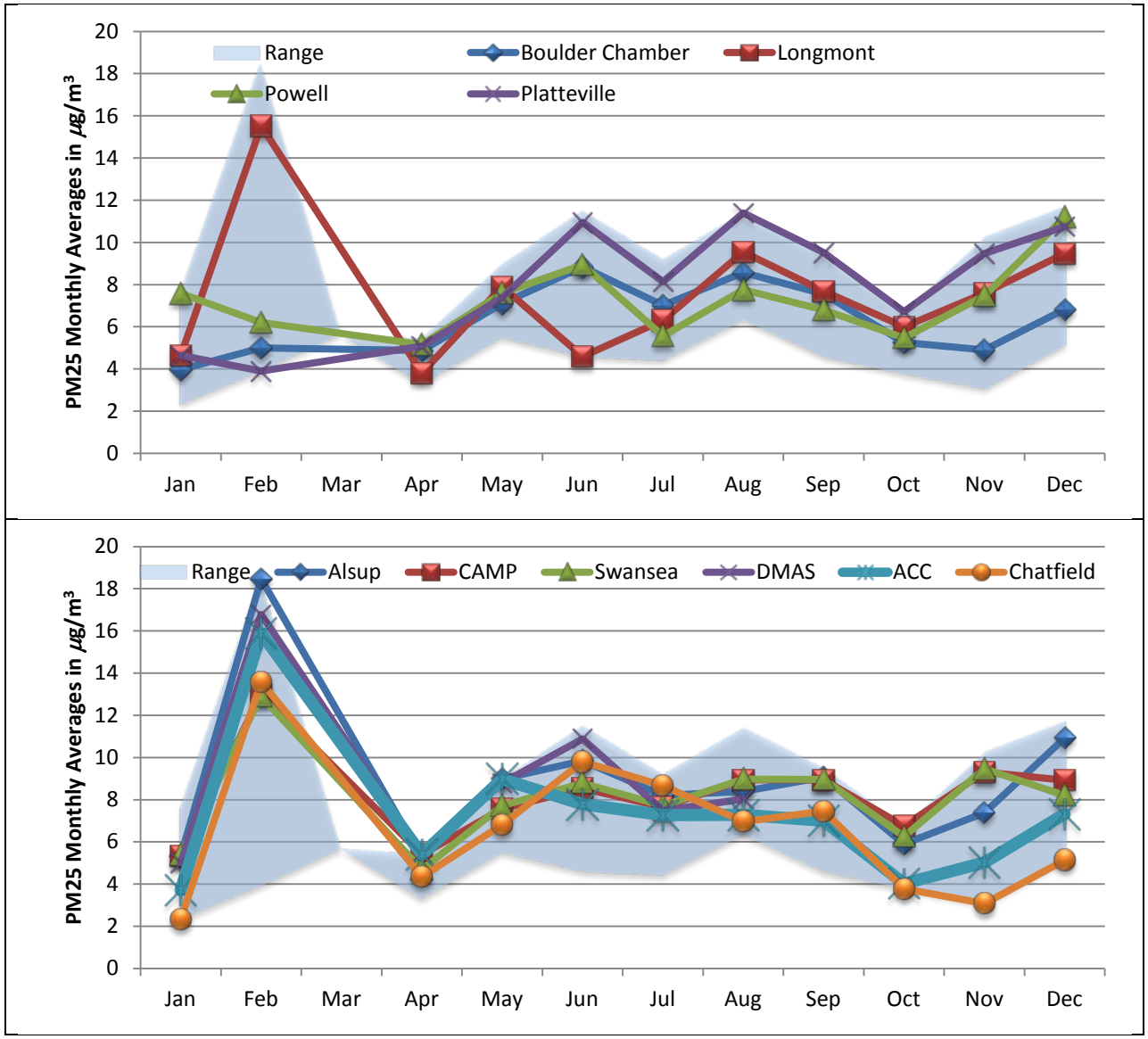


Figure 52. Monthly PM_{10} Averages

5.6. Particulate Matter – $PM_{2.5}$

PM2.5 concentrations are stable throughout much of the year, with a higher period in the winter caused by temperature inversions, and relatively similar at sites across the state. Platteville, Longmont, and Greeley saw high concentrations in December, and most other sites had their highest concentrations in January. The graphs here include exceptional event data. March data is missing due to lab issues resulting in data being invalidated.



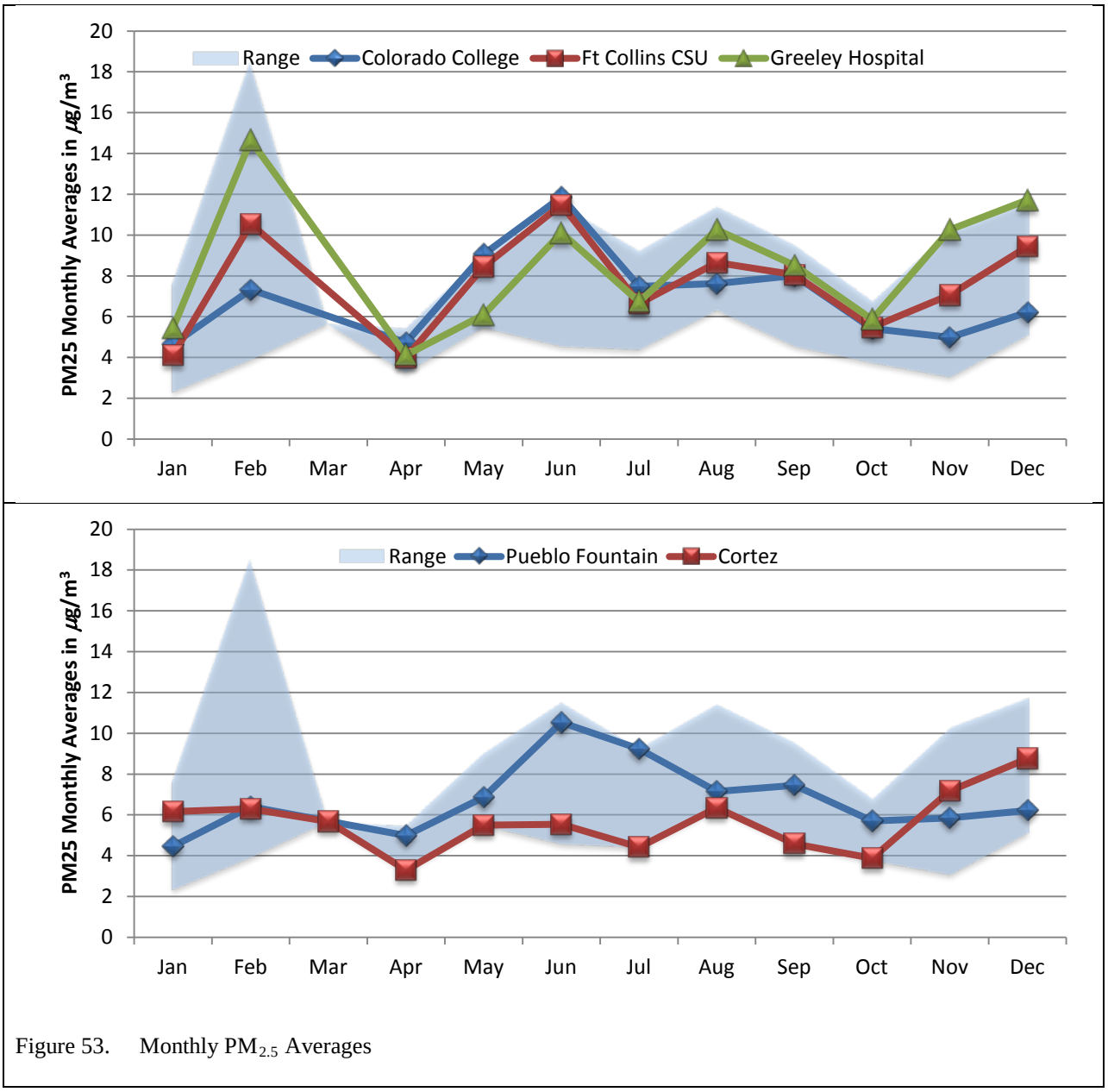


Figure 53. Monthly $PM_{2.5}$ Averages

5.7. Lead

Lead is sampled once every 6 days, and each sample covers a 24-hour period. Lead concentrations are approximately flat throughout the year at DMAS, and well below the standard even at Centennial. The variability of lead concentrations at Centennial is certainly higher than that at DMAS, indicating the airport is likely responsible for the higher lead levels, rather than a more general urban source. As Centennial is a source-oriented monitor, this is to be expected. As with other pollutants, sampling for lead stopped at DMAS in August.

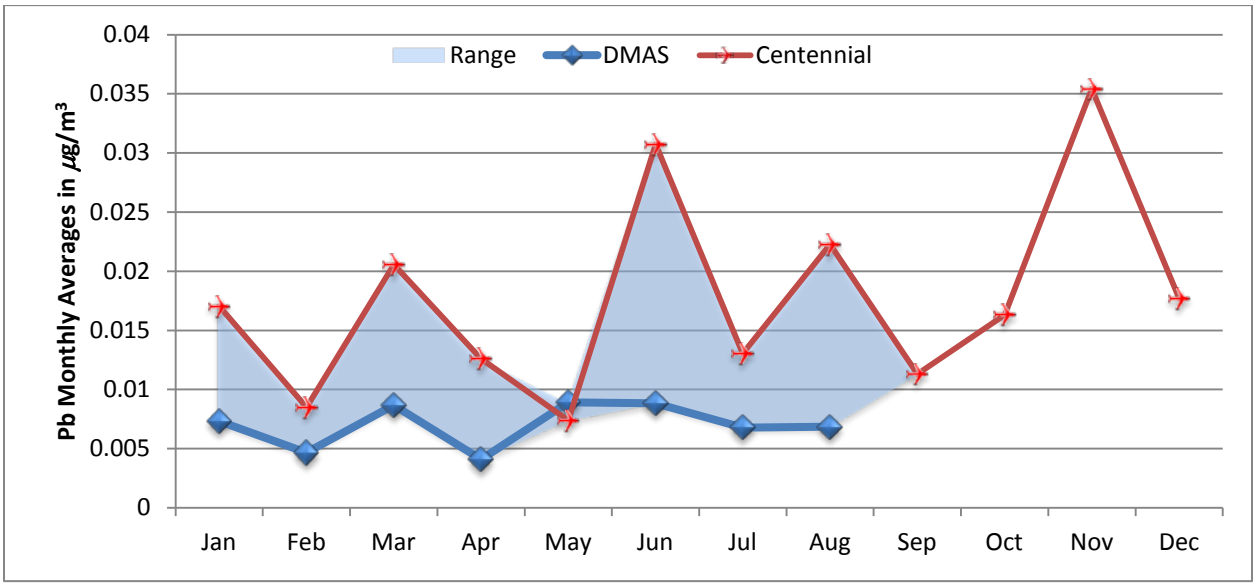


Figure 54. Monthly Lead Averages

6. DATA QUALITY ASSURANCE / QUALITY CONTROL

This section describes the APCD Technical Services Program's success in meeting its data quality objectives for ambient air pollution monitoring data of priority pollutants. This section is laid out in accordance with 40CFR Part 58 Appendix A requirements. Most of the calculations performed for this document were done using EPA's Data Assessment Statistics Calculator (DASC tool) and can be found on EPA's website: http://www.epa.gov/QUALITY/dqa.html. APCD's attainment of quantitative objectives, such as completeness, precision, and bias, are shown in Table 45.

Table 45. Attainment of Quantitative Quality Objectives for Ambient Air Monitoring Data

Measurement	Program met objectives for: (CDPHE goals / EPA requirements)			
	Completeness	**Precision**	**Bias**	**Accuracy**
CO	Yes	Yes	Yes	Yes
NO_2	No/Yes	Yes	Yes	Yes
O_3	Yes	Yes	Yes	Yes
SO_2	No/Yes	Yes	Yes	Yes
Time Integrated PM_{10}	Yes	Yes	Yes	Yes
Time Integrated $PM_{2.5}$	No/Yes	Yes	Yes	Yes
Continuous PM_{10}	No/Yes	No	Yes	Yes
Continuous $PM_{2.5}$	No/Yes	No	Yes	Yes
Pb	Yes	Yes	n/a	n/a
TSP	No/Yes	Yes	Yes	Yes

Other quality objectives were assessed via laboratory and site system audits. The results of these audits indicate compliance with APCD's standard operating procedures and EPA acceptance criteria, with the exception of bias based on the Performance Evaluation Program (PEP) audits for PM2.5 filter-based monitoring[12]. The 2012 PEP audits have not yet been validated by the EPA contractor. Copies of the APCD laboratory audits may be obtained from the Quality Assurance Unit within the APCD.

12 For criteria, see http://www.epa.gov/ttnamti1/files/ambient/pm25/qa/pepadequacy.pdf

Other audits were performed and can be made available for review, for National Air Toxic Trends Stations (NATTS), Speciation Trends Network (STN), Colorado based Ozone sites that are operated by other organizations, and CDPHE meteorological networks. These results are not included in this report because other agencies perform the data assessments for the NATTS and STN networks. Meteorological data is not considered a priority pollutant and so a statistical assessment of this data is not provided.

6.1. Data Quality

Data quality is related to the needs of the end users of the data, and should be of sufficient quality to aid in decision making. Each user specifies their required level of data quality in the form of their data quality objectives (DQOs). Quality objectives for measurement data are designed to ensure that the user's DQOs are met. Measurement quality objectives are concerned with both quantitative objectives (such as representativeness, completeness, accuracy, precision, and detection level) and qualitative objectives (such as site placement, operator training, and sample handling techniques).

6.2. Quality Assurance Procedures

Quality assurance is a general term for the procedures used to ensure that a particular measurement meets the quality requirements for its intended use. In addition to performing tests to determine bias and precision, additional quality indicators (such as sensitivity, representativeness, completeness, timeliness, documentation quality, and sample custody control) are also evaluated. Quality assurance procedures fall under two categories:

• Quality Control (QC) - procedures built into the daily sampling and analysis methodologies to ensure data quality, and

• Quality Assessment (QA) - periodic independent evaluations of data quality.

Some ambient air monitoring is performed by automated equipment located at field sites, while other measurements are made by taking samples from the field to the laboratory for analysis. For this reason, we will divide quality assurance procedures into two parts – field and laboratory quality assurance.

6.2.1 Field Quality Assurance

Quality assurance is a general term for the procedures used to ensure that a particular measurement meets the quality requirements for its intended use. Quality control of continuous analyzers consists of precision checks or flow verifications. The overall precision of filter based sampling methods is measured using collocated samplers. Quality assurance is evaluated by periodic performance and system audits.

Automated analyzers (except O_3) are calibrated by challenging the instrument's response to a known concentration of EPA protocol gas delivered through a dilution system. The analyzer is then adjusted to produce the correct response. O_3 analyzers are calibrated by challenging the analyzer's response withO_3 produced by an independently certified NIST-traceable ozone generator. The site's analyzer is then adjusted to produce the same measured concentration as the traceable analyzer. Manual samplers are calibrated by comparing their volumetric flow rate at one or more levels to the flow measured by a flow transfer standard. Calibrations are performed when an instrument is first installed and at assigned intervals thereafter depending on the analyzer type. Calibrations are also performed after instrument repairs or when quality control charts indicate a drift in response to quality control checks.

Precision is a measure of the variability of an instrument or the variability of the testing source. The precision of continuous gaseous analyzers are evaluated by comparing a sample of a known concentration against the instrument's response. The precision of filter based particulate samplers is determined by collocated sampling – the simultaneous operation of two identical samplers placed side by side. The difference in the results of the two samplers is used to estimate the precision of the entire measurement process (i.e., both field and laboratory precision). Precision of manual particulate samplers is assessed by regular periodic flow checks. Precision of continuous particulate samplers is assessed through the comparison of the ambient data to the FRM data and by regular periodic flow checks.

The bias of automated methods is assessed through field performance evaluations (also called accuracy audits) and through site precision checks. Performance audits are conducted by challenging the instrument with a gas of known NIST traceable concentration. Bias is evaluated by comparing the measured response to the known value. Typically, performance evaluations are performed biannually using samples of several different concentrations.

System audits indicate how well a sampling site and the site operator conforms to the standard operating procedures as well as how well the site is located with respect to its mission (e.g., urban or rural sampling, SLAMS or special purpose sampling site, etc.). Some areas reviewed include: site location (possible obstruction, presence of nearby pollutant sources), site security, site characteristics (urban versus suburban or rural), site maintenance, physical facilities (maintenance, type and operational quality of equipment, buildings, etc.), recordkeeping, sample handling, storage and transport.

6.2.2 Laboratory Technical Systems Audit

Laboratory quality control includes calibration of analytical instrumentation, analysis of blank samples to check for contamination, analysis of spikes to evaluate interferences and target analyte matrix recovery, and analysis of duplicate samples to evaluate precision. Quality assurance is accomplished through laboratory performance and system audits.

Laboratory analytical instruments are calibrated by comparing the instrument's response with standards of a known concentration level. The differences between the measured and known concentrations are then used to adjust the instrument to produce the correct response.

A blank sample is one that has intentionally not been exposed to the pollutant of interest. Analysis of blank samples reveals possible contamination in the laboratory, during field handling or during transportation.

Duplicate analyses of the same sample are performed to monitor the precision of the analytical method.

A regular sample is spiked with a known concentration to determine if the sample matrix is interfering with detection capabilities of the instrumentation.

Regular performance audits are conducted by having the laboratory analyze samples whose physical or chemical properties have been certified by an external laboratory or standards organization. The difference between the laboratory's reported value and the certified values is used to evaluate the analytical method's accuracy.

System audits indicate how well the laboratory conforms to its standard operating procedures. System audits involve sending a QA Auditor to the laboratory to review compliance with standard operating conditions. Areas examined include: record keeping, sample custody, equipment maintenance, personnel training and qualifications, and a general review of facilities and equipment.

The CDPHE Laboratory Services Division (LSD) performs the gravimetric analysis for the filter based particulates. APCD conducted a full Laboratory Technical Systems Audit of the High-Volume (High-Vol), Low-Volume (Low-Vol) Particulate Matter Gravimetric Laboratories and the Chemistry Metals Laboratories December 6th – 8th.

Results from these audits are available upon request from the APCD Quality Assurance Unit. A follow-up audit was conducted in October of 2012.

6.3. Gaseous Criteria Pollutants

6.3.1 Quality Objectives for Measurement Data

The Quality Objectives for the APCD’s ambient air monitoring of gaseous criteria pollutants are shown in Table 46.

Table 46. Data Quality Objectives for Gaseous Criteria Pollutants

Data Quality Indicator	APCD Goal	EPA Requirement
Precision for O_3	7%	7%
Precision for CO, SO_2, NO_2	10%	10%
Precision Completeness	90%	75%
Bias for O_3	7%	7%
Bias for CO, SO_2, NO_2	10%	10%
Accuracy for O_3	10%	10%
Accuracy for CO, SO_2, NO_2	10%	15%
Accuracy Audits (Performance Evaluations) Completeness	2 audits per analyzer per year	25% of analyzers quarterly
90% Probability Intervals	Meet EPA requirement	95% of audit values
NPAP TTP audits for O_3	Meet EPA requirement	10%
NPAP TTP audits CO, SO_2, NO_2	Meet EPA requirement	15%
Overall Data Completeness	90%	75%

6.3.2 Gaseous Data Quality Assessment

6.3.2.1 Summary

Assessment of the data for APCD gaseous criteria pollutants showed that all gaseous analyzers met the minimum EPA criteria and most monitoring sites met APCD goals for precision, bias, accuracy, national performance evaluations, and completeness. There were a number of notable exceptions and changes in the gaseous network during 2012 that include the following:

1) One of the biggest changes APCD undertook during the 2012 calendar year was moving the Ncore monitoring site from the DMAS (Denver Municipal Animal Shelter AQS ID (08-031-0025) site to the La Casa Family Medical Center monitoring site (AQS ID 08 031 0026). The DMAS site removal was required by the owner of the site. Most of the parameters for the DMAS site stopped monitoring at the end of August 2012 and all of the continuous parameters officially started reporting at La Casa January 1st, 2013.

2) The APCD installed an ozone monitor at the CAMP site, (AQS ID 08-031-0002) February 7th, 2012.

3) Monitoring at the Main Street Longmont Carbon Monoxide site (AQS ID 08-013-0009) ended December 31st, 2011. Major construction by the city of Longmont forced APCD to dismantle and remove the shelter from the alley where it was located. With EPA approval, APCD decided there was enough historical monitoring data for the site and concentrations were low enough that monitoring was no longer needed at this site.

4) Carbon Monoxide monitoring at the Auraria - Fire Station #6 monitoring site (AQS ID 08-031-0019) in downtown Denver ended December 31st, 2011. Due to low CO concentrations and the site's redundancy with the CAMP CO monitor, the Auraria CO site was decommissioned in early 2012.

5) Ozone monitoring at the Arvada monitoring site (AQS ID 08-059-0002) was discontinued January 27st, 2012. The Arvada monitoring site showed lower ozone concentrations than the Rocky Flats North site and the National Renewable Energy lab site which led APCD to decommission the site.

6) The Carriage monitoring site, (AQS id 08-031-0014) in metro Denver was shut down at the end of 2012 and removed due to the property no longer being available to APCD.

7) The High Park Fire of 2012 came very close to the Rist Canyon site (AQS ID 08-069-0012). The fire affected communications with the site and data were lost from 6/3/2012-7/14/2012.

8) Sulfur Dioxide data at the DMAS monitoring site for 3/25/2012 through 4/7/2012 were invalidated due to an analyzer malfunction.

NOTE: For more detailed information on monitoring site changes please see the APCD Annual Network Plan, which can be found at http://www.colorado.gov/airquality/tech_doc_repository.aspx#network_plan .

6.3.2.2 Precision (Coefficient of Variation)

At least once every two weeks, precision is determined by sampling a gas of known concentration for every gaseous analyzer. Table 47 summarizes the number of precision checks that were performed (precision count) as well as the percent completeness of these precision checks and an annual summary by organization of the percent of precision checks that fell within the acceptance criteria of +/-10% (+/-7% for O3). Table 47 also summarizes the statistical data quality assessment of these precision checks for all gaseous criteria pollutants. The Coefficient of Variation (CV) for the precision checks is summarized annually by site, quarterly by organization, and annually by organization. The equations used to calculate precision, bias, and upper and lower probability limits for the 90% probability intervals using the bi-weekly precision checks can be found in 40CFR58 Appendix A section 4.1.

6.3.2.3 Bias

For gaseous pollutants the bias is also calculated using the bi-weekly precision checks. The Bias is summarized in Table 47 (by the same groupings as the CV). Additionally a plus or minus bias is assigned to the annual "by site" and "by organization" groupings based on an evaluation of where the 25th and 75th percentiles of percent differences of the precision data fell. If both percentiles fell below zero then the bias was assigned a minus sign, and if both percentiles fell above zero, then the bias was assigned a plus sign. If one bias was positive and one bias was negative (i.e. straddling zero) there is no sign associated with the bias. Organizationally, CO showed a negative 1.5% bias for 2012. Organizationally, SO_2 showed a negative 2.9% bias for 2012. Organizationally ozone showed a non-signed bias of 1.8% for 2012. There was no sign associated with the calculated bias (4.8%) for the NO_2 precision checks, at the 25th and 75th percentiles, for the organization as a whole in 2012.

6.3.2.4 Performance Evaluations (Accuracy Audits)

Audits were performed at least twice on every gaseous analyzer within the APCD network during the 2012 calendar year. The primary goal of these audits is to evaluate the analyzer performance and calibration. Other factors are also noted during these audits such as operator performance, station operational criteria, record keeping, site upkeep issues, and general safety problems.

All Performance Evaluations (accuracy audits) performed for all gaseous analyzers during 2012 passed the EPA criteria of 15%.

6.3.2.5 Probability Intervals (Upper and Lower Probability Limits)

Probability Intervals (upper and lower probability limits) are calculated per 40CFR58 Appendix A section 4, by using the percent differences retrieved from station precision checks. The EPA has established that 95% of the independent audit points taken for a given year should fall within this calculated probability interval to validate the bias calculated from the precision checks. The percent differences between the audit concentrations and the indicated concentrations taken in 2012 for CO were compared to the probability intervals. Out of the 42 audit concentration points taken for CO in 2012, 79% fall between the probability intervals for the organization. There were 144 audit concentration points taken during 2012 for APCD's ozone network. Of those 144 ozone audit points, 26 fall outside the probability intervals. This means that 82% of the audit points for ozone fall between the probability intervals in 2012. Out of the 36 audit points taken in 2012 for NO_2, 100% fall between the probability limits. Out of the 18 audit points taken for SO_2 in 2012, 67% fall between the probability intervals. Three out of the four gaseous criteria pollutants do not meet the requirement that says, "ninety-five percent of the individual percent differences (all audit concentration levels) for the performance evaluations should be captured within the probability intervals for the primary quality assurance organization" (40CFR 58 Appendix A section 4.1.5).

APCD believes the reason it did not meet the above requirement in 2012 is, the probability intervals are calculated based on precision checks that are closer to the middle of the calibration scale, which give small percent differences and tight probability intervals. A newer requirement in the CFR is forcing APCD to audit in the lower portion of the site instrumentation's calibration scale, due to the fact that this is where 80% of the ambient data is being captured. By auditing in the low end of the calibration scale APCD is seeing a higher percent differences between the audit concentration and the instrument response. APCD believes this is due in part, because of the low audit concentration differences producing large percent differences and partly because the instruments are calibrated on a higher scale than where the audits are being conducted. The instruments are being calibrated at a higher scale than where 80% of the ambient data falls due to the relatively small number of episodes that do produce high ambient concentrations which have an effect on public health. Recently, APCD has begun to lower the calibration range on most pollutants and lower the precision values at most of its sites. This will hopefully help to rectify this problem but still allow APCD to capture the higher concentration pollution episodes within the instrument's calibration range.

6.3.2.6 Completeness

Data Completeness for the year is shown by site in Table 47. Precision Completeness is shown as the number of precision checks that were performed and submitted to AQS for the year. Precision completeness is evaluated against the number of checks that should have been performed at each site during the year. Completeness for accuracy audits in 2012 met or exceeded APCD DQO goals for every gaseous analyzer, with a minimum of two audits performed on every analyzer.

6.3.2.7 NPAP TTP Gaseous Audits

National Performance Audit Program (NPAP) audits for the Colorado gaseous network were not performed due to EPA / contractor staffing issues in 2012. EPA is currently working to put the necessary trained staff and audit equipment in place to perform these audits in the near future.

Table 47 summarizes the statistical evaluations for all gaseous precision, accuracy, bias, and completeness data. The basis for these calculations can be found in 40CFR58 Appendix A section 4.1.

Table 47. Summary of Precision, Accuracy, Bias, and Completeness Data for Gaseous Monitoring

Site or Organization	Analyte	Quarter or Year	Precision Count	Precision Completeness (%)	% In DQO Limits	CV (%)	BIAS (%)	+/- on Bias	(90% Probability Interval) Probability Limits		% audit points in Probability Limits	Data Completeness (%)
									Lower	Upper		
Welby	CO	2012	27	100		1.6	1.3		-2.34	2.83		90
CAMP	CO	2012	26	100		2.8	2.4	-	-5.41	3.58		99
Co. Springs Hwy 24	CO	2012	26	100		1.7	1.3		-2.29	2.98		98
Ft. Collins CSU	CO	2012	26	100		1.1	1.0		-2.30	1.20		98
Grand Junction Pitkin	CO	2012	26	100		2.4	2.3	-	-5.19	2.42		98
Greeley Annex	CO	2012	26	100		1.7	1.4		-3.08	2.34		99
DMAS trace[1]	CO	2012	18	100[1]		1.7	1.4		-6.08	2.86		95[1]
CDPHE	CO	1	46			2.6	2.2	-	-5.54	3.23		
CDPHE	CO	2	45			1.5	1.4	-	-3.42	1.73		
CDPHE	CO	3	47			1.9	1.5	-	-3.65	2.71		

Site or Organization	Analyte	Quarter or Year	Precision Count	Precision Completeness (%)	% In DQO Limits	CV (%)	BIAS (%)	+/- on Bias	(90% Probability Interval) Probability Limits		% audit points in Probability Limits	Data Completeness (%)
CDPHE	CO	4	37			1.7	1.4		-2.38	3.24		
CDPHE	CO	2012	175	100	100	1.9	1.5	-	-4.05	2.94	79	97
Welby	SO_2	2012	28	100		3.3	2.5		-5.51	4.97		93
CAMP	SO_2	2012	27	100		3.7	3.0	-	-7.03	4.67		94
DMAS trace[1]	SO_2	2012	20	100[1]		3.1	4.1	-	-7.71	1.71		79[1]
CDPHE	SO_2	1	22			2.8	4.2	-	-7.64	1.17		
CDPHE	SO_2	2	19			4.1	3.5		-7.36	5.05		
CDPHE	SO_2	3	20			2.2	1.8		-4.01	2.59		
CDPHE	SO_2	4	14			4.5	3.3		-5.92	7.07		
CDPHE	SO_2	2012	75	100	100	3.3	2.9	-	-7.01	4.36	67	89
Welby	NO_2	2012	25	100		5.2	4.2		-9.14	7.29		80
CAMP	NO_2	2012	26	100		5.4	5.8	+	-4.82	12.26		92
DMAS [1]	NO_y	2012	18	100		5.7	5.7	-	-11.65	5.66		88[1]
CDPHE	NO_2	1	21			5.9	4.8		-9.4	8.96		
CDPHE	NO_2	2	18			6.7	5.4		-10.28	9.84		
CDPHE	NO_2	3	16			8.2	6.5		-12.04	12.13		
CDPHE	NO_2	4	14			6.0	5.0		-6.75	10.68		
CDPHE	NO_2	2012	69	100	100	5.7	4.8		-9.7	10.27	100	87
Welby	O_3	2012	27	100		1.8	2.3	+	-1.18	4.55		92
CAMP[2]	O_3	2012	23	100		2.3	1.9		-3.58	3.59		99[2]
Highland	O_3	2012	25	100		2.6	2.4	-	-5.61	2.70		92
Aurora East	O_3	2012	26	100		3.3	2.7		-5.12	5.31		99
S. Boulder Crk.	O_3	2012	26	100		2.7	2.2		-4.29	4.41		99
Carriage	O_3	2012	26	100		2.3	1.6		-3.74	3.60		99
DMAS[1]	O_3	2012	18	100		4.2	4.5	-	-9.15	3.39		90[1]
Chatfield	O_3	2012	26	100		2.7	2.2		-4.82	3.91		98
Co. Spgs. Academy	O_3	2012	25	100		2.8	2.5		-5.46	3.32		98
Co. Spgs. Manitou	O_3	2012	26	100		2.3	2.1	+	-2.39	4.94		98
Rifle	O_3	2012	30	100		3.3	2.9		-6.56	4.12		99
Welch	O_3	2012	26	100		1.8	1.3	-	-2.97	2.72		99
Rocky Flats North	O_3	2012	26	100		1.7	1.3		-2.90	2.56		97
NREL	O_3	2012	26	100		2.7	2.3		-3.71	4.84		100
Aspen Park	O_3	2012	26	100		2.8	2.4		-5.09	3.78		97

Site or Organization	Analyte	Quarter or Year	Precision Count	Precision Completeness (%)	% In DQO Limits	CV (%)	BIAS (%)	+/- on Bias	(90% Probability Interval) Probability Limits		% audit points in Probability Limits	Data Completeness (%)
Ft. Collins West	O_3	2012	26	100		2.1	1.6	+	-2.92	3.71		99
Rist Canyon	O_3	2012	23	96		3.7	3.3	+	-4.05	7.43		80
Ft. Collins CSU	O_3	2012	26	100		2.3	1.9		-3.16	4.18		94
Palisade	O_3	2012	30	100		1.7	1.2		-2.73	2.72		99
Cortez	O_3	2012	30	100		2.9	2.3		-4.69	4.55		96
Lay Peak	O_3	2012	44	100		1.7	1.3	-	-3.2	2.59		98
Greeley Tower	O_3	2012	26	100		2.5	2.6	+	-2.26	5.65		99
CDPHE	O_3	1	138			2.8	2.2		-5.21	4.91		
CDPHE	O_3	2	146			2.7	2.1		-4.78	4.89		
CDPHE	O_3	3	159			1.8	1.4		-3.42	3.14		
CDPHE	O_3	4	143			2.5	2.0		-4.35	4.82		
CDPHE	O_3	2012	586	100	99	2.4	1.8		-4.36	4.53	82	96

[1]DMAS Ncore site was shut down and moved to LaCasa late Aug. of 2012 producing only 3 quarters of valid data for 2012 at that site. All the continuous parameters at LaCasa did not begin reporting until Jan of 2013. All completeness data is calculated based on when the DMAS site was in operation only. All the ozone calculations above were based upon the entire years' worth of data, not the ozone season (Mar.-Sept.). EPA's AMP 600 report is based on the ozone season. [2]CAMP started monitoring ozone February 7th, 2012. Completeness data for CAMP is calculated based on when the site was reporting ozone data.

6.4. Particulate Criteria Pollutants

6.4.1 Quality Objectives for Measurement Data

The Quality Objectives for the APCD ambient air monitoring of particulate criteria pollutants are shown in Table 48.

Table 48. Data Quality Objectives for Particulate Pollutants

Data Quality Indicator	APCD Goal	EPA Requirement
Precision High-Vol Filters	10%	10%
Precision Low-Vol Filters	10%	10%
Precision PM_{10} Continuous	10%	10%
Precision $PM_{2.5}$ Continuous	4%	4%
Precision Completeness	90%	75%
Bias Low-Vol / PEP	10%	10%
Accuracy High-Vol	10%	10%
Accuracy Low-Vol	4%	4%
Accuracy PM_{10} Continuous	10%	10%
Accuracy $PM_{2.5}$ Continuous	4%	4%
Accuracy Audits (Performance Evaluations) Completeness	1 audit per analyzer per quarter	25% of analyzers quarterly
Overall Data Completeness	90%	75%
90% Probability Intervals	Meet EPA requirement	95% of audit values

6.4.2 Particulate Data Quality Assessment

6.4.2.1 Summary

Assessment of the data quality for APCD particulate criteria pollutants showed that most samplers met minimum EPA criteria and most monitoring sites met APCD goals for accuracy, precision, completeness, and bias. There were some notable exceptions as well as some changes in the particulate network during 2012, which included the following:

1) All low- volume particulate data handled by the CDPHE LSD were invalidated from 02/13/2012 through 4/8/2012 due to laboratory quality control and quality assurance issues. This loss of data, lead to the Low-Volume particulate network having lower than usual data recovery for 2012, although all sites met EPA annual completeness criteria.

2) One of the biggest changes APCD undertook during the 2012 calendar year was moving the NCore monitoring site from the DMAS (Denver Municipal Animal Shelter AQS id 08-031-0025) site to the La Casa Family Medical Center monitoring site (AQS id 08-031-0026). The DMAS site removal was required by the property management. The city of Denver made major changes to the property making air monitoring at the site impossible. Most of the parameters for the DMAS site stopped monitoring at the end of Aug. 2012. The manual filter based particulate parameters began sampling at La Casa in early Sept. 2012 producing one quarter of valid data. The continuous particulate monitors did not officially start reporting to AQS until early in 2013. Also, see notes above in gaseous section regarding new La Casa site installation.

3) The APCD worked with the Garfield County Health Department to install a new site in Carbondale Colorado (AQS ID 08-045-0018) September of 2012 to monitor PM10 with High Volume samplers. This site is owned by Garfield County, not CDPHE.

4) The APCD decommissioned the Breckenridge site (AQS ID 08-117-0002) at the end of 2012 due to low concentrations over a ten year monitoring period and problems with site access.

5) The APCD decommissioned the Lamar Light and Power site (AQS ID 08-099-0001) December 31st, 2012 because it no longer met siting requirements due to installation of a new facility on the property.

6) The APCD had staffing problems in 2012 which led to it not meeting the EPA required 75% precision completeness DQO for Continuous Particulate. Precision completeness is based off at least one operator flow check on each continuous particulate sampler once per month though out the calendar year. The following Continuous Particulate sites did not meet EPA's 75% precision completeness: Welby PM10 TEOM, Ft. Collins 1405 TEOM, Grand Junction 1405 TEOM, Boulder Marine St. TEOM, Colorado College TEOM, Longmont TEOM and the Chatfield TEOM. APCD is working to correct this issue with better training for staff and better site documentation. APCD also performed twice as many flow audits as are required by EPA (1 per quarter was performed) on all TEOM's within its network. On a side note, the APCD does not use the continuous particulate data to compare to the National Ambient Air Quality Standards (NAAQS). The NAAQS for Colorado are calculated using the filter based particulate monitoring Federal Reference Method (FRM) data.

7) The APCD did not meet its own goal of 90% for overall data completeness at all of the Continuous Particulate sites but did meet EPA's goal of 75% data completeness at all of its Continuous Particulate sites.

6.4.2.2 Precision

The CV for filter-based particulate monitoring is determined from the collocated precision data collected (i.e., two identical samplers operated in the identical manner). Due to the anticipated poor precision for very low levels of pollutants, only collocated measurements at or above a minimum level (greater than or equal 15 μg/m^3 for $PM_{10,}$ 20 ug/m^3 for Total Suspended Particulate or TSP, and 3 μg/m^3 for $PM_{2.5}$) would be called "Valid Pairs" and are used to

evaluate precision. The Coefficient of Variation was calculated with 35 Valid Pairs for DMAS TSP and DMAS TSP collocated for 2012, which was 12.64%, outside the limit. The DMAS TSP was taken down due to the removal of the site late August 2012. The other particulate parameters fell within the DQO limits. The calculations for the statistical presentations in Table 6 are found in 40CFR58 Appendix A section 4.2.

The CV for continuous based particulate monitoring is determined by the monthly flow verification (precision checks) performed on the continuous particulate monitors. The calculations for the statistical presentations in Table 6 are the same calculations that were performed on the gaseous analyzers precision data.

6.4.2.3 Bias

Results of the annual flow rate audits conducted by APCD personnel are shown in Table 49 below. There is no requirement for bias on the High-Vol filter-based particulate monitoring, since the precision is based on collocated sampling. For the filter-based particulate monitoring, Table 49 summarizes bias based on the audits that were performed during the year, since APCD performs particulate audits four times more frequently than the EPA requires. These additional audits are conducted to compensate for the lack of a flow verification precision check program in place for the High-Vol samplers. The bias calculations were also conducted using the Low-Vol audit results since the flow verifications performed on the Low-Vol samplers are not reported to the EPA AQS database. The bias for the continuous particulate monitoring was calculated on the monthly flow verification precision checks with the same calculations that were used to determine the gaseous bias, and can be found in Table 51.

6.4.2.4 Performance Evaluations (Accuracy Audits)

Audits were performed at least quarterly on every particulate sampler within the APCD network during the 2012 calendar year, with the exception of Cortez (only one audit in 2012) and a third quarter Centennial audit due to loss of power to the site. The primary goal of these audits is to evaluate the analyzer performance and calibration. Other factors are also noted during these audits such as operator performance, station operational criteria, record keeping, site upkeep issues, and general safety problems.

All Performance Evaluations (accuracy audits) completed for all particulate analyzers during 2012 passed the APCD objectives with the following exceptions:

1) The PM2.5 FRM sampler at Colorado College (08-041-0017) failed design flow and audit flow (~6%) on 3/16/2012. The associated data was flagged and the sampler was recalibrated immediately.

2) The PM2.5 FRM sampler at Platteville Middle School (08-123-0008) failed design flow and audit flow (~8%) on 8/2/2012. The associated data was flagged and the sampler was recalibrated immediately.

3) The PM2.5 FRM sampler at Pueblo Fountain Magnet School (08-101-0015) failed design flow and audit flow (~11%) on 5/10/2012. The associated data was invalid and the sampler was recalibrated immediately.

4) There were 11 out of 247 High Volume audits performed where the audit flow passed but the design flow failed to meet criteria. In these cases the auditor made adjustments to the samplers to bring the design flow back into specifications, and data was appropriately flagged.

5) The continuous particulate sampler (TEOM 1400a) at CAMP (08-031-0002) failed total audit flow and design flow on 8/23/2012. The sampler's software was adjusted by the auditor bringing the flow into a passing range until PM2.5 staff could get to the site to perform a full calibration and verification.

6) The continuous particulate sampler (TEOM 1405) at Ft. Collins CSU (08-069-0009) failed total audit flow on February 29th, 2012. The PM2.5 staff was notified immediately and the associated data was flagged.

6.4.2.5 Completeness

Data Completeness for the year is shown by site in Table 6 and in the last column of Table 7. Precision Completeness is shown in the column to the right of "Precision Count" in table 7 and is based on the number of monthly flow verifications that were performed. Precision Completeness is shown to the left of "total # pairs" in Table 6, and is based on the number of pairs collected. Precision completeness is evaluated against the number of checks that should have been performed at each site during the year. Completeness for accuracy audits met or exceeded all APCD DQO goals for every particulate analyzer, with a minimum of two audits performed on every analyzer per year.

6.4.2.6 PEP / NPAP Particulate Audits

High Vol National Performance Audit Program (NPAP) audits were not performed by EPA in 2012. NPAP audits for the High-Vol particulate networks are required every three years, and the APCD performed these analyses, which were then evaluated by Region 8 EPA, in 2009. The 2009 results for High-Vol PM_{10} and TSP NPAP audits are available upon request.

Performance Evaluation Program (PEP) audits were conducted with nine separate samples in 2012 on the Low Volume PM2.5 program. Only four of these audit samples can be used for calculating bias. Three of the audits were invalidated due to the QA/QC problems APCD had with the contracted gravimetric lab (March 31st, at Alsup, Greeley and CAMP). One PEP audit sample cannot be used at LaCasa on Dec. 18th due to a concentration below 3 ug/m^3 and another because it was performed on a Low Vol PM10 sampler. Two of the valid audits were conducted at the Cortez site on March 4th and June 2nd. A valid PEP audit was run at Greeley on May 30th and another valid PEP audit sample was taken at Alsup on Dec. 18th. Using the four valid audit samples taken, a mean percent difference between the PEP result and the site result is 23.89%, due to the unusually large percent difference taken at the Colorado College site on May 30th (84.5%). The TEOM at Colorado College reported an average of ~ 17 ug/m^3 for the 24 hour period, which is much closer to the APCD sampler result of 15.2 ug/m^3 on the same day. All of the results for the reported 2012 PEP audits are summarized in Table 49.

Table 49. PM2.5 Low-Volume PEP results.

Audit Date	AQS Site Id.	Site Name	PEP res. (ug/m3)	Site res. (ug/m3)	Percent Difference
3/4/2012	08-083-0006	Cortez	5.28	5.30	0.379%
3/31/2012	08-001-0006	Alsup Elementary	5.45	Lab Error	
3/31/2012	08-123-0006	Greeley Hospital	7.03	Lab Error	
3/31/2012	08-031-0002	CAMP	6.49	Lab Error	
5/30/2012	08-041-0017	Colorado College	8.24	15.21	84.5%1
6/2/2012	08-083-0006	Cortez	4.24	4.00	5.7%
12/18/2012	08-001-0006	Alsup Elementary	3.37	3.20	5.1%
12/18/2012	08-031-0026	LaCasa	2.922	3.70	26.7%2

[1]The TEOM at Colorado College reported an average of ~ 17 ug/m^3 for the 24 hour period on May 30th, 2012 which is much closer to the APCD sampler result of 15.2 ug/m^3 on the same day. [2]This result is technically not valid for percent difference analysis due to the PEP result being below 3 ug/m^3 (2.92) per 40CFR Appendix A section 4.0.

6.4.2.7 Lead

Lead analysis was performed by the CDPHE Laboratory Services Division on filters from TSP samples at Centennial Airport and Denver Municipal Animal Shelter (DMAS). All lead concentrations were lower than .02 *u*g/m^3 required for collocated precision calculations prescribed by 40CFR Appendix A section 4.2. Due to the low concentration shown by the lead samples available for analysis no official statistics were performed for this Data Quality Assessment.

Blind EPA RTI test strips were sent to APCD's contract lead analysis lab in 2012 to test the performance of the lab. EPA has a performance evaluation program used to test laboratories analyzing lead samples. CDPHE participated in this program by asking the contract laboratory to perform the analysis as a part of their routine APCD work load.

Inductively Coupled Plasma - Mass Spectrometry (ICPMS) was used for the analysis. The lab analyzed a total of 18 blind EPA lead test strips in 2012. The average percent difference between the 18 blind samples was 8.9%. Out of the 18 blind test strips analyzed, there was one with a percent difference above 20% and five above 10%. The rest of the 18 blind test strips analyzed were at or below a 10% difference. The results were statistically analyzed per instructions in 40CFR58 Appendix A section 4.2. The statistic assessment is a % Bias based on an analysis of the quarterly flow audits and the blind test strip results and can be found at the bottom of Table 50.

Table 50 below summarizes statistical evaluations for all filter-based particulate precision, accuracy, bias, and completeness data. The values were calculated as described in 40CFR58 Appendix A section 4.2.

Table 50. Summary of Precision, Accuracy, Bias, and Completeness Data for Filter Based Particulate Monitoring

Site or Organization	Parameter	Notes	Performance Evaluations (Accuracy)				Data Completeness	Collocated Precision Statistics			
			# of audits	Bias (%)	LPL (%)	UPL (%)		Total # Pairs	Valid # Pairs	Completeness	CV
Alamosa Muni	High-Vol PM_{10}		16	-1.81	-7.23	3.61	86				
Alamosa ASC	High-Vol PM_{10}		16	-1.39	-7.28	4.49	98				
Aspen	High-Vol PM_{10}		8	-1.87	-3.82	0.07	96				
Boulder	High-Vol PM_{10}		4	-1.69	-3.54	0.15	97				
Breckenridge[1]	High-Vol PM_{10}		8	-3.89	-7.45	-0.33	80[1]				
Carbondale	High-Vol PM_{10}		6	-7.24	-12.77	-1.7	85				
CAMP	High-Vol PM_{10}		4	-1.72	-6.04	2.59	95				
CAMP	High-Vol PM_{10}	collocated	4	-2.15	-4.57	0.27	95	58	52	100	3.58
Canon City	High-Vol PM_{10}		4	-1.15	-3.43	1.13	92				
Clifton	High-Vol PM_{10}		8	-1.06	-6.64	4.51	97				
Crested Butte	High-Vol PM_{10}		8	-2.86	-5.90	0.18	100				
Crested Butte	High-Vol PM_{10}	collocated	4	-2.41	-4.94	0.12	93	57	32	100	7.04
Delta	High-Vol PM_{10}		8	-1.77	-4.81	1.28	99				
Durango	High-Vol PM_{10}		8	-1.46	-6.25	3.32	97				
DVC	High-Vol PM_{10}		16	-3.02	-7.11	1.07	98				
Ft. Collins CSU	High-Vol PM_{10}		8	-2.88	-8.29	2.52	99				
Greeley	High-Vol PM_{10}		8	-2.12	-4.15	-0.10	99				
Lamar	High-Vol		16	-1.08	-5.47	3.31	99				

Site or Organization	Parameter	Notes	Performance Evaluations (Accuracy)				Data Comp	Collocated Precision Statistics			
Municipal	PM_{10}										
Lamar Power Plant	High-Vol PM_{10}		16	-0.85	-3.64	1.93	99				
Longmont	High-Vol PM_{10}		4	-0.01	-2.54	2.51	97				
Mt. Crested Butte	High-Vol PM_{10}		16	-2.32	-7.01	2.38	97				
Pagosa School	High-Vol PM_{10}		16	-2.75	-10.2	4.69	91				
Parachute	High-Vol PM_{10}		8	-2.20	-6.29	1.90	93				
Pueblo	High-Vol PM_{10}		8	-1.20	-2.97	0.57	98				
Rifle	High-Vol PM_{10}		8	-1.71	-4.35	0.93	93				
Steamboat	High-Vol PM_{10}		16	-1.34	-5.82	3.15	96				
Telluride	High-Vol PM_{10}		8	-2.81	-9.55	3.93	98				
Welby	High-Vol PM_{10}		4	-2.26	-3.99	-0.52	87				
CDPHE	High-Vol PM_{10}	organization	264	-2.08	-6.99	2.83	95	115	84	100	6.32
Colorado College	Low-Vol PM_{10}		4	-0.11	-0.73	0.51	85				
Commerce City	Low-Vol PM_{10}		4	-1.52	-2.24	-0.81	84				
DMAS[2]	Low-Vol PM_{10}		3	-2.01	-2.45	-1.57	75[2]				
Grand Junction	Low-Vol PM_{10}		4	0.82	-0.86	2.50	69				
Grand Junction	Low-Vol PM_{10}	collocated	4	-0.19	-0.80	0.42	73	37	30	100	6.65
CDPHE	Low-Vol PM_{10}	organization	19	-0.5	-2.7	1.65	83	37	30	100	6.65
A.C.C.	Low-Vol $PM_{2.5}$		4	-1.18	-4.08	1.72	81				
Boulder	Low-Vol $PM_{2.5}$		4	-0.39	-1.3	0.51	83				
CAMP	Low-Vol $PM_{2.5}$		4	-0.56	-2.33	1.21	82				
CAMP	Low-Vol $PM_{2.5}$	collocated	4	-0.15	-1.1	0.79	80	48	47	100	7.60
Chatfield	Low-Vol $PM_{2.5}$		4	-1.10	-3.34	1.14	83				
Colorado College	Low-Vol $PM_{2.5}$		4	1.85	-2.71	6.41	84				
Commerce City	Low-Vol $PM_{2.5}$		4	-0.63	-1.3	0.04	84				
Commerce	Low-Vol	colloc	4	-1.60	-2.39	-0.82	84	51	48	100	7.60

Site or Organization	Parameter	Notes	Performance Evaluations (Accuracy)				Data Comp	Collocated Precision Statistics			
City	$PM_{2.5}$	ated									
Cortez	Low-Vol $PM_{2.5}$		1	-0.27	0.06	0.06	98				
DMAS[2]	Low-Vol $PM_{2.5}$		3	-1.98	-3.14	-0.83	69				
Ft. Collins CSU	Low-Vol $PM_{2.5}$		4	-0.28	-2.06	1.50	84				
Grand Junction	Low-Vol $PM_{2.5}$		4	0.17	-1.54	1.88	82				
Greeley	Low-Vol $PM_{2.5}$		4	-0.54	-2.66	1.58	82				
Longmont	Low-Vol $PM_{2.5}$		4	-2.09	-3.28	-0.91	84				
Platteville	Low-Vol $PM_{2.5}$		4	-1.90	-9.56	5.76	80				
Pueblo	Low-Vol $PM_{2.5}$		4	0.49	-5.50	6.48	81				
Swansea	Low-Vol $PM_{2.5}$		4	0.65	-0.69	1.98	82				
CDPHE	Low-Vol $PM_{2.5}$	organi zation	86	-0.57	-4.1	2.97	83				
CDPHE	All Low-Vol Particulate	organi zation	105	-0.56	-3.83	2.71	83	136	125	100	7.62
Centennial Airport	TSP		3	-1.71	-10.0	6.58	83				
DMAS[2]	TSP		3	-2.38	-9.3	4.55	92				
DMAS[2]	TSP	colloc ated	3	-4.51	-14.5	5.5	93	37	35	100	12.6
CDPHE	TSP	organi zation	9	-2.87	-10.6	4.91	87	37	35	100	12.6
Centennial Airport	Pb		3	20.7	*NA*	*NA*	84				
DMAS[2]	Pb		3	19.9	*NA*	*NA*	93[2]				
DMAS [2]	Pb	colloc ated	3	27.6	*NA*	*NA*	89[2]				

[1]The Breckenridge High Volume PM10 site was shut down 06/02/2012 due to the site data no longer being needed by APCD. The site showed many years of data with low concentrations and had accessibility issues. The completeness data and statistical calculations are based on only when the site was in operation. [2]DMAS NCore site was shut down and moved to LaCasa late Aug. of 2012 producing only 3 quarters of valid data for 2012 at that site. All completeness data was calculated based of when the site was in operation only. The filter based particulate began operating soon after at the LaCasa site producing ~ one full quarter of valid data. No statistics were performed because only one quarterly audit was performed at LaCasa during that time on the manual particulate samplers. The High Volume PM10 samplers were removed from DMAS and replaced at LaCasa with a Low Volume PM10 FRM manual filter based sampler.

Table 51 summarizes statistical evaluations for all continuous particulate precision, accuracy, bias, and completeness data. The values were calculated in the same manner as the gaseous statistics using the monthly flow rate verification precision checks.

Table 51. Summary of Precision, Accuracy, Bias, and Completeness Data for Continuous Particulate Monitoring

Site or Organization	Particulate Parameter	Quarter or Year	Precision Count	Precision Completeness (%)	Prec. Within DQO Limit	CV (%)	Bias (%)	+/- on bias	90% Probability Interval Probability Limits		% of Audit Points within Probability Limits	Data Completeness (%)
									Lower	Upper		
Welby	PM_{10} TEOM	2012	8	67		2.5	2.1		-4.39	3.05		81
CAMP	PM_{10} TEOM	2012	21	100		2.1	1.9		-4.21	2.93		92
DMAS	PM_{10} TEOM	2012	14	100		2.7	2.4		-5.32	3.38		90
CDPHE	PM_{10} TEOM	1	13			2.1	1.9		-4.19	2.36		
CDPHE	PM_{10} TEOM	2	16			2.9	2.5		-5.21	4.33		
CDPHE	PM_{10} TEOM	3	8			2.6	2.2		-4.68	3.13		
CDPHE	PM_{10} TEOM	4	7			2.9	2.3	-	-4.8	3.48		
CDPHE	PM_{10} TEOM	2012	44	89	100	2.3	2.0		-4.73	3.38	100	88
Ft. Collins 1405	FDMS $PM_{2.5}$	2012	8	58	100	2.0	2.9	-	-4.58	0.29		88
Grand Junction 1405	FDMS $PM_{2.5}$	2012	9	67	100	7.1	5.3		10.27	5.31		89
Boulder - Marine St.	FDMS $PM_{2.5}$	2012	9	67		3.8	3.9	-	-8.36	3.16		75
CAMP	FDMS $PM_{2.5}$	2012	24	100		2.4	2.5		-5.73	3.89		98
NJH	FDMS $PM_{2.5}$	2012	27	100		3.1	3.0		-6.81	3.87		87
DMAS[1]	FDMS $PM_{2.5}$	2012	14	100		2.9	2.7		-6.17	3.05		90
Colorado College	FDMS $PM_{2.5}$	2012	8	67		2.7	2.2		-4.62	3.27		82
Commerce City	$PM_{2.5}$ TEOM	2012	25	100		2.8	2.4		-4.94	4.67		95
Longmont	$PM_{2.5}$ TEOM	2012	8	58		1.8	2.1	-	-4.05	1.15		86
Chatfield	$PM_{2.5}$ TEOM	2012	6	42		2.0	2.9	-	-4.88	0.56		90
Greeley	$PM_{2.5}$ TEOM	2012	11	92		2.7	2.4		-3.45	5.07		92
CDPHE	$PM_{2.5}$ TEOM	1	39			2.2	2.2	-	-5.25	2.28		
CDPHE	$PM_{2.5}$ TEOM	2	46			3.1	2.7		-6.25	4.78		
CDPHE	$PM_{2.5}$ TEOM	3	35			3.4	3.1		-7.13	4.77		
CDPHE	$PM_{2.5}$ TEOM	4	31			2.9	2.6		-5.63	4.34		
CDPHE	$PM_{2.5}$	2012	150	81	100	3.7	2.7		-7.95	5.57	99	88

Site or Organization	Particulate Parameter	Quarter or Year	Precision Coun	Precision Completeness (%)	Prec. Within DQO	CV (%)	Bias (%)	+/- on bias	90% Probability Interval Probability Limits		% of Audit Points within	Data Completeness
	TEOM											

[1] DMAS NCore site was shut down and moved late August of 2012 producing only 3 quarters of valid data for 2012 at that site. All completeness data is calculated based on when the site was in operation only.

7. REFERENCES

Air Pollution Control Division. *Denver Metro Area/North Front Range 8-hour Ozone SIP - Emissions Inventory.* 2010.

AirNow. *Particulate Pollution and Your Health, What is Particulate Pollution?* 2003 1-September. http://www.airnow.gov/index.cfm?action=particle_health.page1 (accessed 2010 16-August).

American Lung Association. *The Perils of Particulates.* New York, 1994.

"Cardiovascular Toxicology." 6, no. 1 (2006).

City of Fort Collins. *Particulate Matter.* 2002 18-April. http://www.fcgov.com/airquality/particulate-matter.php (accessed 2010 17-August).

"Clean Air Act as ammended in 1977, Section 169a." In *42 USC 7491*. 1977.

Elizabeth C. Weatherhead, & Signe Bech Andersen. "The search for signs of recovery of the ozone layer." (Nature) 441 (2006).

Federal Register. *National Ambient Air Quality Standards for Ozone; Final Rule.* Vol. 73, chap. 60. 2008.

"National Primary and Secondary Ambient Air Quality Standards for Sulfer Dioxide." Chap. 50.5 in *Title 40, Code of Federal Regulations*. 2010.

Occupational Health and Safety Administration. *Guidelines for Carbon Monoxide.* 2007 8-January. http://www.osha.gov/SLTC/healthguidelines/carbonmonoxide/recognition.html (accessed 2010 17-August).

Pope, C. A., and Dockery, D.W. "Health Effects of Fine Particulate Air Pollution: Lines that Connect. 2006 Critical Review." *Air & Waste Managers Association*, 2006, 56 ed.

Pope, Thompson G. Pace and Anne. *National Emissions Inventory for Lead - Concepts and Quantities.* 2009.

United States Environmental Protection Agency. *1970-2008 Average Annual Emissions, SO2.* 2013 6-June. http://www.epa.gov/ttnchie1/trends (accessed 2013 16-August).

—. *1970-2012 Average Annual Emissions, CO.* 2013 6-June. http://www.epa.gov/ttn/chief/trends/ (accessed 2013 13-August).

—. *2008 Average Annual Emissions, SO2.* 2013 6-June. http://www.epa.gov/ttnchie1/trends/ (accessed 2013 16-August).

—. *2008 Average Annual Emissions, VOC.* 2013 6-June. http://www.epa.gov/ttnchie1/trends/ (accessed 2013 14-August).

—. *Air Quality Criteria for Oxides of Nitrogen.* 1982.

United States Environmental Protection Agency. "Carbon Monoxide." In *Air Trends.* 2009.

United States Environmental Protection Agency. "Carbon Monoxide." In *Air Quality Systems, Quick Look Report*. 2012.

—. *Ground Level Ozone.* 2009 27-May. http://www.epa.gov/air/airtrends/ozone.html (accessed 2010 16-August).

—. *Index.* 2010 16-August. http://www.epa.gov/air/data/index.html (accessed 2010 16-August).

United States Environmental Protection Agency. "Lead." In *Six Common Air Pollutants*. 2007.

United States Environmental Protection Agency. "Lead." In *National Air Quality Status and Trends Through 2007*. 2008.

United States Environmental Protection Agency. "Lead." In *Air Trends*. 2009.

United States Environmental Protection Agency. "Lead." In *Air Quality System, Quick Look Report*. 2012.

United States Environmental Protection Agency. "Miscellaneous Sources (Fugitive Dust and Ammonia)." In *Procedures Document for National Emissions Inventory, Criteria Air Pollutants*, 4-274. 1999.

—. *Monitor Value Reports - Criteria Air Pollutants.* 2008 2-July. http://www.epa.gov/air/data/monvals.html?us~usa~United%20States (accessed 2010 23-August).

—. *National Air Quality Status and Trends Through 2007.* 2008.

—. *National Ambient Air Quality Standards.* 2010 19-08. http://www.epa.gov/air/criteria (accessed 2010 19-08).

—. *National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data.* 2013 6-June. http://www.epa.gov/ttnchie1/trends/ (accessed 2013 16-August).

—. *National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data.* 2013 6-June. http://www.epa.gov/ttnchie1/trends/ (accessed 2012 16-August).
—. *National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data.* 2013 6-June. http://www.epa.gov/ttnchie1/trends/ (accessed 2013 16-August).
United States Environmental Protection Agency. "National Primary Ambient Air Quality Standards for Carbon Monoxide." Chap. 50.8 in *Title 40, Code of Federal Regulations*. 2009.
—. *Nitrogen Dioxide.* 2010 5-January. http://www.epa.gov/ttn/naaqs/standards/nox/s_nox_index.html (accessed 2010 16-August).
United States Environmental Protection Agency. "Nitrogen Dioxide." In *Air Quality Systems, Quick Look Report*. 2012.
United States Environmental Protection Agency. "Ozone." In *Air Trends*. 2009.
United States Environmental Protection Agency. "Ozone." In *Air Quality Systems, Quick Look Report*. 2010.
United States Environmental Protection Agency. "PM-10." In *Air Quality System, Quick Look Report*. 2012.
United States Environmental Protection Agency. "PM-2.5." In *Air Quality Systems, Quick Look Report*. 2012.
—. *Regulatory Actions.* December 15, 2010. http://epa.gov/air/lead/actions.html (accessed June 29, 2011).
United States Environmental Protection Agency. "Sulfer Dioxide." In *Air Trends*. 2006.
United States Environmental Protection Agency. "Sulfur Dioxide." In *Six Common Air Pollutants*. 2007.
United States Environmental Protection Agency. "Sulfur Dioxide." In *Air Quality System, Quick Look Report*. 2012.
United States Environmental Protection Agency. "Toxic Air Pollutants." In *Air Trends*. 2009.
United States Environmental Protection Agency. "Trends in NO2, CO, and SO2 Concentrations." In *Air Trends*. 2010.
"Visibility Protection for Federal Class 1 Areas." Chap. 51 in *Title 40 Code of Federal Regulations*, 300-309.
Weinmayr, G, E Romeo, M De Sario, S K Weiland, and F Forastiere. "Short-term effects of PM10 and NO2 on respiratory health amongh children with asthma-like symptoms: a systematic review of meta-analysis." *Environmental Health Perspectives* 118, no. 4 (April 2010): 449-57.
Wyoming Department of Environmental Quality. "A Conceptual Model of Winter Ozone Episodes in Southwest Wyoming." Final, Cheyenne, 2010.