COLORADO

Air Pollution Control Division

Department of Public Health & Environment

Technical Services Program

# 2020 Ambient Air Monitoring Network Assessment

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**GLOSSARY**

| | |
|---|---|
| AADT | Annual Average Daily Traffic |
| APCD | Air Pollution Control Division |
| AQS | Air Quality System (EPA database) |
| AQS ID | 9-digit site identification number used in the AQS database |
| ARS | Air Resources Specialists |
| BLM | Bureau of Land Management |
| CAA | Clean Air Act |
| CAMP | Continuous Air Monitoring Program |
| CAQCC | Air Quality Control Commission |
| CDOT | Colorado Department of Transportation |
| CDPHE | Colorado Department of Public Health and Environment |
| CFR | Code of Federal Regulations |
| CO | Carbon monoxide |
| CSA | Combined Statistical Area |
| FEM | Federal Equivalent Method |
| FRAPPÉ | Front Range Air Pollution and Photochemisty Éxperiment |
| FRM | Federal Reference Method |
| GIS | Geographic Information System |
| HEEJ | Health Equity and Environmental Justice collaborative |
| LUR | Land-Use Regression |
| MSA | Metropolitan Statistical Area |
| NAAQS | National Ambient Air Quality Standards |
| NCore | National Core multi-pollutant monitoring stations |
| NO | Nitric oxide |
| $NO_2$ | Nitrogen dioxide |
| $NO_x$ | Reactive nitrogen oxides |
| $NO_y$ | Total reactive nitrogen |
| NOAA | National Oceanic and Atmospheric Administration |
| $O_3$ | Ozone |
| NPS | National Park Service |
| $PM_{2.5}$ | Particulate matter with an equivalent diameter less than or equal to 2.5 μm |
| $PM_{10}$ | Particulate matter with an equivalent diameter less than or equal to 10 μm |
| PMSA | Principal Metropolitan Statistical Area |
| PWEI | Population Weighted Emissions Index |
| QA/QC | Quality Assurance/Quality Control |
| RAQC | Regional Air Quality Council |
| SDoH | Social Determinants of Health index |
| SIP | State Implementation Plan |
| SLAMS | State or Local Air Monitoring Stations |
| $SO_2$ | Sulfur dioxide |
| SPM | Special Purpose Monitor |
| SUIT | Southern Ute Indian Tribe |
| TSP | Total Suspended Particulates |
| μg | Microgram ($10^{-6}$ grams) |
| US EPA | United States Environmental Protection Agency |
| USFS | United States Forest Service |
| VOC | Volatile Organic Compound |
| WLC | Weighted Linear Combination |

## EXECUTIVE SUMMARY

On October 17, 2006, the U.S. Environmental Protection Agency (EPA) amended its ambient air monitoring regulations to include a requirement that all state and local air quality monitoring agencies prepare a technical assessment of their monitoring networks once every five years. This document describes the Colorado Department of Public Health and Environment (CDPHE) Air Pollution Control Division's (APCD) 2020 Ambient Air Monitoring Network Assessment.

### Purpose of the Assessment

The mission of the APCD is to provide our customers with excellent air quality management services that contribute to the protection of public health, the protection of ecosystems, and continual improvement of air quality related aesthetic values (e.g., visibility). The technical assessment presented here will provide decision-makers with the information needed to maximize the efficiency and effectiveness of Colorado's ambient air monitoring network. The assessment also ensures that APCD and its partners have the information needed to protect human health and the environment for current and future generations in Colorado.

As of May 1, 2020, APCD operated a network of 43 air pollution monitoring stations throughout Colorado. The data obtained from these monitors serves a variety of needs. The APCD has chosen the following eleven objectives as being those that most accurately define the overall purposes of the network:

1. To determine background concentrations,
2. To establish regulatory compliance,
3. To track pollutant concentration trends,
4. To assess population exposure,
5. To evaluate emissions reductions,
6. To evaluate the accuracy of model predictions,
7. To assist with forecasting,
8. To locate maximum pollutant concentrations,
9. To assure proper spatial coverage of regions,
10. To assist in source apportionment, and
11. To address environmental justice concerns.

### Assessment

To relate the value of its monitoring activities to its objectives and priorities, the APCD has evaluated the state network on a pollutant-by-pollutant basis to assess the relative value of each pollutant monitor and to identify areas where the inclusion of new monitoring sites would be most beneficial. This assessment was conducted in broad accordance with EPA guidance; however, the analyses and tools used here were assigned relative weights to reflect the unique objectives and priorities of the APCD within the context of the state of Colorado.

### Findings

Overall, the APCD monitoring network meets all federal requirements and adequately supports APCD monitoring objectives. However, while wholesale changes are not necessary at this time, there are several specific, targeted changes that could be made to improve the overall efficiency and effectiveness of the network. The resources saved from these modifications should be reinvested to address monitoring gaps and high priority future monitoring requirements.

**Recommendations**

Sites recommended for closure:

1) Discontinue carbon monoxide monitoring at the Greeley, Fort Collins, and Highway 24 sites due to low concentration values and low relative values within the network.
2) Discontinue ozone monitoring activities at the Welch site due to relatively low concentrations and high redundancy with nearby monitors.
3) Discontinue $PM_{10}$ monitoring activities at Cañon City, Aspen, and Telluride due to the low relative value of these sites.

Sites recommended for relocation:

1) Relocate the Cortez ozone monitor to an area of higher maximum concentrations.

Recommended new sites/monitors:

1) Collocated $NO_2$ monitors would be useful at high concentration ozone monitoring sites in the Front Range, particularly at Fort Collins - West and NREL.
2) Consider the addition of a new $PM_{2.5}$ monitoring site in the I-70 corridor near Vail/Eagle-Vail.

# 1 INTRODUCTION

The Air Pollution Control Division (APCD) of the Colorado Department of Public Health and Environment (CDPHE) has prepared the 2020 Ambient Air Monitoring Network Assessment as an examination and evaluation of the APCD's network of air pollution monitoring stations. The Network Assessment is an extension of the Network Plan, which is required to be submitted annually. The Network Assessment is required to be performed and submitted to the U.S. Environmental Protection Agency (EPA) every 5 years, with this third assessment due on July 1, 2020. The assessment must include specific analyses of the monitoring network, including: (1) a re-evaluation of the objectives and priorities for air monitoring, (2) an evaluation of the network's effectiveness and efficiency relative to its monitoring objectives, and (3) recommendations for network reconfigurations and improvements.

## 1.1 Background and Key Issues

The priorities and objectives of ambient air monitoring programs can change and evolve over time. Monitoring networks must therefore be re-evaluated and reconfigured on a periodic basis to ensure that objectives are obtained. Monitoring objectives may change for a number of different reasons, such as in response to changes in air quality. Air quality in the United States has improved dramatically since the adoption of the Clean Air Act and National Ambient Air Quality Standards (NAAQS).[1] For example, lead (Pb) concentrations in ambient air declined rapidly during the 1980s due to the phase-out of leaded gasoline (Eisenreich et al., 1986), and Pb monitoring activities were therefore deemphasized by the APCD and many other monitoring agencies. Changes in population and consumption patterns are another factor often motivating the re-evaluation of air monitoring programs. For instance, the U.S. population has become increasingly concentrated in suburban and exurban regions over the past 60 years, and rates of vehicle ownership and average distance driven have increased dramatically as the population has spread away from high-density urban centers (Kahn, 2000). This trend has resulted in the need for increased monitoring downwind of pollution sources due to enhanced production of photochemical smog in exurban and even rural environments (Sillman, 1999). Monitoring objectives may also change in response to the establishment of new air quality rules and regulations. Ambient air quality standards are periodically re-evaluated and reviewed by the EPA to ensure that they provide adequate health and environmental protection. This review process has often resulted in the establishment of new standards, including those that pertain to air toxics, fine particulate matter ($PM_{2.5}$), and regional haze. Objectives can also change due to improvements in our understanding of air quality processes or enhanced monitoring capabilities. The basic understanding of air quality issues and the capability to monitor air quality have both improved dramatically over the last five decades.

As a result of such changes, the APCD's air monitoring network may have unnecessary or redundant monitors. Alternatively, the network may be found to have inefficient network configurations for some pollutants, while other regions or pollutants may benefit from enhanced monitoring. This assessment will help the APCD to optimize its current network to help better protect today's population and environment, while maintaining the ability to understand long-term historical air quality trends.

## 1.2 Study Objectives

The objectives of this network assessment are three-fold: (1) to determine whether the existing network is meeting its intended monitoring objectives, (2) to evaluate the network's adequacy for characterizing

[1] http://www.epa.gov/airtrends/

current air quality and impacts from future industrial and population growth, and (3) to identify potential areas where new monitors can be sited or existing monitors removed to support network optimization and/or to meet new monitoring goals. To meet these objectives, a suite of analyses were performed to address the following questions:

- How well does the current monitoring network support current objectives? Which objectives are being met; which objectives are not being met? Are unmet objectives appropriate concerns for APCD? If so, what monitoring is necessary to meet those unaddressed objectives? What are potential future objectives for the monitoring network?
- Are the existing sites collectively capable of characterizing all criteria pollutants? Are the existing sites capable of characterizing criteria pollutant trends (spatially and temporally)? If not, what areas lack appropriate monitoring? If needed, where should new monitors be placed? Does the existing network support future emissions assessment, reconciliation, and modeling studies? Are there parameters at existing sites that need to be added to support these objectives?
- Is the current monitoring network sufficient to adequately assess regional air quality conditions with respect to all criteria pollutants? If not, where should monitors be relocated or added to improve the overall effectiveness of the monitoring network? How can the effectiveness of the monitoring network be maximized?

### 1.3 Guide to this Report

Section 1 resumes with an overview of the Colorado air monitoring network, including some general background on the geography of Colorado and the current state of air quality in the region, and ends with a general description of the assessment methodologies used in this report. Section 2 consists of a quantitative site-to-site comparison of the existing monitoring sites in the APCD network. In this section, a series of assessments are used to assign a relative score to each site to determine its comparative value within the network. Each assessment is assigned a weight and each site within the APCD monitoring network is then ranked by the weighted average of the analyses. Section 3 uses a Geographic Information System (GIS) driven suitability model to locate areas where the existing monitoring network does not adequately represent potential air pollution problems, and where additional sites are potentially needed. This evaluation has been conducted using a series of data maps representing a variety of indicators related to monitoring objectives. The maps are reclassified into a congruous ranking system and organized into three areas: source-oriented, population-oriented, and spatially-oriented. Each area and indicator is then assigned a weight and the spatial average of each weighted indicator is computed. This spatial average is then used to determine the optimal locations at which new monitors should be deployed. Section 4 provides recommendations based upon the evaluations described in the preceding sections. Recommendations concerning the addition of new sites or the relocation/discontinuation of existing sites reflect a variety of factors considered in the preceding evaluations, such as population density, pollution sources, monitoring history, compliance with air quality standards, and environmental justice concerns.

### 1.4 Overview of the Colorado Air Monitoring Network

The APCD currently operates monitors at 43 locations statewide. Ozone ($O_3$) and particulate matter (PM) monitors, including those for particulate matter < 10 µm in diameter ($PM_{10}$), and particulate matter < 2.5 µm in diameter ($PM_{2.5}$), are the most abundant and widespread. Currently, there are $PM_{10}$ monitors at 15 separate locations, $PM_{2.5}$ monitors at 17 locations, $O_3$ monitors at 20 locations, carbon monoxide (CO) monitors at seven locations, nitrogen dioxide ($NO_2$) monitors at six locations, and sulfur dioxide ($SO_2$)

monitors at four locations. The APCD also operates 17 meteorological sites statewide for the continuous measurement of wind speed, wind direction, resultant speed, resultant direction, standard deviation of horizontal wind direction, and temperature. Additionally, relative humidity is also monitored at seven of these locations and total solar radiation is monitored at two sites.

Within the particulate sampling network, the APCD operates both continuous and filter based sampling methods for $PM_{2.5}$ and $PM_{10}$. Continuous monitors sample without the need for subsequent filter retrieval and laboratory analysis, which is required for filter based equipment. Thus, these monitors can continuously record concentrations and send the results back to APCD headquarters on a nearly instantaneous basis. Currently, twelve sites are equipped to measure continuous $PM_{10}$ and, of those twelve sites, eight are located at sites also having filter based $PM_{10}$ monitors. Of the 17 $PM_{2.5}$ monitoring sites, 14 measure $PM_{2.5}$ on a continuous basis, 10 of these sites also having filter based samplers.

Thirty-six of the 43 current monitoring sites have been in operation for ten or more years, while 22 of these have been in operation for 20 or more years. Five monitoring sites have been in operation for more than 40 years. These sites are: Denver CAMP (55 years), Greeley - Hospital (53 years), Welby (47 years), Pagosa Springs School (45 years), and Steamboat Springs (45 years).

Three of the ozone monitoring sites that are located on the western slope and have data included in this report are operated and maintained by a third party contractor, Air Resource Specialists (ARS). These are the Rifle, Palisade and Cortez ozone monitoring sites. ARS keeps these sites in proper working order and performs regular QC checks and data retrieval, while the APCD conducts the independent auditing of the sites for Quality Assurance (QA) purposes.

### 1.4.1 APCD Monitoring History

The State of Colorado has been monitoring air quality statewide since the mid-1960s when high volume and tape particulate samplers, dustfall buckets, and sulfation candles were the state of the art for defining the magnitude and extent of the very visible air pollution problem (Riehl and Crow, 1962). Monitoring for gaseous pollutants (CO, $SO_2$, $NO_2$, and $O_3$) began in 1965 when the federal government established the Continuous Air Monitoring Program (CAMP) station in downtown Denver at the intersection of 21st Street and Broadway, which was the area that was thought at the time to represent the best probability for detecting maximum levels of most of the pollutants of concern. Instruments were primitive by comparison with those of today and were frequently out of service.

Under provisions of the original Federal Clean Air Act of 1970, the Administrator of the U.S. EPA established National Ambient Air Quality Standards (NAAQS) designed to protect the public's health and welfare. Standards were set for TSP, CO, $SO_2$, $NO_2$, and $O_3$. In 1972, the first State Implementation Plan (SIP) was submitted to the EPA. It included an air quality surveillance system in accordance with EPA regulations of August 1971. That plan proposed a monitoring network of 100 monitors (particulate and gaseous) statewide. The system established as a result of that plan and subsequent modifications consisted of 106 monitors.

The 1977 Clean Air Act Amendments required States to submit revised SIPs to the EPA by January 1, 1979. The portion of the Colorado SIP pertaining to air monitoring was submitted separately on December 14, 1979, after a comprehensive review, and upon approval by the Colorado Air Quality Control Commission. The 1979 EPA requirements as set forth in 40 CFR 58.20 have resulted in considerable modification to the network. These and subsequent modifications were made to ensure consistency and compliance with Federal monitoring requirements. Station location, probe siting, sampling methodology, quality assurance and quality control practices, and data handling procedures are all maintained throughout any changes made to the network.

### 1.4.2 Network Modification Procedures

The APCD develops changes to its monitoring network in several ways. New monitoring locations have been added as a result of community concerns about air quality, such as the $PM_{10}$ monitors in Cripple Creek and Hygiene established in 1998. Other monitors have been established in support of special studies, such as the $O_3$ monitoring sites in Aurora and Black Hawk.

Changes in property ownership represent the most common factor motivating network reconfigurations. The APCD owns neither the land nor the buildings where most of the monitors are located, and it is becoming increasingly difficult to get property owner's permission for use due to risk management issues. Other common reasons for relocating or removing monitors from the network are that either the land or building is modified in such a way that the site no longer meets current EPA siting criteria, or the area surrounding the monitor is being modified in a way that necessitates a change in the monitoring location. The most current examples of this are the removal of the Auraria meteorological monitoring station and the relocation of the NCore Denver Municipal Animal Shelter (DMAS) site. The Auraria station was removed due to the construction of a tall building in the immediate vicinity of the monitor that obstructed airflow around the monitoring site. The DMAS site was relocated due to a change in property ownership and land use. Monitors are also removed from the network after review of the data shows that pollutant levels have dropped to the point where it is no longer necessary to continue monitoring at a specific location.

Finally, all monitors are reviewed on a regular basis to determine if they are continuing to meet their monitoring objectives. If the population, land use, or vegetation around the monitor change undesirably over time, a more suitable location for the monitor is sought. An example of this is the $O_3$ monitor previously located at the Aspen Park monitoring site. It was shut down on 9/16/2019, and relocated to Black Hawk.

Detailed site descriptions of each monitoring location can be found in Table A.1 (Appendix A), which summarizes the locations and monitoring parameters of each site currently in operation, by county, alphabetically. The shaded lines in the table list the site AQS identification numbers, address, site start-up date, elevation, and longitude and latitude coordinates. Beneath each site description the table lists each monitoring parameter in operation at that site, the orientation and spatial scale, which national monitoring network it belongs to, the type of monitor in use, and the sampling frequency. The parameter date is the date when valid data were first collected.

### 1.4.3 Description of Monitoring Regions in Colorado

The state has been divided into eight multi-county areas that are generally based on topography and have similar airshed characteristics (see Section 1.4.4). 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. Figure 1 shows the approximate boundaries of these regions.

#### *1.4.3.1 Central Mountains*

The Central Mountains region consists of 12 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 features. Leadville, Steamboat Springs, Cañon City, Salida, Buena Vista, and Aspen represent the larger communities. The population of this region is 235,920, according to the 2014-2018 American Community Survey. 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 federal air quality standards.

The primary monitoring concern in this region is centered on particulate pollution from wood burning and road dust. Currently, there are three particulate monitoring sites operated by the APCD in the Central Mountains region. These sites are located in Steamboat, Aspen, and Canyon City. APCD does not currently operate any gaseous monitors in this region.

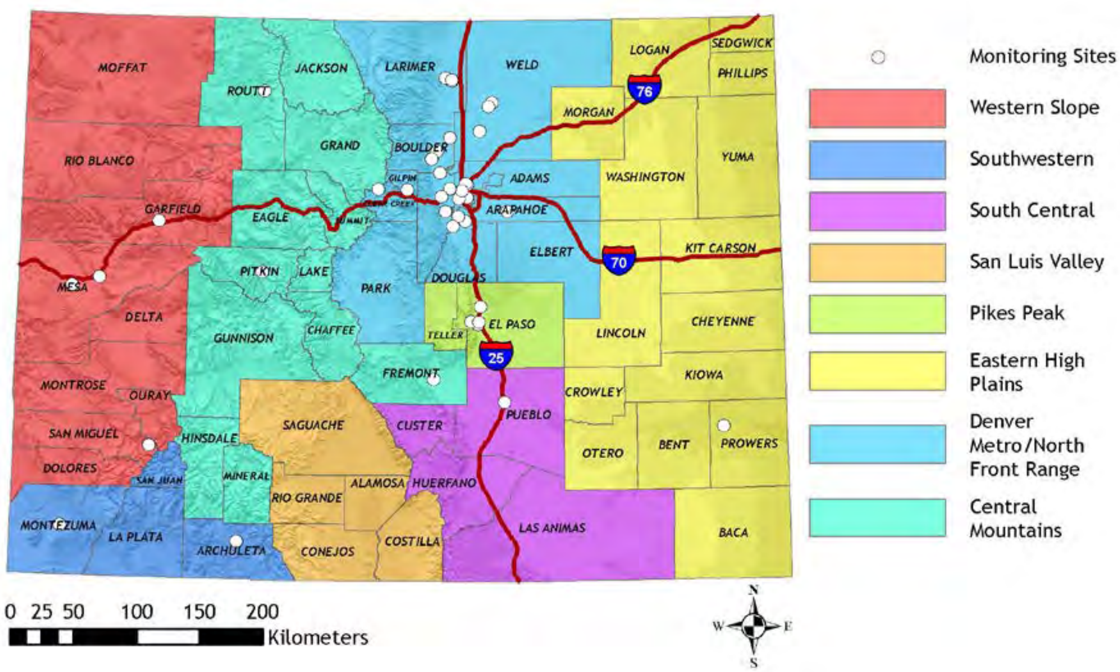


Figure 1. Counties and multi-county monitoring regions discussed in this report. Air quality monitoring sites measuring $O_3$, CO, $NO_2$, $SO_2$, $PM_{10}$, and $PM_{2.5}$ are symbolized with white circles.

### *1.4.3.2 Denver Metro/North Front Range*

The Denver-Metro/North Front Range region is comprised of 13 counties. It includes the largest population area of the state, with 2.85 million people living in the ten-county Denver-Aurora-Lakewood Metropolitan Statistical Area (MSA) and another 954,314 living in the northern Front Range areas of Boulder, Larimer, and Weld counties. This area includes Rocky Mountain National Park and several other wilderness areas.

Since 2002, the region complies with all NAAQS, except for ozone. The area has been exceeding the EPA's current 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 EPA designated the region as a "marginal" nonattainment area after a more stringent ozone standard was adopted in 2008. An even more stringent ozone standard was adopted in 2015.

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

There are currently 49 air quality and meteorological monitors at 25 individual sites in the Northern Front Range Region. There are six CO monitors, 15 $O_3$ monitors, six $NO_2$ monitors, three $SO_2$ monitors, as well as six $PM_{10}$ monitors, 13 $PM_{2.5}$ monitors, and 15 meteorological towers. There are also two air toxics monitoring sites, one located each at CAMP and at Platteville. The CAMP site monitors urban air toxics, while the Platteville site monitors air toxics and ozone precursors in a region of oil and gas development. In addition, there is one site that measures visual range by use of a nephelometer and a transmissometer.

#### *1.4.3.3 Eastern High Plains*

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 133,573 according to the 2014-2018 American Community Survey. Its major population 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 federal 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 Division 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.

For the Eastern High Plains region, there is currently only one $PM_{10}$ monitoring site located in Lamar. There are no gaseous pollutant or meteorological monitoring sites in this region.

#### *1.4.3.4 Pikes Peak*

The Pikes Peak region includes El Paso and Teller counties. The area has a population of approximately 712,226 according to the 2014-2018 American Community Survey. Eastern El Paso County is rural prairie, while the western part of the region is mountainous. 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. All of the area is currently in compliance with federal air quality standards.

Currently, there are four gaseous pollutants monitors at three sites and one particulate monitoring site in the Pikes Peak Region. There is one CO monitor, one $SO_2$ monitor, and two $O_3$ monitors, as well as one $PM_{10}$ and one $PM_{2.5}$ monitor in the region.

### *1.4.3.5 San Luis Valley*

Colorado's San Luis Valley region is in the south central portion of Colorado and is comprised of 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 114 km wide and 196 km long, extending south into New Mexico. The average elevation is 2290 km. Principal towns include Alamosa, Monte Vista, and Del Norte. The population of this region is 46,092 according to the 2014-2018 American Community Survey. 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. All of the area complies with federal air quality standards.

Currently, there are no monitoring sites located in the San Luis Valley.

### *1.4.3.6 South Central*

The South Central region is comprised of Pueblo, Huerfano, Las Animas, and Custer counties. Its population is approximately 190,087 according to the 2014-2018 American Community Survey. Population 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 federal 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.

Currently, there are no gaseous pollutant monitoring sites and one particulate monitoring site in the South Central Region. There is one $PM_{10}$ and one $PM_{2.5}$ monitor located in Pueblo.

### *1.4.3.7 Southwest*

The Southwestern region includes the Four Corners area counties of Montezuma, La Plata, Archuleta, and San Juan. The population of this region is about 94,462, according to the 2014-2018 American Community Survey. 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 the dominant industries, although the oil and gas industry is becoming increasingly important. All of the area complies with federal air quality standards.

Currently there is one gaseous and one particulate monitoring station in the region. There is one $O_3$ monitor located in Cortez and one $PM_{10}$ monitor located in Pagosa Springs.

### *1.4.3.8 Western Slope*

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 314,206, according to the 2014-2018 American Community Survey. 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 federal air quality standards.

Currently, there are two gaseous pollutant monitoring sites and 2 particulate monitoring sites in the Western Slope region.

### 1.4.4 Topography and Air Quality in Colorado

The "airshed" concept has been a useful tool in air quality management. Borrowed from the field of hydrology, the concept is based upon the assumption that topography separates regions of similar air quality and similar sources of air pollution. To the extent that air quality is affected by sources within an airshed, the airshed concept provides an easy way to identify the region of greatest impact associated with a source or group of sources.

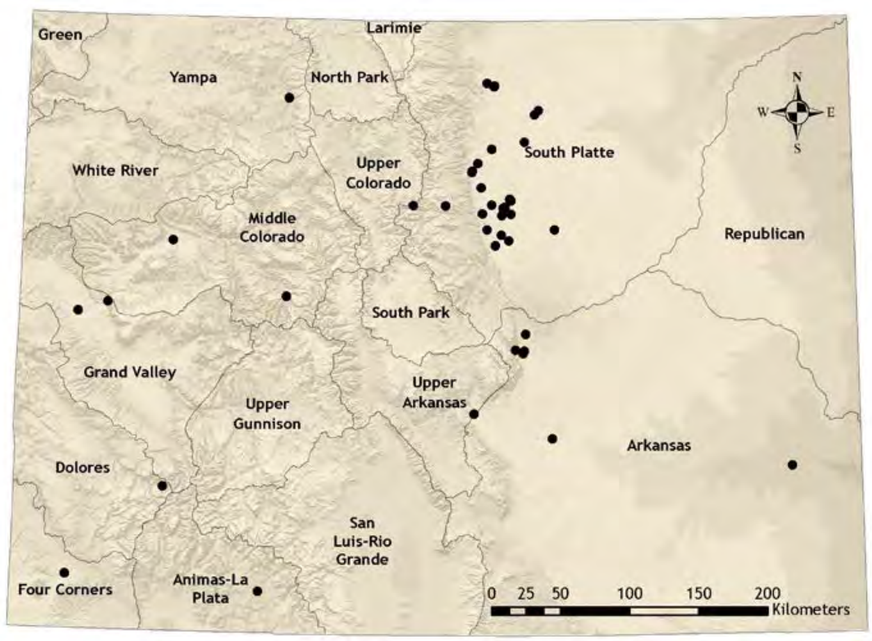


Figure 2. Shaded relief map showing the major airsheds of Colorado. CDPHE monitoring sites are symbolized by black circles.

The airshed concept is particularly relevant in mountainous areas and other regions of complex terrain (Greenland and Carleton, 1982). Daytime heating of elevated terrain creates localized low pressure that draws air up valleys and slopes toward ridge tops. This happens on both sides of an airshed boundary (ridge). In the absence of significant synoptic or regional-scale winds, flows diverge over ridge tops and return in an elevated "current" toward the center of the basin. This tends to isolate the daytime air in each basin. At night, radiational cooling creates slope flows that start at ridge tops (in the absence of synoptic-scale winds) and merge to form drainage flows in the valleys. These fill valleys with cooler air and form inversions that will tend to fill the entire depth of a mountain valley, regardless of the actual depth of the valley in question. Thus, to summarize, as long as larger-scale weather systems do not interfere, a mountain valley system tends to breath, with thermally-driven upslope flows during the day and down-valley slope and drainage flows at night (Doran, 1996).

The APCD has delineated the major airsheds of Colorado through a detailed examination of wind profiler data and temperature measurements across the state. The Colorado airshed scheme is based on the basin-defining topography of the state and estimated scales of basin flows and dispersion when synoptic-scale winds are minimal. This scheme is shown in Figure 2.

The Colorado airshed scheme will be used in this report in support of certain analytical techniques where it is necessary to account for the presence of distinct meteo-geographical boundaries within the state. These analytical techniques are described in detail in subsequent sections.

### 1.4.5 State-Wide Population Statistics

Colorado population data is obtained from the 2010 U.S. Census and the 2014-2018 American Community Survey (ACS), and is summarized in Table 1. The 2010 column refers to the U.S. Census and the 2018 column refers to the ACS. The counties have been grouped by both MSA and state monitoring region, as defined above. A map of the ACS census tract-level population data is presented in Figure 3.

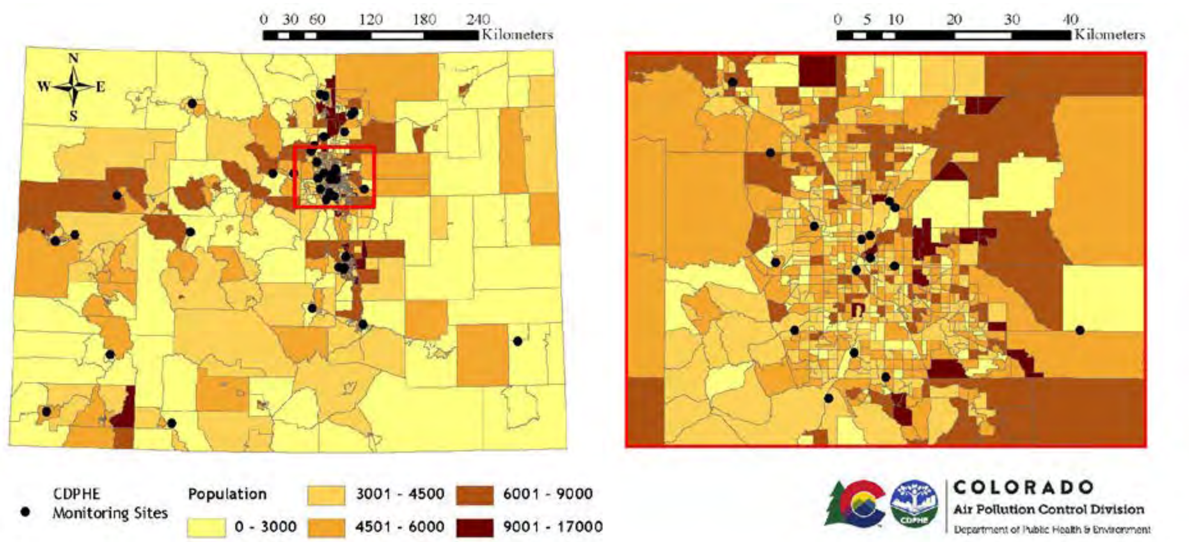


Figure 3. Population by census tract. CDPHE air quality monitoring sites are symbolized by black circles.

Table 1. (Cont.)[2] Population data grouped by county, monitoring region, and Metropolitan Statistical Area (MSA).

| Region | MSA/County | Population 2010 (U.S. Census) | Population 2018 (ACS) | % Change 2010-2018 |
|---|---|---|---|---|
| **Central Mountains** | | **225,793** | **235,920** | **4.5%** |
| | Chaffee | 17,835 | 19,164 | 7.4% |
| | Eagle | 52,064 | 54,357 | 4.4% |
| | Fremont | 46,856 | 47,002 | 0.3% |
| | Grand | 14,790 | 15,066 | 1.9% |
| | Gunnison | 15,314 | 16,537 | 8.0% |
| | Hinsdale | 825 | 878 | 6.4% |
| | Jackson | 1,417 | 1,296 | -8.5% |
| | Lake | 7,288 | 7,585 | 4.1% |
| | Mineral | 728 | 823 | 13.0% |
| | Pitkin | 17,147 | 17,909 | 4.4% |
| | Routt | 23,451 | 24,874 | 6.1% |
| | Summit | 28,078 | 3,0429 | 8.4% |
| **Denver Metro / North Front Range** | | **3,406,613** | **3,804,535** | **11.7%** |
| | ***BOULDER MSA (Boulder County)*** | ***295,610*** | ***321,030*** | ***8.6%*** |
| | ***DENVER-AURORA-LAKEWOOD MSA*** | ***2,556,218*** | ***2,850,211*** | ***11.5%*** |
| | Adams | 443,709 | 497,115 | 12.0% |
| | Arapahoe | 574,808 | 636,671 | 10.8% |
| | Broomfield | 56,098 | 66,120 | 17.9% |
| | Clear Creek | 9,083 | 9,379 | 3.3% |
| | Denver | 604,875 | 693,417 | 14.6% |
| | Douglas | 28,7119 | 328,614 | 14.4% |
| | Elbert | 23,140 | 25,162 | 8.7% |
| | Gilpin | 5,461 | 5,924 | 8.5% |
| | Jefferson | 535,648 | 570,427 | 6.5% |
| | Park | 16,277 | 17,392 | 6.8% |
| | ***FORT COLLINS MSA (Larimer County)*** | ***300,545*** | ***338,161*** | ***12.5%*** |
| | ***GREELEY MSA (Weld County)*** | ***254,240*** | ***295,123*** | ***16.1%*** |
| **Eastern High Plains** | | **136,777** | **133,573** | **-2.3%** |
| | Baca | 3,765 | 3,563 | -5.4% |
| | Bent | 6,523 | 5,809 | -10.9% |
| | Cheyenne | 1,811 | 2,039 | 12.7% |
| | Crowley | 5,850 | 5,630 | -3.7% |
| | Kiowa | 1,410 | 1,449 | 2.8% |
| | Kit Carson | 8,259 | 7,635 | -7.6% |
| | Lincoln | 5,502 | 5,548 | 0.8% |

[2] (Cont.) denotes a table that is either continued on the next page or has continued from the previous page.

Table 1. (Cont.)[2] Population data grouped by county, monitoring region, and Metropolitan Statistical Area (MSA).

| Region | MSA/County | Population 2010 (U.S. Census) | Population 2018 (ACS) | % Change 2010-2018 |
|---|---|---|---|---|
| | Logan | 22,291 | 21,689 | -2.7% |
| | Morgan | 28,213 | 28,257 | 0.2% |
| | Otero | 18,875 | 18,325 | -2.9% |
| | Phillips | 4,467 | 4,318 | -3.3% |
| | Prowers | 12,527 | 12,052 | -3.8% |
| | Sedgwick | 2,403 | 2,350 | -2.2% |
| | Washington | 4,851 | 4,840 | -0.2% |
| | Yuma | 10,030 | 10,069 | 0.4% |
| **Pikes Peak** | | **650,640** | **712,226** | **9.5%** |
| | ***COLORADO SPRINGS MSA*** | ***650,640*** | ***712,266*** | ***9.5%*** |
| | El Paso | 627,238 | 688,153 | 9.7% |
| | Teller | 23,402 | 24,113 | 3.0% |
| **San Luis Valley** | | **45,415** | **46,092** | **1.5%** |
| | Alamosa | 15,454 | 16,444 | 6.4% |
| | Conejos | 8,293 | 8,142 | -1.8% |
| | Costilla | 3,549 | 3,687 | 3.9% |
| | Rio Grande | 12,018 | 11,351 | -5.6% |
| | Saguache | 6,101 | 6,468 | 6.0% |
| **South Central** | | **185,734** | **190,087** | **2.3%** |
| | Custer | 4.248 | 4.640 | 9.2% |
| | Huerfano | 6.639 | 6.583 | -0.8% |
| | Las Animas | 15.383 | 14.179 | -7.8% |
| | ***PUEBLO MSA (Pueblo County)*** | ***159.464*** | ***164.685*** | ***3.3%*** |
| **Southwest** | | **89753** | **94462** | **5.2%** |
| | Archuleta | 12,082 | 12,908 | 6.8% |
| | La Plata | 51,443 | 55,101 | 7.1% |
| | Montezuma | 25,515 | 25,909 | 1.5% |
| | San Juan | 713 | 544 | -23.7% |
| **Western Slope** | | **309,210** | **314,206** | **1.6%** |
| | Delta | 30,897 | 30,346 | -1.8% |
| | Dolores | 2,084 | 1,841 | -11.7% |
| | Garfield | 56,153 | 58,538 | 4.2% |
| | ***GRAND JUNCTION MSA (Mesa County)*** | 146,587 | 149,998 | 2.3% |
| | Moffat | 13,812 | 13,060 | -5.4% |
| | Montrose | 41,179 | 41,268 | 0.2% |
| | Ouray | 4,471 | 4,722 | 5.6% |
| | Rio Blanco | 6,634 | 6,465 | -2.5% |
| | San Miguel | 7,393 | 7,968 | 7.8% |

## 1.5 Assessment Methodology

### 1.5.1 Parameters Assessed

This Network Assessment will address the criteria pollutants monitored by APCD during the period 2015-2019: carbon monoxide (CO), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), ozone ($O_3$), and two size fractions of particulate matter, $PM_{10}$ (particles < 10 µm in diameter), $PM_{2.5}$ (particles < 2.5 µm in diameter), and lead (Pb).

#### *1.5.1.1 Carbon Monoxide (CO)*

CO is a colorless and odorless gas formed when carbon compounds in fuel undergo incomplete combustion. The majority of CO emissions to ambient air originate from mobile sources (i.e., transportation), particularly in urban areas, where as much as 85% of all CO emissions may come from automobile exhaust. CO can cause harmful health effects by reducing oxygen delivery to the body's organs and tissues. High concentrations of CO generally occur in areas with heavy traffic congestion. In Colorado, peak CO concentrations typically occur during the colder months of the year when CO automotive emissions are highest and nighttime temperature inversions are more frequent (Reddy et al., 1995).

The EPA first set air quality standards for CO in 1971. For protection of both public health and welfare, EPA set an 8-hour primary standard at 9 parts per million (ppm) and a 1-hour primary standard at 35 ppm. In a review of the standards completed in 1985, the EPA revoked the secondary standards (for public welfare) due to a lack of evidence of adverse effects on public welfare at or near ambient concentrations. The last review of the CO NAAQS was completed in 2011 and the EPA chose not to revise the standards at that time.

The seven CO monitors currently operated by the APCD are associated both with State Maintenance Plan requirements and CFR requirements. However, the EPA has revised the minimum requirements for CO monitoring by requiring CO monitors to be sited near roads in certain urban areas. EPA has also specified that monitors required in CBSAs of 2.5 million or more persons are to be operational by January 1, 2015, and that monitors required in CBSAs of one million or more persons are required to be operational by January 1, 2017. A monitor has been collocated with the near roadway $NO_2$ site (I-25 Denver) to satisfy these requirements.

#### *1.5.1.2 Nitrogen Dioxide ($NO_2$)*

$NO_2$ is one of a group of highly reactive gasses known as "oxides of nitrogen," or nitrogen oxides ($NO_x$). Other $NO_x$ species include nitric oxide (NO), nitrous acid ($HNO_2$), and nitric acid ($HNO_3$). The EPA's National Ambient Air Quality Standard uses $NO_2$ as the indicator for the larger group of nitrogen oxides. $NO_2$ forms quickly from emissions from cars, trucks and buses, power plants, and off-road equipment. In addition to contributing to the formation of ground-level ozone, and fine particle pollution, $NO_2$ is linked with a number of adverse effects on the respiratory system (Kampa and Castanas, 2008).

The EPA first set standards for $NO_2$ in 1971, setting both a primary standard (to protect health) and a secondary standard (to protect the public welfare) at 0.053 parts per million (53 ppb), averaged annually. The Agency has reviewed the standards twice since that time, but chose not to revise the annual standards at the conclusion of each review. In January 2010, the EPA established an additional primary standard at

100 ppb, averaged over one hour. Together the primary standards protect public health, including the health of sensitive populations; i.e., people with asthma, children, and the elderly (Weinmayr et al., 2010).

The APCD has monitored $NO_2$ at eight locations in Colorado in the past. In 2020, the APCD will operate 6 $NO_2$ monitors. The Denver CAMP monitor exceeded the $NO_2$ standard in 1977, though the Welby monitor has never exceeded the standard of 53 ppb as an annual average. $NO_2$ concentrations have exhibited a gradual decline over the past 20 years.

The EPA has established requirements for an $NO_2$ monitoring network that will include monitors at locations where maximum $NO_2$ concentrations are expected to occur, including within 50 meters of major roadways, as well as monitors sited to measure area-wide $NO_2$ concentrations that occur more broadly across communities. Per these requirements, at least one monitor must be located near a major road in any urban area with a population greater than or equal to 500,000 people. A second monitor is required near another major road in areas with either: (1) population greater than or equal to 2.5 million people, or (2) one or more road segments with an annual average daily traffic (AADT) count greater than or equal to 250,000 vehicles. In addition to the near roadway monitoring, there must be one monitoring station in each CBSA with a population of 1 million or more persons to monitor a location of expected highest $NO_2$ concentrations representing the neighborhood or larger spatial scales. The CAMP and Welby sites satisfy this requirement.

### *1.5.1.3 Sulfur Dioxide ($SO_2$)*

Sulfur dioxide ($SO_2$) is one of a group of highly reactive gasses known as “oxides of sulfur,” or sulfur oxides ($SO_x$). The largest sources of $SO_2$ emissions are from fossil fuel combustion at power plants (73%) and other industrial facilities (20%). Smaller sources of $SO_2$ emissions include industrial processes such as extracting metal from ore, and the burning of high sulfur containing fuels by locomotives, large ships, and non-road equipment. $SO_2$ is linked with a number of adverse effects on the respiratory system (Kampa and Castanas, 2008; Ware et al., 1986). Furthermore, $SO_2$ dissolves in water and is oxidized to form sulfuric acid, which is a major contributor to acid rain, as well as fine sulfate particles in the $PM_{2.5}$ fraction, which degrade visibility and represent a human health hazard.

The EPA first promulgated standards for $SO_2$ in 1971, setting a 24-hour primary standard at 140 ppb and an annual average standard at 30 ppb (to protect health). A 3-hour average secondary standard at 500 ppb was also adopted to protect the public welfare. In 1996, the EPA reviewed the $SO_2$ NAAQS and chose not to revise the standards. However, in 2010, the EPA revised the primary $SO_2$ NAAQS by establishing a new 1-hour standard at a level of 75 parts per billion (ppb). The two existing primary standards were revoked because they were deemed inadequate to provide additional public health protection given a 1-hour standard at 75 ppb.

The APCD has monitored $SO_2$ at eight locations in Colorado in the past. Currently, there are four monitoring sites in operation. No area of the country has been found to be out of compliance with the current $SO_2$ standards.

$SO_2$ monitoring requirements include the need for calculating a Population Weighted Emissions Index (PWEI). This figure is calculated for each MSA by multiplying the population of the MSA by the $SO_2$ emissions for that MSA and dividing by 1 million. This PWEI value is then used to determine areas in need of $SO_2$ monitoring. A sum of the most recent emissions data by county give a total for $SO_2$ emissions of 15,235 tons per year for the Denver PMSA. The calculated PWEI for this region is 37,930 million persons-tons per year. This indicates the need for one $SO_2$ monitor in the Denver MSA according to the EPAs monitoring rules for $SO_2$. The CAMP, La Casa, and Welby sites satisfy this requirement.

Using the same calculation for the Colorado Springs MSA, the calculated PWEI is 8,207 million persons-tons per year. Because of the increase in population in Colorado Springs, there is a need for one $SO_2$ monitor in this MSA. The Highway 24 site satisfies this requirement.

#### *1.5.1.4 Ozone ($O_3$)*

$O_3$ is an atmospheric oxidant composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground-level is formed via photochemical reactions among $NO_x$ and volatile organic compounds (VOCs) in the presence of sunlight (Monks, 2005). Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents are some of the major sources of $NO_x$ and VOCs. Breathing ozone can trigger a variety of health problems, particularly for children, the elderly, and people of all ages who have lung diseases such as asthma (Kampa and Castanas, 2008; Lippmann, 1989). Urban areas generally experience the highest ozone concentrations, but even rural areas may be subject to increased ozone levels because air masses can carry ozone and its precursors hundreds of kilometers away from their original source regions (Holland et al., 1999; National Research Council, 1992).

Sunlight and warm weather facilitate the ozone formation process and lead to high concentrations. Ozone is therefore considered to be primarily a summertime pollutant. However, ozone can also be a wintertime pollutant in some areas. Emerging science has indicated that snow-covered oil and gas-producing basins in the western U.S. are subject to wintertime ozone concentrations well in excess of current air quality standards. High ozone concentrations in winter are thought to occur when stable atmospheric conditions allow for a build-up of precursor chemicals, and the reflectivity of the snow cover increases the rate of UV-driven reactions during the day. Ozone and its precursors are then effectively trapped under the inversion. The Upper Green River Basin in Wyoming has been studied to model such effects (Carter and Seinfeld, 2012). Exceptionally high ozone concentrations have also been measured in the Uintah basin in Utah under such conditions (Edwards et al., 2014). To ensure compliance with the 2008 and 2015 $O_3$ standards, the EPA has extended the $O_3$ monitoring requirements for Colorado by 5 months, essentially redefining Colorado’s $O_3$ season as January thru December.

In 1971, the EPA promulgated the first NAAQS for photochemical oxidants, setting a 1-hour primary standard at 80 pbb ($O_3$ is one of a number of chemicals that are common atmospheric oxidants). The level of the primary standard was then revised in 1979 from 80 ppb to 120 ppb and the chemical designation of the standard was changed from “photochemical oxidants” to “ozone.” In 1993, the EPA reviewed the $O_3$ NAAQS and chose not to revise the standards. However, in 1997, the EPA promulgated a new level of the NAAQS for $O_3$ of 80 ppb as an annual fourth-highest daily maximum eight-hour concentration, averaged over three years. The $O_3$ NAAQS was then revised in 2008 when the EPA set an 8-hour standard of 75 ppb. This change had a significant impact on the number of $O_3$ monitors in Colorado that were in violation of the standard, with the APCD then operating 5 sites out of 19 that had three-year design values (2012 - 2014) in excess of the current eight-hour $O_3$ NAAQS standard of 75 ppb (only three of these sites had design values in excess of 80 ppb). On October 26, 2015, the EPA again revised the $O_3$ NAAQS standard from its current value of 75 ppb to a level of 70 ppb. During 2019, there were seven sites that exceeded the NAAQS standard of 70 ppb.

The EPA’s monitoring requirements for $O_3$ include placing certain numbers of monitors in areas with high populations. For example, in Metropolitan Statistical Areas (MSAs) with a population greater than ten million people, the EPA recommends the placement of at least four monitors in areas with design value concentrations that are greater than or equal to 85% of the $O_3$ standard. The largest MSA in Colorado is the Denver-Aurora-Lakewood MSA. This MSA includes the counties of Adams, Arapahoe, Broomfield, Denver, Douglas, Elbert, Gilpin, Jefferson, and Park, and has a population of approximately 2.5 million. Table 2 lists EPAs $O_3$ monitoring requirements.

Table 2. EPA's minimum ozone monitoring requirements.

| MSA population | Most recent 3-year design value concentrations ≥ 85% of any $O_3$ NAAQS | Most recent 3-year design value concentrations < 85% of any $O_3$ NAAQS |
|---|---|---|
| > 10 million | 4 | 2 |
| 4 - 10 million | 3 | 1 |
| 350,000 - 4 million | 2 | 1 |
| 50,000 - 350,000 | 1 | 0 |

### *1.5.1.5 Particulate Matter (PM)*

Atmospheric particulate matter (PM) is microscopic solid or liquid mass suspended in the air. PM can be made up of a number of different components, including acidic aerosols (i.e., nitrates and sulfates), organic carbon, 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, or composition.

Particle size is the factor most directly linked to the health impacts of atmospheric PM. Particles of less than 10 micrometers (µm) in diameter ($PM_{10}$) are inhalable and thus pose a health threat. Particles less than 2.5 µm in diameter ($PM_{2.5}$) can penetrate deeply into the alveoli, while the smallest particles, such as those less than 0.1 µm in diameter (ultrafine particles), can penetrate all the way into the bloodstream. Exposure to such particles can affect the lungs, the heart, and the cardiovascular system (Pope III and Dockery, 2006). Particles with diameters between 2.5 µm and 10 µm ($PM_{10-2.5}$) represent less of a health concern, although they can irritate the eyes, nose, and throat, 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). Note that $PM_{10}$ encompasses all particles smaller than 10 microns, including the $PM_{2.5}$ and ultrafine fractions.

EPA first established standards for PM in 1971. The reference method specified for determining attainment of the original standards was the high-volume sampler, which collects PM up to a nominal size of 25 to 45 µm (referred to as total suspended particulates or TSP). The primary standards, as measured by the indicator TSP, were 260 µg $m^{-3}$ (as a 24-hour average) not to be exceeded more than once per year, and 75 µg $m^{-3}$ (as an annual geometric mean). In October 1979, the EPA announced the first periodic review of the air quality criteria and NAAQS for PM, and significant revisions to the original standards were promulgated in 1987. In that decision, the EPA changed the indicator for particles from TSP to $PM_{10}$. EPA also revised the level and form of the primary standards. The EPA promulgated significant revisions to the NAAQS again in 1997. In that decision, the EPA revised the PM NAAQS in several respects. While it was determined that the PM NAAQS should continue to focus on particles less than or equal to 10 µm in diameter (i.e., $PM_{10}$), the EPA also decided that the fine and coarse fractions of $PM_{10}$ should be considered separately. The Agency's decision to modify the standards was based on evidence that serious health effects were associated with short- and long-term exposure to fine particles in areas that met the existing $PM_{10}$ standards (Heal et al., 2012). The EPA added new standards, using $PM_{2.5}$ as the indicator for fine particles and using $PM_{10}$ as the indicator for the $PM_{10-2.5}$ fraction. The EPA established two new $PM_{2.5}$ standards: an annual standard of 15 µg $m^{-3}$, based on the 3-year average of annual arithmetic mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors, and a 24-hour standard of 65 µg $m^{-3}$, based on the 3-year average of the 98th percentile of 24-hour $PM_{2.5}$ concentrations at each population-oriented monitor within an area. These standards were modified again in 2006 and 2012. The current NAAQS for $PM_{10}$ is a primary 24-hour standard of 150 µg $m^{-3}$ not to be exceeded more than once per year on average over 3 years. There are currently three NAAQS for $PM_{2.5}$: (1) a primary annual standard of 12 µg $m^{-3}$, based on the 3-year average of annual arithmetic mean $PM_{2.5}$ concentrations, (2) a secondary annual standard of 15 µg $m^{-3}$, based on the 3-year average of annual arithmetic mean $PM_{2.5}$ concentrations, and (3) and a 24-hour standard of 35 µg $m^{-3}$, based on the 3-year average of the 98th percentile of 24-hour $PM_{2.5}$ concentrations.

*$PM_{10}$*

In 2020, the APCD will operate $PM_{10}$ monitors at 15 different locations. Eleven of these sites use manual filter-based $PM_{10}$ samplers and eight are also equipped with collocated continuous (i.e., “hourly”) monitors. There are four sites with collocated filter-based samplers (CAMP, La Casa, Longmont, and Grand Junction - Powell Bldg.).

*$PM_{2.5}$*

$PM_{2.5}$ concentration values are reported in four different groups of readings by the APCD. Data from instruments sampling according to the Federal Reference Method (FRM) are reported with the 88101 parameter code, data from continuous samplers that reasonably compare to the FRM are reported with the 88500 parameter code, data from continuous samplers that don't compare reasonably to the FRM are reported with the 88501 parameter code, and speciation data is reported with the 88502 parameter code. There are 10 FRM instruments at 9 sites. Of these 9 sites, six are collocated with a continuous instrument and two are collocated with another FRM; one site (Rifle) has a continuous $PM_{2.5}$ monitor but no FRM. Speciation samples are taken at three sites, which are all collocated with an FRM instrument.

#### *1.5.1.6 Lead (Pb)*

Lead is a metal found naturally in the environment and in manufactured products. The major sources of lead in ambient air 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 sources of lead emissions in the air today. The highest levels of airborne lead are generally found near lead smelters and general aviation airports. Other stationary sources include waste incinerators, utilities, and lead-acid battery manufacturers. Exposure to lead occurs mainly through inhalation of air and ingestion of lead in food, water, soil, or dust. Exposure to lead is linked to neurological impairments such as seizures, intellectual disability, and behavioral disorders.

On October 15, 2008, EPA strengthened the National Ambient Air Quality Standards for lead. The level for the previous lead standard was 1.5 µg $m^{-3}$, not to be exceeded as an average for a calendar quarter, based on an indicator of lead in total suspended particulates (TSP). The new standard, measured in either TSP or low-volume PM10 samples, has a level of 0.15 µg $m^{-3}$, not to be exceeded as an average for any rolling three-month period within three years. Monitoring for lead is required at non-airport sources which emit 0.50 or more tons per year and from each airport which emits 1.0 or more tons per year based on either the most recent National Emission Inventory or other scientifically justifiable methods and data

The last lead-specific sampling in Colorado, at the La Casa NCore site, was discontinued on December 31, 2015 due to low concentrations and not being required. Lead monitoring was also performed at Centennial Airport in the past, but was discontinued due to low concentrations and due to lead emissions being below 1 ton per year. Lead does continue to be monitored as part of National Air Toxics Trends Stations project on $PM_{10}$ samplers in Grand Junction and via three $PM_{2.5}$ Speciation Trends Network sites.

### 1.5.2 Current State of Air Quality in Colorado

Table 3 summarizes the 2019 criteria pollutant design value data for all sites operated by the APCD. For the purposes of determining compliance with regulatory standards, three-year average design values are compared to the NAAQS value for many of the criteria pollutants evaluated here (see Table 19). Three-year average design values are presented in Section 2 of this report and are used in various analyses. The 2019 values are presented in Table 3 to provide a summary of the most recent data. Detailed site information is provided in subsequent sections of this Introduction and in Table A-1 of Appendix A.

Currently, all State and Local Air Monitoring Station (SLAMS) and Special Purpose Monitor (SPM) sites are in attainment for CO, $NO_2$, $SO_2$, $PM_{10}$, and $PM_{2.5}$. During 2019, there were seven $O_3$ monitoring sites in the APCD network that had three-year average fourth-highest daily maximum eight-hour concentrations in excess of the $O_3$ NAAQS. These sites are all located in the Denver Metro/North Front Range region. There was one exceedance of the $PM_{10}$ standard in 2019. This exceedance, which was recorded at the Steamboat Springs (08-007-0003) monitoring site, was due to dust from sweeping an adjacent parking lot and has been discussed with the city.

Table 3. Summary of 2019 CO, $NO_2$, $SO_2$, $O_3$, $PM_{10}$, and $PM_{2.5}$ design values.

| Site Name | Pollutant | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | CO (ppm) | | $NO_2$ (ppb) | | $SO_2$ (ppb) | $O_3$ (ppb) | $PM_{10}$ ($\mu g\ m^{-3}$) | $PM_{2.5}$ ($\mu g\ m^{-3}$) | |
| | **8-Hr** | **1-Hr** | **Annual** | **1-Hr** | **1-Hr** | **4th Max 8-Hr** | **24-Hr** | **Annual** | **24-Hr** |
| Arapahoe Comm. Coll. | | | | | | | | 6.0 | 26.6 |
| Aspen | | | | | | | 50 | | |
| Aurora East | | | | | | 66 | | | |
| Black Hawk | | | | | | 64 | | | |
| Boulder - Chamber | | | | | | | 53 | 5.8 | 19.0 |
| Boulder Reservoir | | | | | | 69 | | | |
| CAMP | 1.6 | 2.4 | 18.6 | 66.0 | 6.6 | 67 | 79 | 7.0 | 23.8 |
| Cañon City | | | | | | | 31 | | |
| Chatfield | | | | | | 78 | | 6.2 | 25.1 |
| Colorado College | | | | | | | 38 | 5.7 | 13.2 |
| Cortez | | | | | | 60 | | | |
| Ft. Collins - CSU | | | | | | | | 6.0 | 19.7 |
| Ft. Collins - Mason | 1.3 | 2.1 | | | | 64 | | | |
| Ft. Collins - West | | | | | | 71 | | | |
| GJ - Powell Bldg. | | | | | | | 47 | 5.5 | 14.5 |
| Greeley - Hospital | | | | | | | | 9.1 | 25.7 |
| Highland | | | | | | 73 | | | |
| HWY 24 | 1.6 | 2.6 | | | 9.6 | | | | |
| La Casa | 1.3 | 1.7 | 18.4 | 60.0 | 7.1 | 65 | 61 | 7.5 | 22.0 |
| Lamar - Mun. | | | | | | | 105 | | |
| Longmont - Mun. | | | | | | | 58 | 7.4 | 35.7 |
| Manitou Springs | | | | | | 64 | | | |
| I-25 Denver | 2.0 | 2.6 | 24.1 | 69.4 | | | | | |
| I-25 Globeville | | | 26.7 | 68.7 | | | | | |
| NREL | | | | | | 75 | | | |
| Pagosa Springs | | | | | | | 68 | | |
| Palisade | | | | | | 63 | | | |
| Platteville | | | | | | | | 7.3 | 22.9 |
| Pueblo | | | | | | | 89 | 5.5 | 8.4 |
| Rifle - Health Dept. | | | | | | 57 | | | |
| Rocky Flats North (RFN) | | | 3.6 | 28.8 | | 72 | | | |
| Steamboat Springs | | | | | | | 228 | | |
| Telluride | | | | | | | 61 | | |
| Tri-County Health | | | | | | | 119 | 9.0 | 22.6 |
| USAFA | | | | | | 65 | | | |
| Welby | 1.3 | 1.7 | 16.6 | 61.8 | 5.7 | 60 | 75 | | |
| Welch | | | | | | 72 | | | |
| Weld Co. Tower | 0.8 | 1.3 | | | | 63 | | | |

### 1.5.3 Technical Approach

A number of different quantitative indicators are used in this report to compare sites within the existing network and to identify areas where the inclusion of new monitoring sites would be most beneficial. The indicators were chosen to represent a number of variables relevant to air pollution: population density, traffic volume, stationary source density, modeled and measured concentrations, etc. However, each indicator is not necessarily of equal importance to the overall analysis, and the relative importance of each indicator should be expected to vary among pollutants. For example, while traffic volume and point source density (i.e., “source-oriented” indicators) may be good predictors of CO, $SO_2$, and $NO_2$ concentration, these indicators are less relevant for $O_3$, a secondary pollutant whose concentration is often reduced via $NO_x$ titration in areas immediately surrounding pollution sources. To reflect this variability among the factors addressed in the assessment, APCD has determined weights of relative importance to use when combining the individual indicators for each parameter assessed.

Decisions regarding the types of indicators used and their weights of relative importance were ultimately based on the purposes, objectives, and priorities of the APCD monitoring network as decided by technical experts and program managers at the APCD. Before beginning the network assessment, the objectives of the network were reviewed and prioritized. The APCD has chosen the following eleven objectives as being those that most accurately define the overall purposes of the network:

1. To determine background concentrations,
2. To establish regulatory compliance,
3. To track pollutant concentration trends,
4. To assess population exposure,
5. To evaluate emissions reductions,
6. To evaluate the accuracy of model predictions,
7. To assist with forecasting,
8. To locate maximum pollutant concentrations,
9. To assure proper spatial coverage of regions,
10. To assist in source apportionment, and
11. To address environmental justice concerns.

Each analytical technique used in the technical assessment was selected to support a specific objective of the overall network. This technical assessment consists of two phases: site-to-site comparisons and suitability modeling. These two assessment phases are briefly described below.

#### *1.5.3.1 Phase I: Site-to-Site Comparisons*

Site-by-site comparison analyses, described in detail in Section 2, assign a score to individual monitors according to a specific monitoring purpose. These analyses are good for assessing which monitors might be candidates for modification or removal.

Several steps are involved in a site-by-site analysis:

1. Determine which monitoring purposes are most important,
2. Assess the history of the monitor (including original purposes),
3. Select a list of site-by-site analysis indicators based on purposes and available resources,
4. Weight indicators based on the importance of their related purpose,
5. Score monitors for each indicator,
6. Sum scores and rank monitors, and
7. Examine lowest ranking monitors for possible resource reallocation.

The low-ranking monitors should be examined carefully on a case-by-case basis. There may be regulatory or historical reasons to retain a specific monitor. Also, the site could be made potentially more useful by monitoring a different pollutant or using a different technology.

Table 4 describes the site-to-site comparison analyses used in Section 2 of the assessment.

Table 4. Site-to-site comparison analyses used in this report.

| Analysis | Description | Objectives Assessed |
|---|---|---|
| Number of Parameters Monitored | Multiple pollution parameters monitored at a site make that site more cost-effective. This analysis is the primary indicator of economic value of a site. | Evaluate model predictions<br>Source apportionment |
| Trends Impact | This analysis ranks sites by the length of their continuous monitoring records. Monitors that have longer historical records are more valuable for tracking long-term trends. | Track concentration trends<br>Evaluate emissions trends |
| Measured Concentration | This analysis ranks sites by their design value. Sites measuring higher concentrations are more important from a regulatory perspective. | Locate max concentrations<br>Establish regulatory compliance |
| Deviation from the NAAQS | This analysis ranks sites by the difference between their design value and the NAAQS. Sites near the NAAQS are considered more important. Sites well above or below the NAAQS do not provide as much information in terms of regulatory compliance. | Establish regulatory compliance<br>Assist with forecasting |
| Monitor-to-Monitor Correlation | Measured concentrations at one monitor are compared to those measured at other monitors to determine if concentrations correlate temporally. Monitors with lower correlations have more unique value and are ranked higher. | Assure proper spatial coverage |
| Removal Bias | Measured values for each individual pollutant are interpolated across the entire study area. Sites are systematically removed and the interpolation is repeated. The difference between the measured concentration and the predicted concentration is the site's removal bias. The greater a site's bias, the higher its ranking. | Assure proper spatial coverage<br>Evaluate model predictions |
| Area Served | Sites are ranked based on their spatial coverage. Sites serving larger areas are ranked higher. | Assure proper spatial coverage<br>Determine background |
| Population Served | Using the Area Served polygons, the number of people living within each polygon is calculated. Sites serving higher populations are ranked higher. | Assess population exposure<br>Environmental justice |
| Emissions Inventory | Total annual emissions are aggregated by site using the Area Served polygons. Sites with higher emissions are ranked higher. | Evaluate emissions reductions Locate maximum concentrations |
| Traffic Counts | Uses current Annual Average Daily Traffic (AADT) data from both highways and major roads within the study area. Area Served polygons are used to assign a traffic volume to each monitoring site. A second indicator of road density is also calculated for each polygon, and a weighted average is created. Sites with higher traffic counts are ranked higher. | Evaluate emissions reductions Locate maximum concentrations |

### *1.5.3.2 Phase II: Suitability Modeling*

Suitability modeling, which is described in detail in Section 3, has been conducted to determine areas where the existing monitoring network does not adequately represent potential air pollution problems, and where additional sites are potentially needed. This is considered a “bottom-up” technique, as it examines directly the phenomena that are thought to cause high pollutant concentrations and/or population exposure, such as emissions (traffic and stationary) and population density. For example, emissions inventory data can be used to determine the areas of maximum expected concentrations of pollutants directly emitted (i.e., primary emissions). Emission inventory data are less useful to understand secondary pollutants formed in the atmosphere (i.e., $O_3$, $PM_{2.5}$). Suitability models are developed using a series of data maps representing a variety of indicators. The maps are reclassified into a congruous ranking system and organized into three purpose areas: source-oriented, population-oriented, and spatially-oriented. Each area and indicator is then assigned a weight, and the spatial average of each weighted indicator is computed. This spatial average is then used to determine the optimal locations at which new monitors should be deployed. In general, the results of these analyses indicate where monitors are best located based on specific objectives and expected pollutant behavior. However, the development of a useful suitability model relies on a thorough understanding of the phenomena that cause air quality problems, including the often complex source/sink relationships that determine pollutant concentrations in ambient air.

Table 5 describes the indicators used in the suitability model, the results of which are described in Section 3 of the assessment.

Table 5. Suitability model indicators used in this report.

| | Analysis | Description | Objectives Assessed |
|---|---|---|---|
| Source - Oriented | Emissions Inventory | Uses the point-source emissions inventory data from Section 2 to identify areas of the highest point source pollution that are least represented by existing monitors. | Evaluate emissions reductions<br>Locate maximum concentrations |
| | Traffic Counts | Uses traffic density and road density maps from Section 2 to identify areas of the highest traffic pollution that are least represented by existing monitors. | |
| Population-Oriented | Population Density | Uses population density maps from Section 2 to identify areas of high population density that are least represented by existing monitors. | Assess population exposure<br>Environmental justice |
| Spatially-Oriented | Distance from an Existing Monitor | Uses the ground distance between existing monitoring sites to identify areas of the state least represented by existing monitors. | Assure proper spatial coverage<br>Determine background |
| | Interpolation Map | Uses interpolation maps generated with monitoring data to identify areas of high pollutant concentration that are least represented by existing monitors. | Locate max concentrations<br>Establish regulatory compliance<br>Evaluate model predictions |

### 1.5.4 Data Sources

Raw air pollution data for all of the analyses were obtained from the EPA's Air Quality System (AQS) database. Data were extracted for the five-year period 2015-2019. Yearly and five-year averages were derived from the raw data. Other summary statistics were calculated as needed, such as maximum values or the fourth-highest 8-hour $O_3$ concentration at a particular monitoring site. For the monitor-to-monitor correlation study, concentration data was averaged over 24-hour periods for all criteria pollutants. One advantage of averaging data at a single time resolution is that this technique normalizes data that has been collected at differing intervals; e.g., $PM_{10}$ concentrations that had been collected at 24-hour intervals vs. gaseous pollutant concentrations that are typically reported on an hourly basis.

Population data were obtained from the 2010 U.S. Census and the 2014-2018 American Community Survey (ACS).

Point source emissions data was obtained from the 2020 APCD facilities inventory, which lists reported emissions for over 28,000 permitted facilities within Colorado.

Road data and average annual daily traffic (AADT) counts were obtained from the Colorado Department of Transportation (CDOT). The most current available traffic count data from 2018 were used exclusively in this assessment.

### 1.5.5 Sites Considered in this Network Assessment

This network assessment takes into account all monitoring sites included in the AQS database and located within Colorado, including those sites operated by the U.S. Forest Service (USFS), the National Park Service (NPS), the Bureau of Land Management (BLM), the Southern Ute Indian Tribe (SUIT), the EPA, and the city of Aspen. Since most analytical assessments take into account the spatial location of existing monitoring sites, it is logical to include sites operated by other agencies, especially since data from these sites are available in the AQS database. Inclusion of these other sites also greatly increases the power of spatial interpolations, which play an important role in this assessment. However, only APCD sites are explicitly evaluated here. Four APCD-operated sites with data available in the AQS database are not assessed in this report. These sites include two $PM_{2.5}$ monitoring stations (Boulder - CU - Athens and NJH-E) that are equipped only with continuous monitors. These sites are not included in the assessment because the hourly data obtained with these monitors is not comparable to that obtained from the filter-based FRM samplers. Furthermore, because the continuous $PM_{2.5}$ network addresses the monitoring objective of providing timely data to the public, an objective that is not addressed explicitly in the assessment, that network will not be evaluated here. Other sites not considered include the Arvada, Grand Junction - Pitkin, and DESCI sites, which do not measure any criteria pollutants.

Table 6 lists all of the APCD sites used in this assessment.

Table 6. APCD monitoring sites considered in this assessment. Detailed site descriptions can be found in Appendix A.

| AQS Site Number | Site Name | County | Parameters Monitored | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $O_3$ | CO | $NO_2$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | Met |
| 08-001-0008 | Tri County Health (TCH) | Adams | | | | | **X** | **X** | |
| 08-001-3001 | Welby | Adams | **X** | **X** | **X** | **X** | **X** | | **X** |
| 08-005-0002 | Highland Reservoir | Arapahoe | **X** | | | | | | **X** |
| 08-005-0005 | Arapaho Community College | Arapahoe | | | | | | **X** | |
| 08-005-0006 | Aurora - East | Arapahoe | **X** | | | | | | **X** |
| 08-007-0001 | Pagosa Springs School | Archuleta | | | | | **X** | | |
| 08-013-0003 | Longmont - Municipal Bldg. | Boulder | | | | | **X** | **X** | |
| 08-013-0012 | Boulder Chamber of Commerce | Boulder | | | | | **X** | **X** | |
| 08-013-1001 | Boulder - CU | Boulder | | | | | | **X** | |
| 08-013-0014 | Boulder Reservoir | Boulder | **X** | | | | | | **X** |
| 08-019-0006 | Mines Peak | Clear Creek | **X** | | | | | | |
| 08-031-0002 | CAMP | Denver | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| 08-031-0013 | National Jewish Health (NJH) | Denver | | | | | | **X** | |
| 08-031-0026 | La Casa | Denver | **X** | **X** | | **X** | **X** | **X** | **X** |
| 08-031-0027 | I-25 Denver | Denver | | **X** | **X** | | | **X** | **X** |
| 08-031-0028 | I-25 Globeville | Denver | | | **X** | | | **X** | **X** |
| 08-035-0004 | Chatfield State Park | Douglas | **X** | | | | | **X** | **X** |
| 08-041-0013 | U.S. Air Force Academy (USAFA) | El Paso | **X** | | | | | | |
| 08-041-0015 | Highway 24 | El Paso | | **X** | | **X** | | | **X** |
| 08-041-0016 | Manitou Springs | El Paso | **X** | | | | | | |
| 08-041-0017 | Colorado College | El Paso | | | | | **X** | **X** | |
| 08-043-0003 | Cañon City | Fremont | | | | | **X** | | |
| 08-045-0012 | Rifle – Health Dept. | Garfield | **X** | | | | | | |
| 08-047-0003 | Black Hawk | Gilpin | **X** | | | | | | |
| 08-059-0002 | Arvada | Jefferson | | | | | | | **X** |
| 08-059-0005 | Welch | Jefferson | **X** | | | | | | **X** |
| 08-059-0006 | RFN | Jefferson | **X** | | **X** | | | | **X** |
| 08-059-0011 | NREL | Jefferson | **X** | | | | | | |
| 08-069-0009 | Fort Collins – CSU - Edison | Larimer | | | | | | **X** | |
| 08-069-0011 | Fort Collins - West | Larimer | **X** | | | | | | |
| 08-069-1004 | Fort Collins - Mason | Larimer | **X** | **X** | | | | | **X** |
| 08-077-0017 | Grand Junction (GJ) – Powell Bldg | Mesa | | | | | **X** | **X** | |
| 08-077-0018 | Grand Junction (GJ) – Pitkin | Mesa | | | | | | | **X** |
| 08-077-0020 | Palisade - Water Treatment | Mesa | **X** | | | | | | **X** |
| 08-083-0006 | Cortez – Health Dept | Montezuma | **X** | | | | | **X** | |
| 08-097-0006 | Aspen - Library | Pitkin | | | | | **X** | | |
| 08-099-0002 | Lamar - Municipal Bldg. | Prowers | | | | | **X** | | |
| 08-101-0015 | Pueblo – Fountain School | Pueblo | | | | | **X** | **X** | |
| 08-107-0003 | Steamboat Springs | Routt | | | | | **X** | | |
| 08-113-0004 | Telluride | San Miguel | | | | | **X** | | |
| 08-123-0006 | Greeley - Hospital | Weld | | | | | | **X** | |
| 08-123-0008 | Platteville Middle School | Weld | | | | | | **X** | |
| 08-123-0009 | Greeley –County Tower | Weld | **X** | **X** | | | | | **X** |

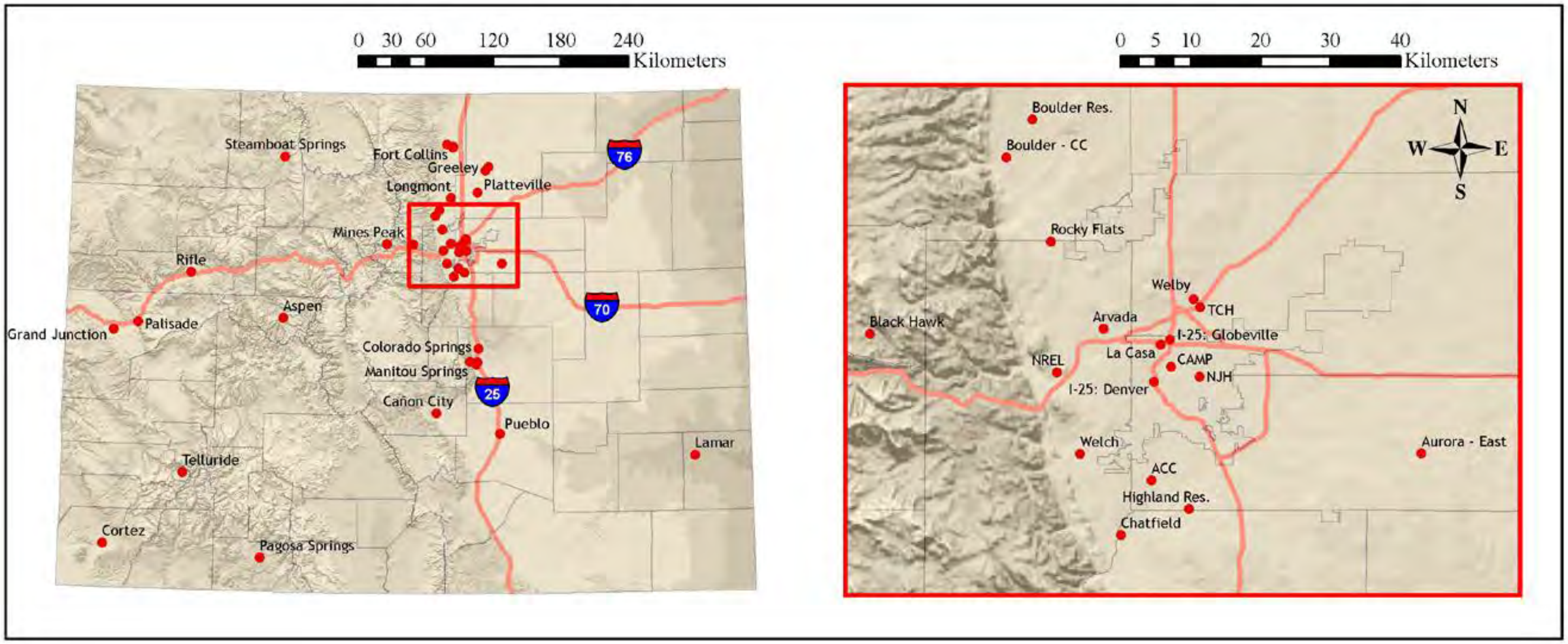


Figure 4. Map of Colorado with an inset map of the Denver metropolitan area showing the location of all monitoring sites operated by the APCD and listed in Table 6. Note that the Mines Peak site is shown on the map, although it has not been assessed in this report on account of its unique monitoring objectives. For the purpose of improving the readability of the map, labels for monitoring sites in Fort Collins, Grand Junction, and Colorado Springs have been combined under a single label. Detailed site information, including AQS identification numbers, site descriptions and histories, addresses and coordinates, monitoring start dates, site elevations, site orientation/scale designations, etc., can be found in Appendix A of this document.

# 2 SITE-TO-SITE COMPARISONS

In this section, the existing APCD monitoring network is assessed in a series of quantitative site-to-site comparison analyses. Each analysis assigns a score to individual monitors within each network based on a particular indicator (see Table 4). Each indicator is assigned a weight that reflects its overall importance relative to APCD's monitoring objectives and each monitor within each APCD monitoring network is then ranked by the weighted average of the analyses. These rankings are then used for subsequent analyses, including assessing which sites may no longer be needed and can be terminated. Indicators have been chosen to represent a number of different variables; e.g., economic cost-effectiveness, proximity to population and pollution sources, measured and modeled pollutant concentrations, etc. The objective of using many different, often competing, indicators is to provide a comprehensive evaluation technique that attempts to address all of the APCD's monitoring objectives, which are themselves often conflicting; e.g., the assessment of population exposure in areas of maximum pollutant concentrations and the determination of background concentrations are fundamentally different objectives requiring separate monitoring strategies. Weighting factors are used to emphasize indicators of particular relevance within each of the APCDs pollutant monitoring networks.

## 2.1 Number of Parameters Monitored

This analysis was performed by simply counting the number of parameters measured at each monitoring site. Sites having the most parameters measured were ranked highest and sites with the same number of parameters measured were ranked equally. The scores were determined using a linear conversion in which the site with the fewest measured parameters was assigned a score of one and the site with the most measured parameters was assigned a maximum score equal to the number of sites in the network (e.g., seven for the CO monitoring network).

While criteria pollutants are the primary focus of this analysis, wind speed/direction and temperature difference parameters were also considered, as these data are valuable for forecasting and modeling purposes and thus are entered into the AQS database. Note that many APCD sites also record measurements of other non-criteria pollutants and meteorological parameters such as temperature, barometric pressure, and relative humidity, which have not been considered in this analysis.

By emphasizing the intensity and complementarity of monitoring activities at a given location over the spatial distribution of all monitoring activities, this analysis addresses two of the APCD's monitoring network purposes: model evaluation and source apportionment. Furthermore, sites with collocated measurements of several pollutants are more cost-effective to maintain compared to sites measuring only one or two parameters, making this a good method for assessing a site's relative economic value. The main advantages of this method include its simplicity to perform and its applicability to all pollutant parameters. A disadvantage of the method is that it does not differentiate between different pollutant types and the relative importance of each. For example, it gives the same weight to an $O_3$ monitor as to a CO monitor, even though $O_3$ is of much more regulatory concern within the state of Colorado.

### 2.1.1 Results for All Parameters

Tables 7-12 list each APCD monitoring site in the CO, $NO_2$, $SO_2$, $O_3$, $PM_{10}$, and $PM_{2.5}$ ambient networks, respectively, along with the total number of parameters monitored at each site and the score associated with each site.

Table 7. All APCD CO monitoring sites ranked by total number of parameters monitored.

| Site Name | AQS Number | Total Number of Parameters Monitored | Rank | Score |
|---|---|---|---|---|
| CAMP | 08-031-0002 | 7 | 1 | 7.0 |
| La Casa | 08-031-0026 | 7 | 1 | 7.0 |
| Welby | 08-001-3001 | 6 | 2 | 5.5 |
| I-25: Denver | 08-031-0027 | 4 | 3 | 2.5 |
| Highway 24 | 08-041-0015 | 3 | 4 | 1.0 |
| Fort Collins - Mason | 08-069-1004 | 3 | 4 | 1.0 |
| Greeley - County Tower | 08-123-0009 | 3 | 4 | 1.0 |

Table 8. All APCD $NO_2$ monitoring sites ranked by total number of parameters monitored.

| Site Name | AQS Number | Total Number of Parameters Monitored | Rank | Score |
|---|---|---|---|---|
| CAMP | 08-031-0002 | 7 | 1 | 6.0 |
| La Casa | 08-031-0026 | 7 | 1 | 6.0 |
| Welby | 08-001-3001 | 6 | 2 | 4.8 |
| I-25: Denver | 08-031-0027 | 4 | 3 | 2.3 |
| I-25: Globeville | 08-031-0028 | 3 | 4 | 1.0 |
| Rocky Flats - N. | 08-059-0006 | 3 | 4 | 1.0 |

Table 9. All APCD $SO_2$ monitoring sites ranked by total number of parameters monitored.

| Site Name | AQS Number | Total Number of Parameters Monitored | Rank | Score |
|---|---|---|---|---|
| CAMP | 08-031-0002 | 7 | 1 | 4.0 |
| La Casa | 08-031-0026 | 7 | 1 | 4.0 |
| Welby | 08-001-3001 | 6 | 2 | 3.3 |
| Highway 24 | 08-041-0015 | 3 | 3 | 1.0 |

Table 10. All APCD $O_3$ monitoring sites ranked by total number of parameters monitored.

| Site Name | AQS Number | Total Number of Parameters Monitored | Rank | Score |
|---|---|---|---|---|
| CAMP | 08-031-0002 | 7 | 1 | 19.0 |
| La Casa | 08-031-0026 | 7 | 1 | 19.0 |
| Welby | 08-001-3001 | 6 | 2 | 16.0 |
| Chatfield State Park | 08-035-0004 | 3 | 3 | 7.0 |
| Rocky Flats - N. | 08-059-0006 | 3 | 3 | 7.0 |
| Fort Collins - Mason | 08-069-1004 | 3 | 3 | 7.0 |
| Greeley - County Tower | 08-123-0009 | 3 | 3 | 7.0 |
| Highland Reservoir | 08-005-0002 | 2 | 4 | 4.0 |
| Aurora - East | 08-005-0006 | 2 | 4 | 4.0 |
| Boulder Reservoir | 08-013-0014 | 2 | 4 | 4.0 |
| Welch | 08-059-0005 | 2 | 4 | 4.0 |
| Palisade Water Treatment | 08-077-0020 | 2 | 4 | 4.0 |
| USAFA | 08-041-0013 | 1 | 5 | 1.0 |
| Manitou Springs | 08-041-0016 | 1 | 5 | 1.0 |
| Rifle - Health Dept. | 08-045-0012 | 1 | 5 | 1.0 |
| Black Hawk | 08-047-0003 | 1 | 6 | 1.0 |
| NREL | 08-059-0011 | 1 | 6 | 1.0 |
| Fort Collins - West | 08-069-0011 | 1 | 6 | 1.0 |
| Cortez - Health Dept. | 08-083-0006 | 1 | 6 | 1.0 |

Table 11. All APCD $PM_{10}$ monitoring sites ranked by total number of parameters monitored.

| Site Name | AQS Number | Total Number of Parameters Monitored | Rank | Score |
|---|---|---|---|---|
| CAMP | 08-031-0002 | 7 | 1 | 15.0 |
| La Casa | 08-031-0026 | 7 | 1 | 15.0 |
| Welby | 08-001-3001 | 6 | 2 | 12.7 |
| Tri County Health (TCH) | 08-001-0008 | 2 | 3 | 3.3 |
| Longmont - Municipal Bldg. | 08-013-0003 | 2 | 3 | 3.3 |
| Boulder Chamber of Commerce | 08-013-0012 | 2 | 3 | 3.3 |
| Colorado College | 08-041-0017 | 2 | 3 | 3.3 |
| Grand Junction - Powell Bldg. | 08-077-0017 | 2 | 3 | 3.3 |
| Pueblo - Fountain School | 08-101-0015 | 2 | 3 | 3.3 |
| Pagosa Springs School | 08-007-0001 | 1 | 4 | 1.0 |
| Cañon City - City Hall | 08-043-0003 | 1 | 4 | 1.0 |
| Aspen | 08-097-0008 | 1 | 4 | 1.0 |
| Lamar - Municipal Bldg. | 08-099-0002 | 1 | 4 | 1.0 |
| Steamboat Springs | 08-107-0003 | 1 | 4 | 1.0 |
| Telluride | 08-113-0004 | 1 | 4 | 1.0 |

Table 12. All APCD $PM_{2.5}$ monitoring sites ranked by total number of parameters monitored.

| Site Name | AQS Number | Total Number of Parameters Monitored | Rank | Score |
|---|---|---|---|---|
| CAMP | 08-031-0002 | 7 | 1 | 16.0 |
| La Casa | 08-031-0026 | 7 | 2 | 16.0 |
| I-25: Denver | 08-031-0027 | 4 | 3 | 8.5 |
| I-25: Globeville | 08-031-0028 | 3 | 4 | 6.0 |
| Chatfield State Park | 08-035-0004 | 3 | 4 | 6.0 |
| Tri County Health (TCH) | 08-001-0008 | 2 | 5 | 3.5 |
| Longmont - Municipal Bldg. | 08-013-0003 | 2 | 5 | 3.5 |
| Boulder Chamber of Commerce | 08-013-0012 | 2 | 5 | 3.5 |
| Colorado College | 08-041-0017 | 2 | 5 | 3.5 |
| Grand Junction - Powell Bldg. | 08-077-0017 | 2 | 5 | 3.5 |
| Pueblo - Fountain School | 08-101-0015 | 2 | 5 | 3.5 |
| Arapaho Community College | 08-005-0005 | 1 | 6 | 1.0 |
| National Jewish Health (NJH) | 08-031-0013 | 1 | 6 | 1.0 |
| Fort Collins - CSU | 08-069-0009 | 1 | 6 | 1.0 |
| Greeley - Hospital | 08-123-0006 | 1 | 6 | 1.0 |
| Platteville - Middle School | 08-123-0008 | 1 | 6 | 1.0 |

## 2.2 Trends Impact

In this analysis, monitoring sites in each network were ranked based on the length of their continuous measurement record for the pollutant of interest. Sites possessing an extended historical record are valuable for tracking long-term pollutant trends, and the continuation of these long uninterrupted records is deemed desirable. Therefore, those monitors with the longest uninterrupted historical records were scored the highest, while monitors with records of equal length were scored equally.

This analysis simply considers the number of years that a monitor has been operating continuously. Note that if a monitor had alternating periods of operation, then only the most recent operating period is considered.

This analysis is valuable in that it addresses two of the APCD's monitoring network purposes: trend tracking and emission reduction evaluation. The main advantages of this method are its simplistic analytical approach and its usefulness for identifying sites that provide a basis for assessing long-term trends. The main disadvantages of the method are: (1) the magnitude and direction of past trends are not necessarily good predictors of future trends due to potential changes in population or emissions, and (2) the length of a continuous record does not ensure that data are of good quality throughout the entire time period.

### 2.2.1 Results for all Parameters

Tables 13-18 list each APCD monitoring site in the CO, $NO_2$, $SO_2$, $O_3$, $PM_{10}$, and $PM_{2.5}$ ambient networks, respectively, along with the total number of years (rounded to the nearest integer) that the site has been monitoring the pollutant of interest and the score associated with each site

Table 13. All APCD CO monitoring sites ranked by length of monitoring record.

| Site Name | Length of Continuous Monitoring Record (years) | Rank | Score |
|---|---|---|---|
| CAMP | 54 | 1 | 7.0 |
| Welby | 46 | 2 | 6.0 |
| Fort Collins - Mason | 39 | 3 | 5.2 |
| Highway 24 | 21 | 4 | 3.0 |
| La Casa | 6 | 5 | 1.2 |
| I-25: Denver | 6 | 5 | 1.2 |
| Greeley - County Tower | 4 | 6 | 1.0 |

Table 14. All APCD $NO_2$ monitoring sites ranked by length of monitoring record.

| Site Name | Length of Continuous Monitoring Record (years) | Rank | Score |
|---|---|---|---|
| CAMP | 54 | 1 | 6.0 |
| Welby | 43 | 2 | 4.9 |
| Rocky Flats - N. | 24 | 3 | 3.0 |
| I-25: Denver | 6 | 4 | 1.2 |
| La Casa | 5 | 5 | 1.1 |
| I-25: Globeville | 4 | 6 | 1.0 |

Table 15. All APCD $SO_2$ monitoring sites ranked by length of monitoring record.

| Site Name | Length of Continuous Monitoring Record (years) | Rank | Score |
|---|---|---|---|
| CAMP | 54 | 1 | 4 |
| Welby | 46 | 2 | 3.5 |
| La Casa | 6 | 3 | 1 |
| Highway 24 | 6 | 3 | 1 |

Table 16. All APCD $O_3$ monitoring sites ranked by length of monitoring record.

| Site Name | Length of Continuous Monitoring Record (years) | Rank | Score |
|---|---|---|---|
| CAMP | 47 | 1 | 19.0 |
| Welby | 46 | 2 | 18.6 |
| Highland Reservoir | 41 | 3 | 16.7 |
| Fort Collins - Mason | 39 | 4 | 15.9 |
| Welch | 28 | 5 | 11.7 |
| Rocky Flats - N. | 27 | 6 | 11.3 |
| NREL | 25 | 7 | 10.6 |
| USAFA | 23 | 8 | 9.8 |
| Greeley - County Tower | 17 | 9 | 7.5 |
| Chatfield State Park | 15 | 10 | 6.7 |
| Manitou Springs | 15 | 10 | 6.7 |
| Fort Collins - West | 13 | 11 | 6.0 |
| Palisade Water Treatment | 11 | 12 | 5.2 |
| Rifle - Health Dept. | 11 | 12 | 5.2 |
| Cortez - Health Dept. | 11 | 12 | 5.2 |
| Aurora - East | 10 | 13 | 4.8 |
| La Casa | 6 | 14 | 3.3 |
| Boulder Reservoir | 3 | 15 | 2.1 |
| Black Hawk | 0 | 16 | 1.0 |

Table 17. All APCD $PM_{10}$ monitoring sites ranked by length of monitoring record.

| Site Name | Length of Continuous Monitoring Record (years) | Rank | Score |
|---|---|---|---|
| Longmont - Municipal Bldg. | 34 | 1 | 15.0 |
| Pagosa Springs School | 34 | 1 | 15.0 |
| CAMP | 33 | 2 | 14.5 |
| Welby | 33 | 2 | 14.5 |
| Lamar - Municipal Bldg. | 33 | 2 | 14.5 |
| Steamboat Springs | 33 | 2 | 14.5 |
| Telluride | 29 | 3 | 12.7 |
| Boulder Chamber of Commerce | 25 | 4 | 10.9 |
| Grand Junction - Powell Bldg. | 17 | 5 | 7.3 |
| Cañon City - City Hall | 15 | 6 | 6.4 |
| Colorado College | 11 | 7 | 4.6 |
| Pueblo - Fountain School | 10 | 8 | 4.2 |
| La Casa | 7 | 9 | 2.8 |
| Aspen | 4 | 10 | 1.5 |
| Tri County Health (TCH) | 3 | 11 | 1.0 |

Table 18. All APCD $PM_{2.5}$ monitoring sites ranked by length of monitoring record.

| Site Name | Length of Continuous Monitoring Record (years) | Rank | Score |
|---|---|---|---|
| CAMP | 20 | 1 | 16.0 |
| Longmont - Municipal Bldg. | 20 | 1 | 16.0 |
| Boulder Chamber of Commerce | 20 | 1 | 16.0 |
| Arapaho Community College | 20 | 1 | 16.0 |
| National Jewish Health (NJH) | 20 | 1 | 16.0 |
| Fort Collins - CSU | 20 | 1 | 16.0 |
| Greeley - Hospital | 20 | 1 | 16.0 |
| Platteville - Middle School | 20 | 1 | 16.0 |
| Grand Junction - Powell Bldg. | 17 | 3 | 13.4 |
| Chatfield State Park | 14 | 4 | 10.7 |
| Colorado College | 11 | 5 | 8.1 |
| Pueblo - Fountain School | 10 | 6 | 7.2 |
| La Casa | 7 | 7 | 4.5 |
| I-25: Denver | 5 | 8 | 2.8 |

## 2.3 Measured Concentrations

This analysis ranks monitors by the magnitude of pollutant concentrations that they measure. The indicator is based on each monitoring site's design value, which is generally the highest concentration measured over a particular averaging interval in a given year (Table 19). Monitors with higher design values are ranked higher than those with lower design values. The assumption of this analysis is that sites measuring high concentrations are more important for determining NAAQS compliance and assessing population exposure. A drawback of this analysis is that it does not consider monitor siting issues, as a monitor located in a high concentration area may not measure maximum potential concentrations if it has not been sited optimally. Furthermore, because this analysis focuses only on those monitors measuring high concentrations, which are often urban monitors located in high-population areas, it does not take into account low-concentration monitors that are important for other reasons, such as rural monitors that measure background pollutant concentrations and assure appropriate spatial coverage.

Table 19. National Ambient Air Quality Standards (NAAQS) for the criteria pollutants assessed in this report. Primary standards provide public health protection, while secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings. Units of measure are parts per million (ppm) by volume, parts per billion (ppb) by volume, and micrograms per cubic meter (µg $m^{-3}$).

| Pollutant | Primary / Secondary | Averaging Time | Level | Form |
|---|---|---|---|---|
| Carbon Monoxide (CO) | Primary | 8-hr | 9 ppm | Not to be exceeded more than once per year |
| | | 1-hr | 35 ppm | |
| Lead (Pb) | Primary and Secondary | Rolling 3-month average | 0.15 µg $m^{-3}$ | Not to be exceeded |
| Nitrogen Dioxide ($NO_2$) | Primary | 1-hr | 100 ppb | 98th percentile of 1-hour daily maximum concentrations, averaged over 3 years |
| | Primary and Secondary | Annual | 53 ppb | Annual mean |
| Sulfur Dioxide ($SO_2$) | Primary | 1-hr | 75 ppb | 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years |
| | Secondary | 3-hr | 0.5 ppm | Not to be exceeded more than once per year |
| Ozone ($O_3$) | Primary and Secondary | 8-hr | 0.070 ppm | Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years |
| $PM_{10}$ | Primary and Secondary | 24-hr | 150 µg $m^{-3}$ | Not to be exceeded more than once per year on average over 3 years |
| $PM_{2.5}$ | Primary | Annual | 12 µg $m^{-3}$ | Annual mean, averaged over 3 years |
| | Secondary | Annual | 15 µg $m^{-3}$ | Annual mean, averaged over 3 years |
| | Primary and Secondary | 24-hr | 35 µg $m^{-3}$ | 98th percentile, averaged over 3 years |

### 2.3.1 Results for All Parameters

Tables 20-25 list each APCD monitoring site in the CO, $NO_2$, $SO_2$, $O_3$, $PM_{10}$, and $PM_{2.5}$ ambient networks, respectively, along with the annual design values measured during the period 2017-2019, the average design value for that period, and the score associated with each site.

Table 20. All APCD CO monitoring sites ranked by design value.

| Site Name | Max 1-Hour Concentration (ppm) | | | | Rank | Score |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | Three-Year Average | | |
| CAMP | 4.1 | 4.5 | 2.5 | 3.7 | 1 | 7.0 |
| I-25: Denver | 2.7 | 4.0 | 2.8 | 3.2 | 2 | 5.5 |
| La Casa | 2.9 | 3.8 | 1.8 | 2.8 | 3 | 4.7 |
| Highway 24 | 2.7 | 2.8 | 2.7 | 2.7 | 4 | 4.4 |
| Fort Collins - Mason | 2.1 | 2.6 | 2.1 | 2.3 | 5 | 3.3 |
| Welby | 2.2 | 2.5 | 1.8 | 2.2 | 6 | 3.0 |
| Greeley - County Tower | 1.5 | 1.5 | 1.3 | 1.4 | 7 | 1.0 |

Table 21. All APCD $NO_2$ monitoring sites ranked by design value.

| Site Name | 98th Percentile of 1-Hour Daily Max Concentrations (ppb) | | | | Rank | Score |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | Three-Year Average | | |
| I-25: Globeville | 69.8 | 69.6 | 68.7 | 69.4 | 1 | 6.0 |
| CAMP | 67.4 | 66.2 | 66.0 | 66.5 | 2 | 5.7 |
| I-25: Denver | 63.2 | 62.2 | 69.4 | 64.9 | 3 | 5.5 |
| Welby | 58.5 | 60.3 | 61.8 | 60.2 | 4 | 4.9 |
| La Casa | 60.2 | 57.4 | 60.0 | 59.2 | 5 | 4.7 |
| Rocky Flats - N. | - | - | 28.8 | 28.8 | 6 | 1.0 |

Table 22. All APCD $SO_2$ monitoring sites ranked by design value.

| Site Name | 99th Percentile of 1-Hour Daily Max Concentrations (ppb) | | | | Rank | Score |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | Three-Year Average | | |
| Highway 24 | 21.8 | 9.0 | 9.6 | 13.5 | 1 | 4.0 |
| La Casa | 16.4 | 6.8 | 7.1 | 10.1 | 2 | 2.1 |
| Welby | 15.1 | 6.2 | 5.7 | 9.0 | 3 | 1.5 |
| CAMP | 10.1 | 7.9 | 6.6 | 8.2 | 4 | 1.0 |

Table 23. All APCD $O_3$ monitoring sites ranked by design value.

| Site Name | 4th Highest 8-hr Daily Max Concentration (ppm) | | | | Rank | Score |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | Three-Year Average | | |
| Chatfield State Park | 0.074 | 0.083 | 0.078 | 0.078 | 1 | 19.0 |
| NREL | 0.076 | 0.080 | 0.075 | 0.077 | 2 | 17.7 |
| Rocky Flats - N. | 0.075 | 0.081 | 0.072 | 0.076 | 3 | 16.7 |
| Fort Collins - West | 0.075 | 0.081 | 0.071 | 0.075 | 4 | 16.3 |
| Highland Reservoir | 0.072 | 0.077 | 0.073 | 0.074 | 5 | 14.7 |
| Boulder Reservoir | 0.073 | 0.077 | 0.069 | 0.073 | 6 | 13.7 |
| Welch | 0.075 | 0.066 | 0.072 | 0.071 | 7 | 11.7 |
| Greeley - County Tower | 0.072 | 0.073 | 0.065 | 0.070 | 8 | 10.7 |
| Aurora - East | 0.069 | 0.072 | 0.066 | 0.069 | 9 | 9.7 |
| U.S. Air Force Academy | 0.069 | 0.073 | 0.065 | 0.069 | 9 | 9.7 |
| Manitou Springs | 0.070 | 0.072 | 0.064 | 0.068 | 10 | 9.3 |
| CAMP | 0.067 | 0.071 | 0.067 | 0.068 | 11 | 9.0 |
| La Casa | 0.068 | 0.072 | 0.065 | 0.068 | 11 | 9.0 |
| Fort Collins - Mason | 0.066 | 0.072 | 0.064 | 0.067 | 12 | 8.0 |
| Welby | 0.068 | 0.069 | 0.060 | 0.065 | 13 | 6.3 |
| Palisade Water Treatment | 0.064 | 0.069 | 0.063 | 0.065 | 14 | 6.0 |
| Black Hawk | - | - | 0.064 | 0.064 | 15 | 4.7 |
| Cortez - Health Dept. | 0.059 | 0.067 | 0.060 | 0.062 | 16 | 2.7 |
| Rifle - Health Dept. | 0.059 | 0.065 | 0.057 | 0.060 | 17 | 1.0 |

Table 24. All APCD $PM_{10}$ monitoring sites ranked by design value.

| Site Name | Max 24-Hour Concentration (µg $m^{-3}$) | | | | Rank | Score |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | Three-Year Average | | |
| Pueblo - Fountain School | 168 | 155 | 89 | 137 | 1 | 15.0 |
| Tri County Health (TCH) | 124 | 158 | 119 | 134 | 2 | 14.5 |
| Steamboat Springs | 77 | 56 | 228 | 120 | 3 | 12.6 |
| Lamar - Municipal Bldg. | 87 | 159 | 105 | 117 | 4 | 12.1 |
| CAMP | 90 | 149 | 79 | 106 | 5 | 10.5 |
| Welby | 82 | 106 | 75 | 88 | 6 | 7.9 |
| La Casa | 81 | 102 | 61 | 81 | 7 | 7.0 |
| Pagosa Springs School | 72 | 88 | 68 | 76 | 8 | 6.2 |
| Longmont - Municipal Bldg. | 97 | 63 | 58 | 73 | 9 | 5.8 |
| Boulder Chamber of Commerce | 79 | 57 | 53 | 63 | 10 | 4.4 |
| Telluride | 75 | 47 | 61 | 61 | 11 | 4.1 |
| Colorado College | 83 | 40 | 38 | 54 | 12 | 3.0 |
| Aspen | 52 | 45 | 50 | 49 | 13 | 2.4 |
| Grand Junction - Powell Bldg. | 51 | 45 | 47 | 48 | 14 | 2.2 |
| Cañon City - City Hall | 48 | 39 | 31 | 39 | 15 | 1.0 |

Table 25. All APCD $PM_{2.5}$ monitoring sites ranked by design value.

| Site Name | 98th Percentile of 24-Hour Concentrations (µg $m^{-3}$) | | | | Rank | Score |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | Three-Year Average | | |
| Chatfield State Park | 27.2 | 36.7 | 25.1 | 29.7 | 1 | 16.0 |
| Longmont - Municipal Bldg. | 18.6 | 29.1 | 35.7 | 27.8 | 2 | 14.3 |
| I-25: Globeville | 22.4 | 25.1 | 28.9 | 25.5 | 3 | 12.2 |
| Tri County Health (TCH) | 23.7 | 27.2 | 22.6 | 24.5 | 4 | 11.3 |
| Greeley - Hospital | 22.0 | 23.6 | 25.7 | 23.8 | 5 | 10.6 |
| I-25: Denver | 22.2 | 23.7 | 23.0 | 23.0 | 6 | 9.9 |
| National Jewish Health (NJH) | - | 21.3 | 23.7 | 22.5 | 7 | 9.4 |
| Arapaho Community College | 18.9 | 20.1 | 26.6 | 21.9 | 8 | 8.9 |
| CAMP | 20.4 | 20.2 | 23.8 | 21.5 | 9 | 8.5 |
| La Casa | 21.0 | 20.3 | 22.0 | 21.1 | 10 | 8.1 |
| Platteville - Middle School | 17.2 | 20.5 | 22.9 | 20.2 | 11 | 7.3 |
| Boulder Chamber of Commerce | 17.4 | 22.0 | 19.0 | 19.5 | 12 | 6.7 |
| Fort Collins - CSU | 18.1 | 20.4 | 19.7 | 19.4 | 13 | 6.6 |
| Grand Junction - Powell Bldg. | 16.2 | 16.4 | 14.5 | 15.7 | 14 | 3.2 |
| Colorado College | 17.1 | 15.5 | 13.2 | 15.3 | 15 | 2.8 |
| Pueblo - Fountain School | 15.7 | 15.8 | 8.4 | 13.3 | 16 | 1.0 |

## 2.4 Deviation from the NAAQS

In this analysis, sites that measure design values close to the NAAQS exceedance threshold (Table 19) are ranked higher than those sites with design values well above or below it. Sites that are closest to the threshold are considered most valuable for the purpose of determining compliance with the NAAQS, whereas sites measuring values well above or below the NAAQS do not provide as much information in this regard. The purpose of this technique is to give weight to those sites that are closest to the standard; therefore, the absolute value of the difference between the measured design value and the standard is used to score each monitor. Monitors with the smallest absolute difference will rank as most important. This analysis has a disadvantage in that monitors with design values higher than the standard (i.e., those in violation of the standard) may be considered more valuable from the standpoint of compliance and public health than those with design values lower than the standard, but with a similar absolute difference. The objectives assessed by this analysis are regulatory compliance and forecasting assistance.

Design values for APCD monitoring sites are typically well below the NAAQS for most criteria pollutants, making this indicator redundant with the Measured Concentrations indicator for those networks. For this reason, the Deviation from the NAAQS indicator was applied only to the $O_3$ monitoring network, as this is the only network having sites with design values both above and below the NAAQS.

### 2.4.1 Results for all Parameters

Tables 26 lists each APCD monitoring site in the $O_3$ ambient network, showing the average design value for the period 2017-2019, the difference between the average design values and the level of the NAAQS, and the score associated with each site.

Table 26. All APCD $O_3$ monitoring sites ranked by deviation from the primary $O_3$ NAAQS.

| Site Name | 3-Year Average Design Value (ppm) | NAAQS | Deviation | Rank | Score |
|---|---|---|---|---|---|
| Greeley - County Tower | 0.070 | 70 | 0.000 | 1 | 19.0 |
| Welch | 0.071 | 70 | -0.001 | 2 | 17.1 |
| Aurora - East | 0.069 | 70 | 0.001 | 2 | 17.1 |
| U.S. Air Force Academy (USAFA) | 0.069 | 70 | 0.001 | 2 | 17.1 |
| Manitou Springs | 0.068 | 70 | 0.002 | 3 | 16.5 |
| CAMP | 0.068 | 70 | 0.002 | 4 | 15.9 |
| La Casa | 0.068 | 70 | 0.002 | 4 | 15.9 |
| Fort Collins - Mason | 0.067 | 70 | 0.003 | 5 | 14.0 |
| Boulder Reservoir | 0.073 | 70 | -0.003 | 6 | 13.4 |
| Highland Reservoir | 0.074 | 70 | -0.004 | 7 | 11.6 |
| Welby | 0.065 | 70 | 0.005 | 8 | 10.9 |
| Palisade Water Treatment | 0.065 | 70 | 0.005 | 9 | 10.3 |
| Fort Collins - West | 0.075 | 70 | -0.005 | 10 | 8.4 |
| Rocky Flats - N. | 0.076 | 70 | -0.006 | 11 | 7.8 |
| Black Hawk | 0.064 | 70 | 0.006 | 12 | 7.8 |
| NREL | 0.077 | 70 | -0.007 | 13 | 6.0 |
| Cortez - Health Dept. | 0.062 | 70 | 0.008 | 14 | 4.1 |
| Chatfield State Park | 0.078 | 70 | -0.008 | 15 | 3.5 |
| Rifle - Health Dept. | 0.060 | 70 | 0.010 | 16 | 1.0 |

### 2.5 Monitor-to-Monitor Correlation

In this analysis, sites are ranked based on the correlation of their measured concentrations with those of the other monitors in the network. Monitors measuring concentrations that correlate well with those measured at other sites are considered redundant, and are consequently assigned a lower ranking. Monitors with concentrations that do not correlate with other monitors are considered unique, and as such have more value for spatial monitoring objectives and are therefore assigned a higher ranking. The advantages of this method are: (1) it gives a measure of the site's uniqueness and representativeness, and (2) it is useful for identifying redundant sites. The disadvantages are that it requires large amounts of data with a high data completeness rate, and that the correlations are likely pollutant specific. The objectives assessed by this analysis are model evaluation, spatial coverage, and interpolation.

To conduct this analysis, 24-hour average concentration values were compiled for each criteria parameter monitored within Colorado for the period 2015-2019. Data obtained from sites in Colorado operated by other federal, local, and tribal agencies were considered in this analysis to ensure a spatially robust sample; however, the correlations observed between these sites and those in the APCD network are not considered when ranking the APCD monitors. The concentrations measured at each monitoring site were compared to those measured at every other monitoring site in the state using a matrix format, in which each monitoring pair was subjected to linear regression from which a Pearson correlation coefficient ($r^2$) was generated. The maximum correlation was then recorded for each site, as well as the number of sites well-correlated with that site. It is assumed here that sites having an $r^2$ value of 0.6 or greater are well-correlated. Sites were ranked based on both their maximum correlation and the number of sites well-correlated with them. A distance matrix was also developed, and a correlogram plot of distance vs. correlation was created for each parameter.

#### 2.5.1 Carbon Monoxide (CO)

Table 27. CO monitor-to-monitor correlation analysis scores.

| Site Name | Max. Correlation | | $r^2 \geq 0.6$ | | Average | Score |
|---|---|---|---|---|---|---|
| | Value | Score | No. of Sites | Score | Rank | |
| Highway 24 | 0.62 | 7.0 | 1 | 7.0 | 1 | 7.0 |
| Greeley - County Tower | 0.68 | 5.3 | 1 | 7.0 | 2 | 6.1 |
| Fort Collins - Mason | 0.68 | 5.3 | 2 | 4.0 | 3 | 4.6 |
| Welby | 0.71 | 4.2 | 2 | 4.0 | 4 | 4.1 |
| CAMP | 0.80 | 1.2 | 2 | 4.0 | 5 | 2.6 |
| La Casa | 0.81 | 1.0 | 3 | 1.0 | 6 | 1.0 |
| I-25: Denver | 0.81 | 1.0 | 3 | 1.0 | 6 | 1.0 |

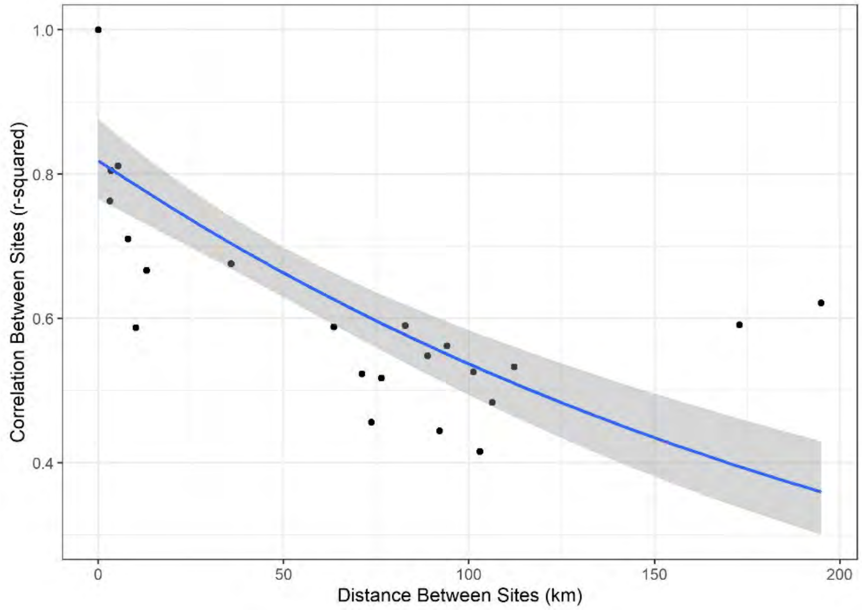

Figure 5. Correlogram for all CO monitoring sites in Colorado.

### 2.5.2 Nitrogen Dioxide ($NO_2$)

Table 28. $NO_2$ monitor-to-monitor correlation analysis scores.

| Site Name | Max. Correlation | | $r^2 \geq 0.6$ | | Average | Score |
|---|---|---|---|---|---|---|
| | Value | Score | No. of Sites | Score | Rank | |
| Rocky Flats - N. | 0.40 | 6.0 | 0 | 6.0 | 1 | 6.0 |
| Welby | 0.79 | 1.9 | 4 | 1.0 | 2 | 1.5 |
| CAMP | 0.86 | 1.3 | 4 | 1.0 | 3 | 1.1 |
| La Casa | 0.86 | 1.3 | 4 | 1.0 | 3 | 1.1 |
| I-25: Globeville | 0.88 | 1.0 | 4 | 1.0 | 4 | 1.0 |
| I-25: Denver | 0.88 | 1.0 | 4 | 1.0 | 4 | 1.0 |

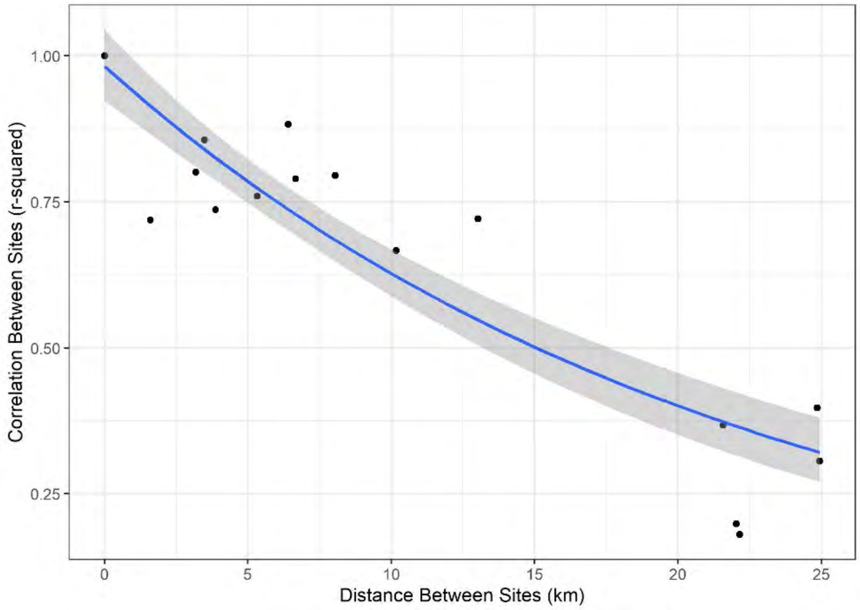


Figure 6. Correlogram for all $NO_2$ monitoring sites in Colorado.

### 2.5.3 Sulfur Dioxide ($SO_2$)[3]

Table 29. $SO_2$ monitor-to-monitor correlation analysis scores.

| Site Name | Max. Correlation | | $r^2 \geq 0.6$ | | Average | Score |
|---|---|---|---|---|---|---|
| | Value | Score | No. of Sites | Score | Rank | |
| Highway 24 | 0.09 | 4.0 | 0 | - | 1 | 4.0 |
| Welby | 0.28 | 2.8 | 0 | - | 2 | 2.8 |
| CAMP | 0.55 | 1.0 | 0 | - | 3 | 1.0 |
| La Casa | 0.55 | 1.0 | 0 | - | 3 | 1.0 |

[3] No correlogram is shown for $SO_2$ due to the limited number of existing monitoring sites and the low correlations observed.

### 2.5.4 Ozone ($O_3$)

Table 30. $O_3$ monitor-to-monitor correlation analysis scores.

| Site Name | Max. Correlation | | $r^2 \geq 0.6$ | | Average | Score |
|---|---|---|---|---|---|---|
| | Value | Score | No. of Sites | Score | Rank | |
| Black Hawk | 0.61 | 19.0 | 1 | 19.0 | 1 | 19.0 |
| Cortez - Health Dept. | 0.70 | 14.0 | 2 | 17.6 | 2 | 15.8 |
| USAFA | 0.72 | 12.9 | 6 | 12.1 | 3 | 12.5 |
| Rifle - Health Dept. | 0.83 | 6.8 | 2 | 17.6 | 4 | 12.2 |
| Palisade Water Treatment | 0.83 | 6.8 | 2 | 17.6 | 4 | 12.2 |
| Manitou Springs | 0.75 | 11.0 | 9 | 7.9 | 5 | 9.5 |
| Welby | 0.87 | 4.6 | 5 | 13.5 | 6 | 9.0 |
| Fort Collins - Mason | 0.85 | 5.3 | 6 | 12.1 | 7 | 8.7 |
| Greeley - County Tower | 0.85 | 5.3 | 6 | 12.1 | 7 | 8.7 |
| Aurora - East | 0.85 | 5.5 | 10 | 6.5 | 8 | 6.0 |
| Fort Collins - West | 0.82 | 7.3 | 12 | 3.8 | 9 | 5.5 |
| Rocky Flats - N. | 0.93 | 1.0 | 9 | 7.9 | 10 | 4.5 |
| Boulder Reservoir | 0.82 | 7.3 | 14 | 1.0 | 11 | 4.1 |
| Welch | 0.92 | 1.7 | 10 | 6.5 | 12 | 4.1 |
| NREL | 0.93 | 1.0 | 10 | 6.5 | 13 | 3.8 |
| Highland Reservoir | 0.91 | 2.0 | 11 | 5.2 | 14 | 3.6 |
| Chatfield State Park | 0.91 | 2.0 | 11 | 5.2 | 14 | 3.6 |
| La Casa | 0.93 | 1.3 | 11 | 5.2 | 15 | 3.2 |
| CAMP | 0.93 | 1.3 | 13 | 2.4 | 16 | 1.9 |

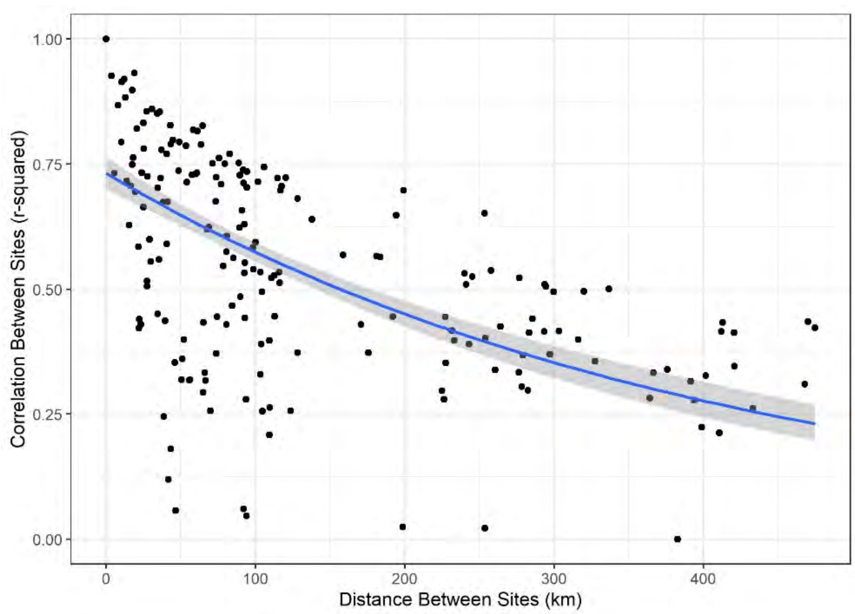


Figure 7. Correlogram for all $O_3$ monitoring sites in Colorado.

### 2.5.5 $PM_{10}$

Table 31. $PM_{10}$ monitor-to-monitor correlation analysis scores.

| Site Name | Max. Correlation | | $r^2 \geq 0.6$ | | Average | Score |
|---|---|---|---|---|---|---|
| | Value | Score | No. of Sites | Score | Rank | |
| Cañon City - City Hall | 0.23 | 15.0 | 0 | 15.0 | 1 | 15.0 |
| Grand Junction - Powell Bldg. | 0.28 | 13.9 | 0 | 15.0 | 2 | 14.4 |
| Pagosa Springs School | 0.28 | 13.8 | 0 | 15.0 | 3 | 14.4 |
| Welby | 0.38 | 11.5 | 0 | 15.0 | 4 | 13.3 |
| Pueblo - Fountain School | 0.39 | 11.2 | 0 | 15.0 | 5 | 13.1 |
| Lamar - Municipal Bldg. | 0.39 | 11.2 | 0 | 15.0 | 5 | 13.1 |
| Telluride | 0.47 | 9.4 | 0 | 15.0 | 6 | 12.2 |
| Steamboat Springs | 0.50 | 8.8 | 0 | 15.0 | 7 | 11.9 |
| Aspen | 0.50 | 8.8 | 0 | 15.0 | 7 | 11.9 |
| Colorado College | 0.53 | 8.0 | 0 | 15.0 | 8 | 11.5 |
| Longmont - Municipal Bldg. | 0.58 | 6.8 | 0 | 15.0 | 9 | 10.9 |
| Boulder Chamber of Commerce | 0.58 | 6.8 | 0 | 15.0 | 9 | 10.9 |
| Tri County Health (TCH) | 0.61 | 6.2 | 1 | 8.0 | 10 | 7.1 |
| La Casa | 0.84 | 1.0 | 1 | 8.0 | 11 | 4.5 |
| CAMP | 0.84 | 1.0 | 2 | 1.0 | 12 | 1.0 |

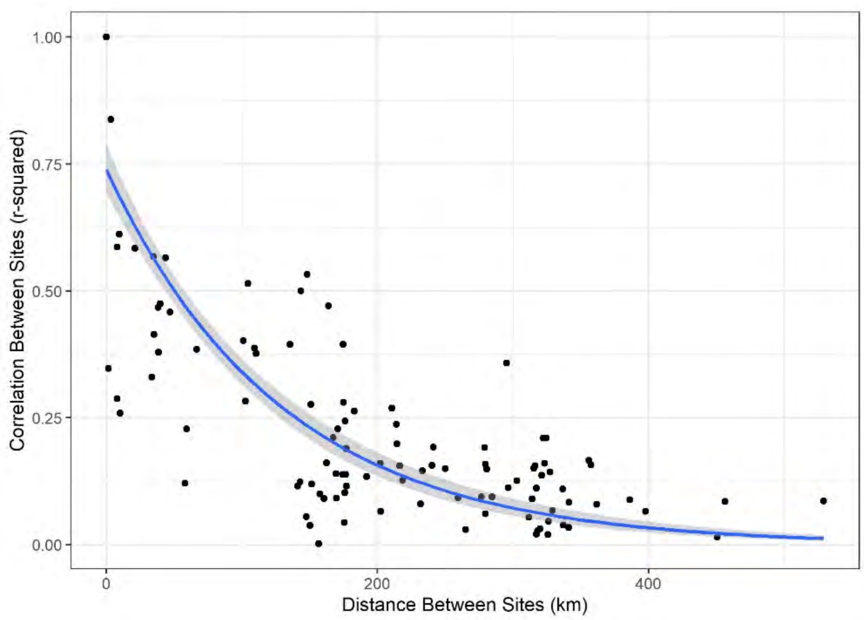


Figure 8. Correlogram for all $PM_{10}$ monitoring sites in Colorado.

### 2.5.6 $PM_{2.5}$

Table 32. $PM_{2.5}$ monitor-to-monitor correlation analysis scores.

| Site Name | Max. Correlation | | $r^2 \geq 0.6$ | | Average | Score |
|---|---|---|---|---|---|---|
| | Value | Score | No. of Sites | Score | Rank | |
| Grand Junction - Powell Bldg. | 0.14 | 16.0 | 0 | 16.0 | 1 | 16.0 |
| Pueblo - Fountain School | 0.64 | 6.2 | 1 | 14.5 | 2 | 10.4 |
| Colorado College | 0.64 | 6.2 | 3 | 11.5 | 3 | 8.9 |
| Platteville - Middle School | 0.79 | 3.3 | 3 | 11.5 | 4 | 7.4 |
| Greeley - Hospital | 0.77 | 3.7 | 4 | 10.0 | 5 | 6.8 |
| Boulder Chamber of Commerce | 0.73 | 4.6 | 5 | 8.5 | 6 | 6.6 |
| Fort Collins - CSU | 0.76 | 4.0 | 6 | 7.0 | 7 | 5.5 |
| I-25: Globeville | 0.83 | 2.6 | 6 | 7.0 | 8 | 4.8 |
| Tri County Health (TCH) | 0.77 | 3.7 | 7 | 5.5 | 9 | 4.6 |
| Chatfield State Park | 0.83 | 2.7 | 7 | 5.5 | 10 | 4.1 |
| Arapaho Community College (ACC) | 0.84 | 2.4 | 7 | 5.5 | 11 | 3.9 |
| CAMP | 0.91 | 1.1 | 8 | 4.0 | 12 | 2.6 |
| Longmont - Municipal Bldg. | 0.79 | 3.3 | 10 | 1.0 | 13 | 2.2 |
| I-25: Denver | 0.88 | 1.7 | 9 | 2.5 | 14 | 2.1 |
| National Jewish Health (NJH) | 0.91 | 1.0 | 10 | 1.0 | 15 | 1.0 |
| La Casa | 0.91 | 1.0 | 10 | 1.0 | 15 | 1.0 |

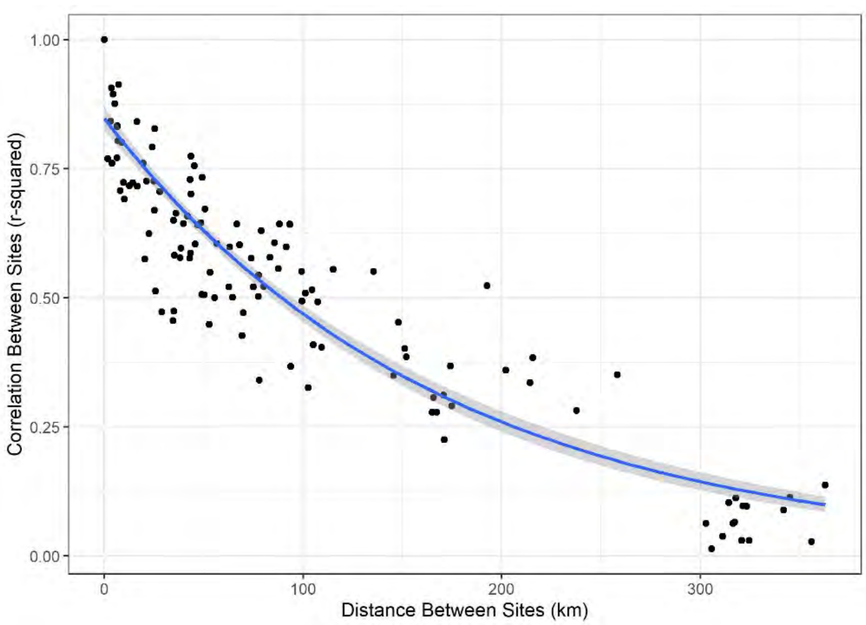


Figure 9. Correlogram for all $PM_{2.5}$ monitoring sites in Colorado.

## 2.6 Removal Bias

This analysis evaluates the contribution of each monitoring site to the creation of an interpolation map. For each pollutant parameter, an interpolation map is created using all CDPHE monitoring data. Each APCD monitoring site is then systematically removed from the dataset and the interpolation map is regenerated. The difference between the actual value measured at the monitoring site and the predicted value from the interpolation once the site was removed is recorded; this is the removal bias. Sites are then ranked using the absolute value of the difference, with higher values being given higher rankings.

Five-year (2015-2019) average concentration values have been used in this analysis for each pollutant parameter, thus this analysis focuses on the long-term contributions that each site makes in determining the monitored pollution surface. The removal bias technique would likely result in a different interpretation if a different temporal scale were used; however, this network assessment has other analysis techniques that focus on shorter averaging periods (e.g., Measured Concentration).

Removal bias is a useful technique for noting redundancies in the monitoring network. Sites with a high removal bias are important for creating an accurate interpolation map, thus their values add a unique perspective to the overall pollution surface. On the other hand, sites with a low removal bias difference could possibly be redundant with other sites, at least in the long-term temporal scale.

In the following sections, an interpolation map of the predicted pollution surface generated using all CDPHE monitoring data is shown for $O_3$, $PM_{10}$, and $PM_{2.5}$, which were the only pollutant networks subjected to this analysis. The accompanying tables show the results of the removal bias analysis and the associated scores and rankings for each site. Note that there are not enough sites in the CO, $NO_2$, and $SO_2$ monitoring networks to apply this analysis.

### 2.6.1 Ozone ($O_3$)

Table 33. $O_3$ monitoring sites ordered and ranked by removal bias.

| Site Name | Avg. Concentration (2015-2019) | Interpolated Concentration | Removal Bias | Rank | Score |
|---|---|---|---|---|---|
| Fort Collins - Mason | 0.0277 | 0.0375 | 0.0099 | 1 | 19.0 |
| Fort Collins - West | 0.0378 | 0.0281 | -0.0097 | 2 | 18.7 |
| Rifle - Health Dept. | 0.0287 | 0.0368 | 0.0081 | 3 | 15.8 |
| Rocky Flats - N. | 0.0419 | 0.0339 | -0.0080 | 4 | 15.7 |
| Aurora - East | 0.0406 | 0.0335 | -0.0071 | 5 | 13.9 |
| NREL | 0.0397 | 0.0336 | -0.0061 | 6 | 12.2 |
| Black Hawk | 0.0436 | 0.0382 | -0.0054 | 7 | 10.8 |
| Manitou Springs | 0.0399 | 0.0351 | -0.0048 | 8 | 9.7 |
| Palisade Water Treatment | 0.0371 | 0.0324 | -0.0048 | 8 | 9.7 |
| Welby | 0.0258 | 0.0303 | 0.0045 | 9 | 9.2 |
| U.S. Air Force Academy (USAFA) | 0.0350 | 0.0389 | 0.0039 | 10 | 8.2 |
| Greeley - County Tower | 0.0300 | 0.0340 | 0.0039 | 10 | 8.2 |
| Cortez - Health Dept. | 0.0335 | 0.0356 | 0.0021 | 11 | 4.8 |
| Highland Reservoir | 0.0370 | 0.0349 | -0.0021 | 11 | 4.8 |
| La Casa | 0.0266 | 0.0284 | 0.0017 | 12 | 4.1 |
| Boulder Reservoir | 0.0351 | 0.0368 | 0.0017 | 13 | 4.0 |
| Chatfield State Park | 0.0370 | 0.0355 | -0.0015 | 14 | 3.7 |
| CAMP | 0.0271 | 0.0282 | 0.0011 | 15 | 3.0 |
| Welch | 0.0355 | 0.0355 | 0.0000 | 16 | 1.0 |

Average $O_3$ concentrations in Colorado are highest at high elevation sites, particularly in the mountainous areas of the Central Mountains and Denver Metro/North Front Range regions, where annual average $O_3$ concentrations reach values as high as 50 ppb (Figure 10). The observation of enhanced $O_3$ concentrations with elevation in Colorado has been attributed to the low availability of nitric oxide (NO), which typically acts to reduce $O_3$ concentrations. High average concentrations are also observed in the suburban and rural regions immediately surrounding the Denver Metro area. Removal bias tends to be highest for these sites due to the steep gradient in average $O_3$ concentration that exists from the city center to the outlying suburban and rural regions. This gradient is a well-known feature of the spatial distribution of $O_3$ concentrations in and around large cities, where concentrations are depressed via $NO_x$ titration in the urban center and reach maximum values along the suburban fringe (Sillman, 1999). In Figure 11, measured values are plotted against modeled (i.e., interpolated) values.

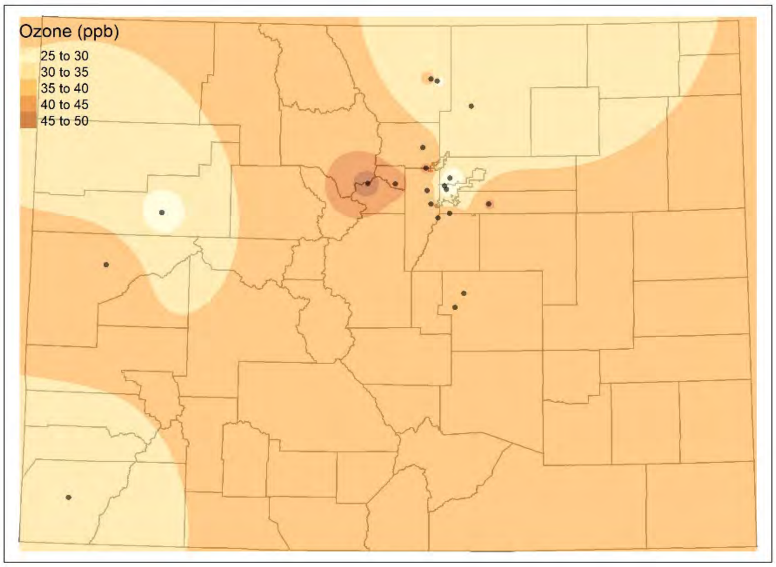


Figure 10. Interpolation map for $O_3$. The CDPHE $O_3$ monitors used to generate the map are symbolized by white circles.

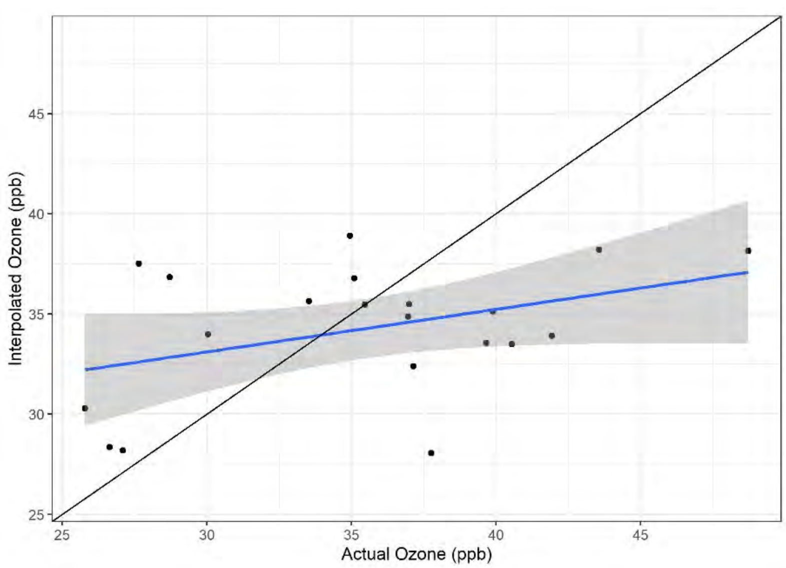


Figure 11. Removal bias for $O_3$ with actual concentration values plotted against modeled (i.e., interpolated) values.

### 2.6.2 $PM_{10}$

Table 34. $PM_{10}$ monitoring sites ordered and ranked by removal bias.

| Site Name | Avg. Concentration (2015-2019) | Interpolated Concentration | Removal Bias | Rank | Score |
|---|---|---|---|---|---|
| Tri County Health (TCH) | 35.23 | 25.78 | -9.45 | 1 | 15.0 |
| Welby | 25.85 | 34.62 | 8.77 | 2 | 14.0 |
| La Casa | 22.85 | 28.99 | 6.14 | 3 | 10.0 |
| Aspen | 15.09 | 20.82 | 5.73 | 4 | 9.4 |
| Cañon City - City Hall | 14.94 | 20.06 | 5.12 | 5 | 8.5 |
| CAMP | 28.60 | 24.40 | -4.21 | 6 | 7.1 |
| Grand Junction - Powell Bldg. | 15.83 | 19.28 | 3.45 | 7 | 6.0 |
| Boulder Chamber of Commerce | 20.84 | 24.21 | 3.37 | 8 | 5.8 |
| Steamboat Springs | 17.94 | 21.24 | 3.30 | 9 | 5.7 |
| Longmont - Municipal Bldg. | 20.58 | 23.43 | 2.85 | 10 | 5.1 |
| Colorado College | 17.91 | 20.71 | 2.79 | 11 | 5.0 |
| Telluride | 17.33 | 19.11 | 1.78 | 12 | 3.4 |
| Lamar - Municipal Bldg. | 19.59 | 20.88 | 1.29 | 13 | 2.7 |
| Pagosa Springs School | 19.60 | 18.77 | -0.83 | 14 | 2.0 |
| Pueblo - Fountain School | 18.64 | 18.78 | 0.15 | 15 | 1.0 |

Average annual $PM_{10}$ concentrations in Colorado are typically highest in the Denver Metro/North Front Range region, particularly at monitoring sites located near the city center, where emission density is typically highest (Figure 12).

Although dust storms occur infrequently, these events have a significant effect on the statistics calculated from the data. Sites impacted by dust storms have median values that are 3-7 $\mu g\ m^{-3}$ lower than their mean values, and coefficients of variation (CV; the ratio of the standard deviation to the mean) that are greater than or equal to one. In other words, although average $PM_{10}$ concentrations on the Eastern High Plains regions appear high, this is mostly a result of windblown dust events that skew the statistics. In terms of median values, the highest concentrations are observed at the CAMP, Welby, and Tri County Health sites, all located in central Denver. There is no apparent spatial trend in the removal bias results, although sites impacted by dust storms do tend to rank high in this analysis.

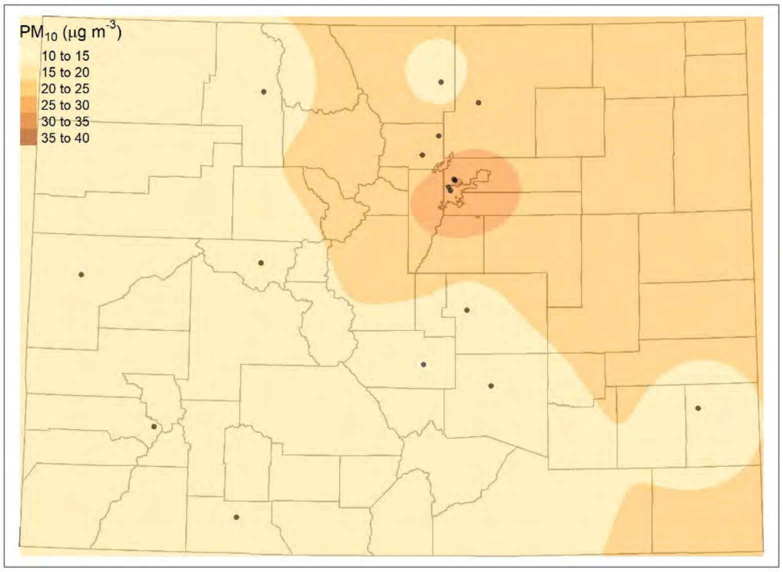


Figure 12. Interpolation map for $PM_{10}$. The CDPHE $PM_{10}$ monitors used to generate the map are symbolized by white circles.

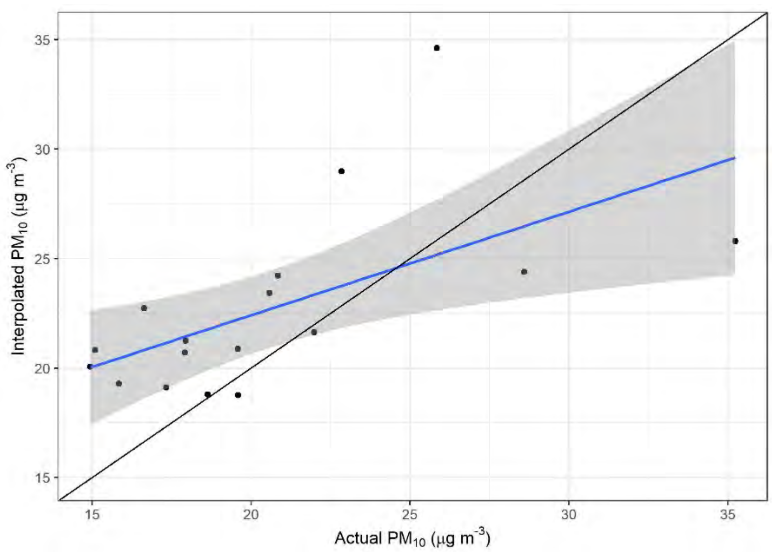


Figure 13. Removal bias for $PM_{10}$ with actual concentration values plotted against modeled (i.e., interpolated) values.

### 2.6.3 $PM_{2.5}$

Table 35. $PM_{2.5}$ monitoring sites ordered and ranked by removal bias.

| Site Name | Avg. Concentration (2015-2019) | Interpolated Concentration | Removal Bias | Rank | Score |
|---|---|---|---|---|---|
| Boulder Chamber of Commerce | 5.70 | 8.27 | 2.57 | 1 | 16.0 |
| I-25: Globeville | 9.68 | 7.50 | -2.19 | 2 | 13.4 |
| La Casa | 7.30 | 9.19 | 1.90 | 3 | 11.5 |
| Arapaho Community College | 5.94 | 7.82 | 1.87 | 4 | 11.3 |
| Pueblo - Fountain School | 5.25 | 7.08 | 1.83 | 5 | 11.0 |
| Greeley - Hospital | 9.15 | 7.60 | -1.54 | 6 | 9.1 |
| Tri County Health (TCH) | 9.80 | 8.28 | -1.52 | 7 | 8.9 |
| Longmont - Municipal Bldg. | 8.76 | 7.37 | -1.39 | 8 | 8.1 |
| Colorado College | 5.94 | 7.27 | 1.33 | 9 | 7.6 |
| Platteville - Middle School | 7.32 | 8.29 | 0.97 | 10 | 5.2 |
| Fort Collins - CSU | 7.21 | 8.12 | 0.91 | 11 | 4.8 |
| Grand Junction - Powell Bldg. | 6.17 | 7.06 | 0.89 | 12 | 4.7 |
| National Jewish Health (NJH) | 7.59 | 8.20 | 0.62 | 13 | 2.8 |
| I-25: Denver | 8.44 | 7.90 | -0.55 | 14 | 2.4 |
| CAMP | 7.75 | 8.27 | 0.52 | 15 | 2.2 |
| Chatfield State Park | 7.23 | 6.88 | -0.34 | 16 | 1.0 |

Average annual $PM_{2.5}$ concentrations in Colorado are typically highest at sites located in the Denver Metro/North Front Range region (Figure 14). Due to steep gradients in $PM_{2.5}$ concentrations in and around this area, removal bias also tends to be higher for these sites.

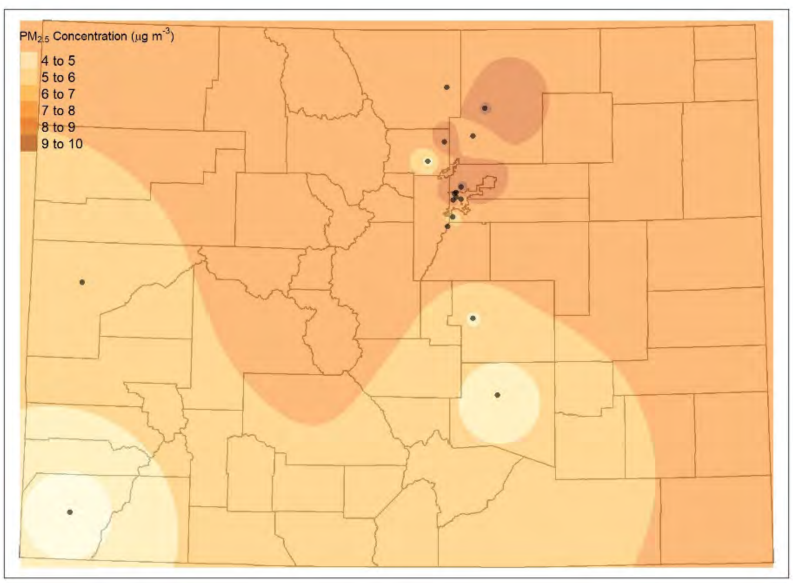


Figure 14. Interpolation map for $PM_{2.5}$. The CDPHE monitors used to generate the map are symbolized by white circles.

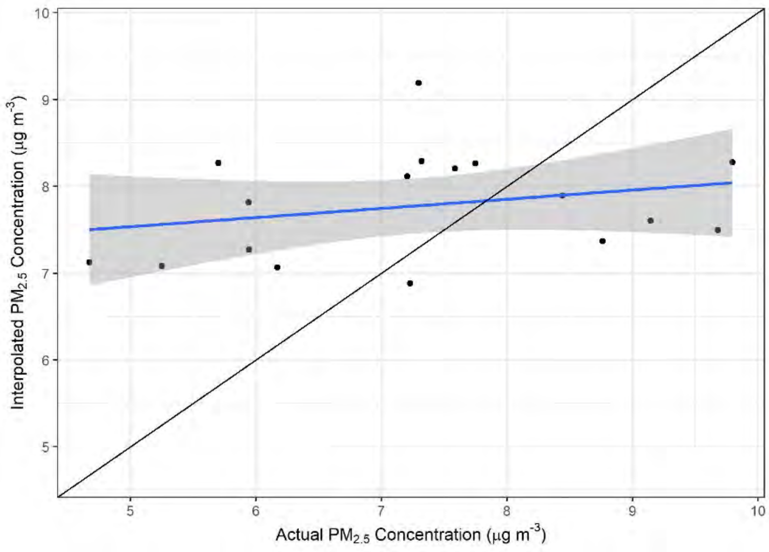


Figure 15. Removal bias results for $PM_{2.5}$.

## 2.7 Area Served

This analysis ranks monitoring sites in each network based on the extent of their spatial coverage; i.e., the size of their Area Served polygons. Conceptually, this zone represents the area around the monitoring site that is close enough to be represented by the concentrations measured at the monitor. The appropriate size and shape of this area is difficult to define precisely. The most common technique used to determine the spatial coverage of an air pollution monitor involves applying Thiessen polygons (also known as Voronoi diagrams) to represent each monitor's area of representation (Pope and Wu, 2014). Thiessen polygons are commonly used in geography to assign a zone of influence around a point or in place of interpolation techniques to generalize a set of sample measurements to the areas closest to them. They are created by delineating an area around a monitoring site in which each point is closer to that monitoring site than any other monitoring site.

The Thiessen polygon technique is a purely spatial construct and does not take into account meteorology, landscape topography, or other factors that may influence the extent of a monitor's spatial coverage. Therefore, while the technique may be appropriate for states with dense monitoring networks (e.g., California) or simple topography (e.g., Florida), its utility is limited in Colorado due to the sparseness of monitoring sites and the complexity of the terrain. For example, the presence of distinct meteo-geographical boundaries within Colorado (e.g., the Continental Divide, Palmer Divide, Cheyenne Ridge, etc.) limits atmospheric transport between airsheds, effectively separating regions of similar air quality and similar sources of air pollution (see Section 1.4.4). This can lead to some unreasonable results in the application of the Thiessen polygon technique, such as polygons that intersect the Continental Divide. Therefore, the Thiessen polygon approach has been modified in the present case: for airsheds possessing only one monitor, Thiessen polygons have not be constructed; rather, the entire area of the airshed has been assigned to that monitor. For airsheds possessing multiple monitors, Thiessen polygons have been drawn to assign coverage areas to each monitor within the airshed; however, the polygons were clipped such that they would not intersect airshed boundaries.

Restricting the Area Served polygons to airshed boundaries produces a more reasonable approximation of the extent of each monitoring site's spatial coverage; however, some polygons are so large that the monitoring point could not be said to adequately represent the entire area. For example, several of the polygons for $PM_{2.5}$ have dimensions of over 100 km, while the monitor-to-monitor correlation study described in Section 2.5.6 suggests that $PM_{2.5}$ concentrations are only weakly correlated over this distance of separation (Figure 9). Therefore, we have imposed a further restriction on the ultimate size of each monitor's area of representation: for each pollutant network, we have used the parameter correlograms presented in Section 2.5 to define a maximum radius of spatial extent as the distance where the correlation coeffiecient between monitors drops below an $r^2$ value of 0.6 (i.e., the maximum distance at which sites are still well-correlated according to the monitor-to-monitor correlation study). This maximum radius of spatial extent was then used as an upper-limit on the size of each Area Served polygon. The maximum spatial extent values for the CO, $NO_2$, $O_3$, $PM_{10}$, and $PM_{2.5}$ networks are 16.5, 17.1, 91.3, 11.4, and 17.1 km, respectively. The correlogram for $SO_2$ was not robust enough to derive a maximum radius value due to the limited availability of data from within the state; therefore, we have assumed a value of 11.4 km for the $SO_2$ network (i.e., the value obtained from the CO correlogram).

In the following section, maps are presented showing the Area Served polygons derived for each APCD monitoring network. The accompanying tables show the results of the Area Served analysis and the associated scores and rankings for each site. Note that the presence of monitoring sites operated by other agencies in Colorado has not been considered in the delineation of the Area Served polygons for the APCD sites being assessed in this report.

### 2.7.1 Carbon Monoxide (CO)

Table 36. All APCD CO monitoring sites ranked by area served.

| Site Name | Area Served ($km^2$) | Rank | Score |
|---|---|---|---|
| Greeley - County Tower | 855 | 1 | 7.0 |
| Fort Collins - Mason | 855 | 1 | 7.0 |
| Highway 24 | 829 | 2 | 6.8 |
| Welby | 536 | 3 | 4.2 |
| I-25: Denver | 406 | 4 | 3.0 |
| La Casa | 187 | 5 | 1.1 |
| CAMP | 181 | 6 | 1.0 |

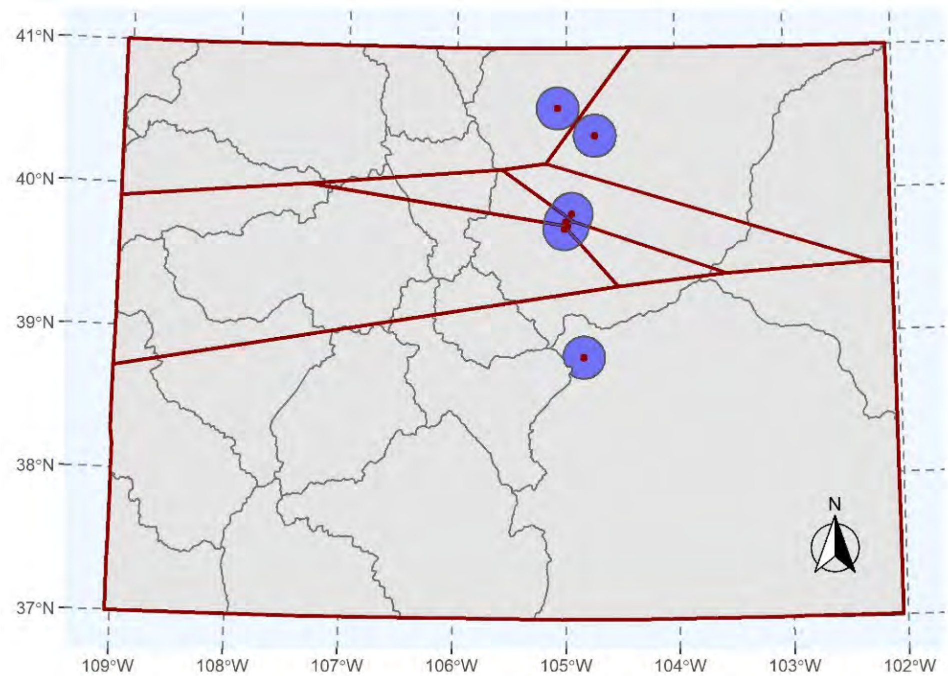


Figure 16. Map of Colorado showing the Area served polygons derived for the CO monitoring network.

### 2.7.2 Nitrogen Dioxide ($NO_2$)

Table 37. All APCD $NO_2$ monitoring sites ranked by area served.

| Site Name | Area Served ($km^2$) | Rank | Score |
|---|---|---|---|
| Rocky Flats - N. | 772 | 1 | 6.0 |
| Welby | 501 | 2 | 4.2 |
| I-25: Denver | 430 | 3 | 3.7 |
| CAMP | 181 | 4 | 2.0 |
| La Casa | 104 | 5 | 1.4 |
| I-25: Globeville | 39 | 6 | 1.0 |

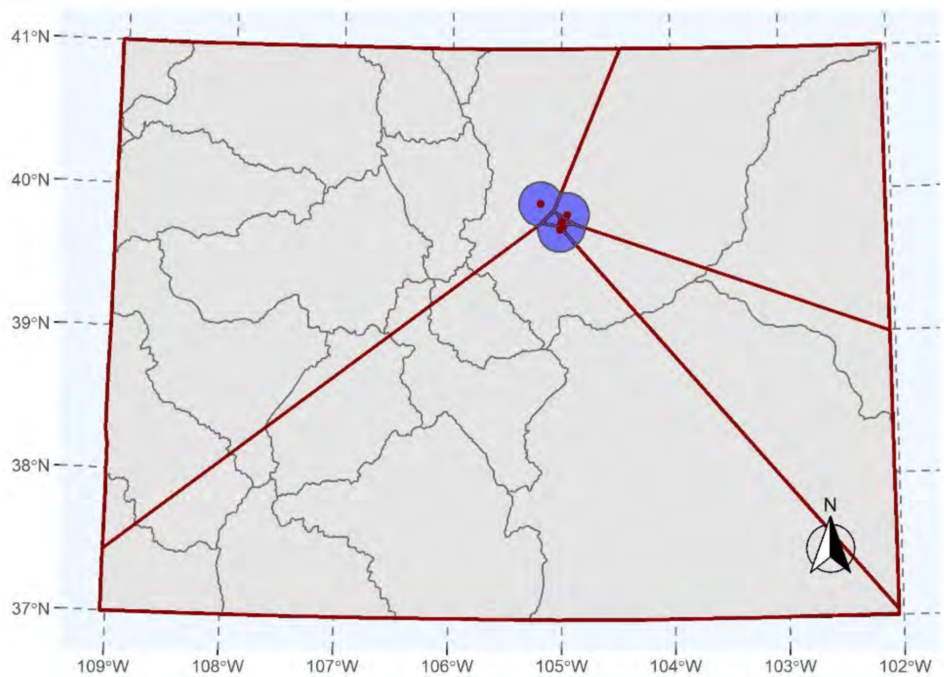


Figure 17. Map of Colorado showing the Area served polygons derived for the $NO_2$ monitoring network.

### 2.7.3 Sulfur Dioxide ($SO_2$)

Table 38. All APCD $SO_2$ monitoring sites ranked by area served.

| Site Name | Area Served ($km^2$) | Rank | Score |
|---|---|---|---|
| Highway 24 | 408 | 1 | 4.0 |
| Welby | 286 | 2 | 2.6 |
| CAMP | 228 | 3 | 1.9 |
| La Casa | 148 | 4 | 1.0 |

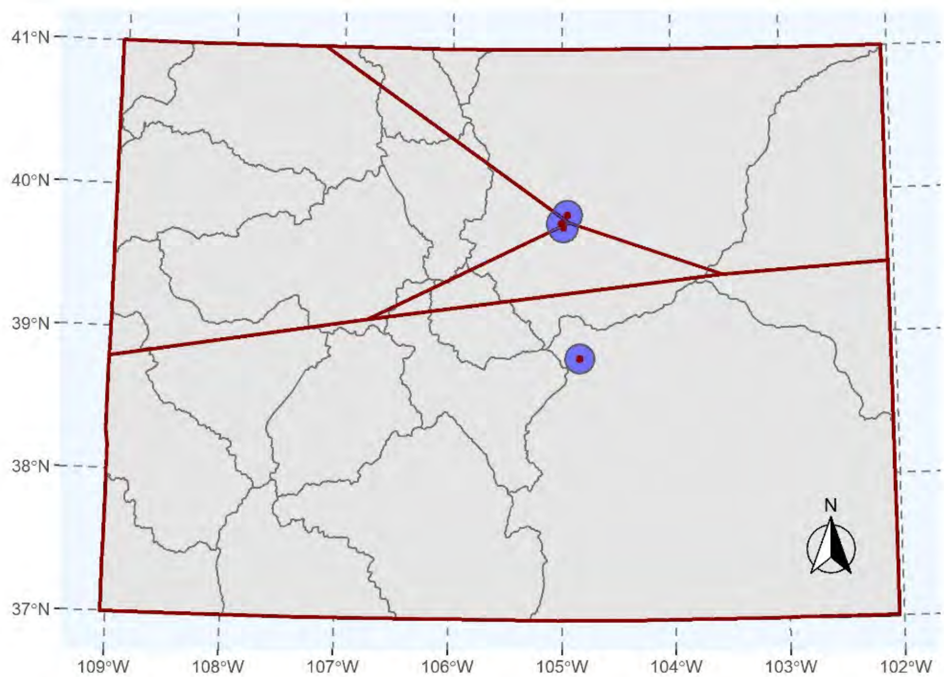

Figure 18. Map of Colorado showing the Area served polygons derived for the $SO_2$ monitoring network.

### 2.7.4 Ozone ($O_3$)

Table 39. All APCD $O_3$ monitoring sites ranked by area served.

| Site Name | Area Served (km$^2$) | Rank | Score |
|---|---|---|---|
| Palisade Water Treatment | 10,145 | 1 | 19.0 |
| Rifle - Health Dept. | 9,389 | 2 | 17.6 |
| Greeley - County Tower | 9,085 | 3 | 17.1 |
| Aurora - East | 8,496 | 4 | 16.0 |
| Manitou Springs | 7,207 | 5 | 13.7 |
| Cortez - Health Dept. | 6,083 | 6 | 11.7 |
| USAFA | 4,844 | 7 | 9.5 |
| Fort Collins - West | 4,451 | 8 | 8.8 |
| Boulder Reservoir | 2,288 | 9 | 4.9 |
| Fort Collins - Mason | 2,182 | 10 | 4.7 |
| Chatfield State Park | 1,955 | 11 | 4.3 |
| Black Hawk | 1,376 | 12 | 3.3 |
| Welby | 1,199 | 13 | 3.0 |
| Highland Reservoir | 914 | 14 | 2.4 |
| Welch | 547 | 15 | 1.8 |
| Rocky Flats - N. | 501 | 16 | 1.7 |
| NREL | 351 | 17 | 1.4 |
| CAMP | 272 | 18 | 1.3 |
| La Casa | 111 | 19 | 1.0 |

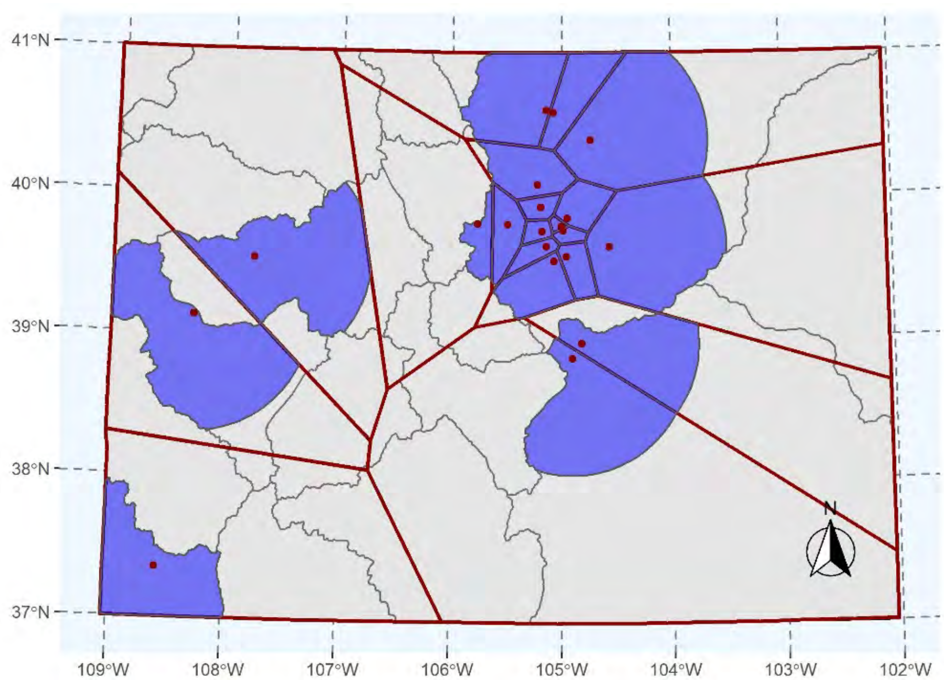


Figure 19. Map of Colorado showing the Area served polygons derived for the $O_3$ monitoring network.

### 2.7.5 $PM_{10}$

Table 40. All APCD $PM_{10}$ monitoring sites ranked by area served.

| Site Name | Area Served ($km^2$) | Rank | Score |
|---|---|---|---|
| Steamboat Springs | 408 | 1 | 15.0 |
| Aspen | 408 | 1 | 15.0 |
| Grand Junction - Powell Bldg. | 408 | 1 | 15.0 |
| Colorado College | 408 | 1 | 15.0 |
| Lamar - Municipal Bldg. | 408 | 1 | 15.0 |
| Pagosa Springs School | 408 | 1 | 15.0 |
| Pueblo - Fountain School | 408 | 1 | 15.0 |
| Boulder Chamber of Commerce | 403 | 2 | 14.7 |
| Longmont - Municipal Bldg. | 403 | 2 | 14.7 |
| Telluride | 254 | 3 | 6.8 |
| CAMP | 218 | 4 | 4.9 |
| Cañon City - City Hall | 213 | 5 | 4.6 |
| Welby | 170 | 6 | 2.4 |
| La Casa | 146 | 7 | 1.1 |
| Tri County Health (TCH) | 144 | 8 | 1.0 |

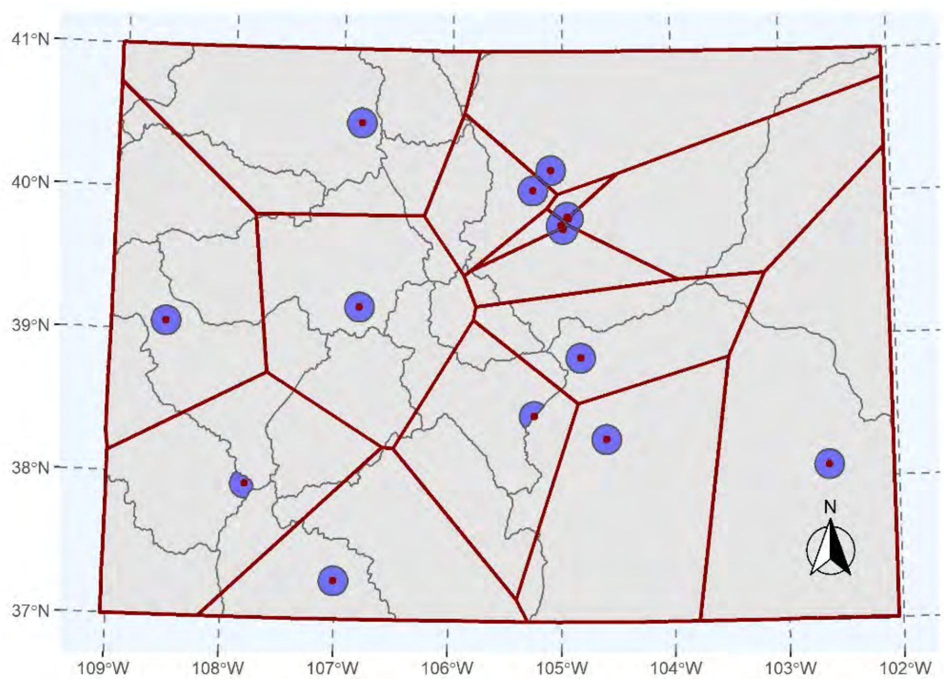


Figure 20. Map of Colorado showing the Area served polygons derived for the $PM_{10}$ monitoring network.

### 2.7.6 $PM_{2.5}$

Table 41. All APCD $PM_{2.5}$ monitoring sites ranked by area served.

| Site Name | Area Served (km²) | Rank | Score |
|---|---|---|---|
| Pueblo - Fountain School | 918 | 1 | 16.0 |
| Fort Collins - CSU | 918 | 1 | 16.0 |
| Grand Junction - Powell Bldg. | 914 | 2 | 15.9 |
| Colorado College | 906 | 3 | 15.8 |
| Greeley - Hospital | 843 | 4 | 14.8 |
| Platteville - Middle School | 796 | 5 | 13.3 |
| Longmont - Municipal Bldg. | 759 | 6 | 12.6 |
| Chatfield State Park | 711 | 7 | 10.9 |
| Tri County Health (TCH) | 610 | 8 | 8.9 |
| Arapaho Community College (ACC) | 494 | 9 | 6.6 |
| Boulder Chamber of Commerce | 354 | 10 | 6.6 |
| National Jewish Health (NJH) | 293 | 11 | 5.6 |
| I-25: Denver | 211 | 12 | 4.2 |
| La Casa | 193 | 13 | 3.9 |
| I-25: Globeville | 36 | 14 | 1.3 |
| CAMP | 16 | 15 | 1.0 |

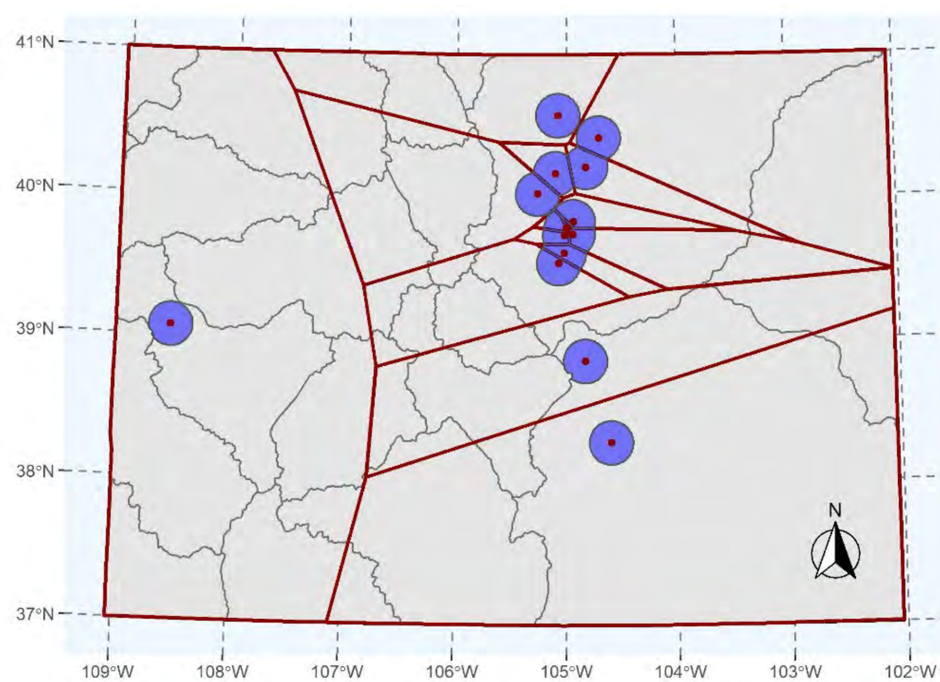


Figure 21. Map of Colorado showing the Area served polygons derived for the $PM_{2.5}$ monitoring network.

## 2.8 Population Served

This analysis attempts to quantify the population represented by each monitoring site. It has been well-established that high population densities are associated with high emissions and high ambient pollutant concentrations; therefore, monitors representing more population will typically be of greater importance in determining regulatory compliance. Furthermore, the collection of data that is representative of the greatest possible number of people is an important monitoring objective; therefore, monitors with the highest population counts are given the highest rank in this analysis.

Calculating the population served by a particular monitor requires two steps: (1) a determination of the area of representation for each monitor, and (2) a determination of the population within each monitor's area of representation. Areas of representation for each monitor were determined using a modified Thiessen polygon approach as described in Section 2.7. Tract-level data from the 2014-2018 ACS was then used within ArcGIS to create a polygon coverage map of census tracts within Colorado, which is presented in Figure 3. The population within each monitor's Area Served polygon was then determined by summing the population count totals for those census tract polygons that intersect each Area Served polygon.

The advantage of this analysis is that it provides a simple technique to quantify the population represented by a particular monitor. This technique will provide more weight to sites located in areas of high population density and sites with large areas of representation.

### 2.8.1 Results for All Parameters

Tables 42-47 list the Population Served and associated score for each APCD monitoring site in the CO, $NO_2$, $SO_2$, $O_3$, $PM_{10}$, and $PM_{2.5}$ ambient networks, respectively.

Table 42. All APCD CO monitoring sites ranked by population served.

| Site Name | Population Served | Rank | Score |
|---|---|---|---|
| I-25: Denver | 754,638 | 1 | 7.0 |
| Welby | 640,084 | 2 | 5.8 |
| Highway 24 | 593,391 | 3 | 5.3 |
| CAMP | 581,734 | 4 | 5.2 |
| La Casa | 347,911 | 5 | 2.7 |
| Fort Collins - Mason | 292,885 | 6 | 2.1 |
| Greeley - County Tower | 191,643 | 7 | 1.0 |

Table 43. All APCD $NO_2$ monitoring sites ranked by population served.

| Site Name | Population Served | Rank | Score |
|---|---|---|---|
| I-25 Denver | 766,401 | 1 | 6.0 |
| CAMP | 582,025 | 2 | 4.6 |
| Welby | 554,924 | 3 | 4.4 |
| RFN | 421,437 | 4 | 3.3 |
| La Casa | 245,174 | 5 | 2.0 |
| I-25 Globeville | 121,964 | 6 | 1.0 |

Table 44. All APCD $SO_2$ monitoring sites ranked by population served.

| Site Name | Population Served | Rank | Score |
|---|---|---|---|
| CAMP | 714,480 | 1 | 4.0 |
| Welby | 449,014 | 2 | 1.9 |
| Highway 24 | 407,909 | 3 | 1.6 |
| La Casa | 330,965 | 4 | 1.0 |

Table 45. All APCD $O_3$ monitoring sites ranked by population served.

| Site Name | Population Served | Rank | Score |
|---|---|---|---|
| CAMP | 856,881 | 1 | 19.0 |
| Highland Reservoir | 740,496 | 2 | 16.4 |
| Welby | 665,714 | 3 | 14.8 |
| Manitou Springs | 608,518 | 4 | 13.5 |
| USAFA | 445,880 | 5 | 9.9 |
| Boulder Reservoir | 375,432 | 6 | 8.4 |
| Fort Collins - Mason | 350.389 | 7 | 7.8 |
| Welch | 326,697 | 8 | 7.3 |
| Aurora - East | 301,507 | 9 | 6.8 |
| Greeley - County Tower | 299,614 | 10 | 6.7 |
| La Casa | 282,552 | 11 | 6.3 |
| Rocky Flats - N. | 272,673 | 12 | 6.1 |
| Palisade Water Treatment | 233,934 | 13 | 5.3 |
| NREL | 229,237 | 14 | 5.2 |
| Chatfield State Park | 171,002 | 15 | 3.9 |
| Rifle - Health Dept. | 120,976 | 16 | 2.8 |
| Fort Collins - West | 120,217 | 17 | 2.8 |
| Black Hawk | 61,443 | 18 | 1.5 |
| Cortez - Health Dept. | 40,332 | 19 | 1.0 |

Table 46. All APCD $PM_{10}$ monitoring sites ranked by population served.

| Site Name | Population Served | Rank | Score |
|---|---|---|---|
| CAMP | 700,353 | 1 | 15.0 |
| Colorado College | 468,626 | 2 | 10.3 |
| Welby | 342,148 | 3 | 7.7 |
| La Casa | 326,155 | 4 | 7.4 |
| Boulder Chamber of Commerce | 201,565 | 5 | 4.9 |
| Longmont - Municipal Bldg. | 160,839 | 6 | 4.0 |
| Tri County Health (TCH) | 160,275 | 7 | 4.0 |
| Pueblo - Fountain School | 147,239 | 8 | 3.8 |
| Grand Junction - Powell Bldg. | 133,737 | 9 | 3.5 |
| Steamboat Springs | 22,843 | 10 | 1.2 |
| Cañon City - City Hall | 22,495 | 11 | 1.2 |
| Aspen | 17,909 | 12 | 1.1 |
| Lamar - Municipal Bldg. | 16,434 | 13 | 1.1 |
| Pagosa Springs School | 12,908 | 14 | 1.0 |
| Telluride | 11,366 | 15 | 1.0 |

Table 47. All APCD $PM_{2.5}$ monitoring sites ranked by population served.

| Site Name | Population Served | Rank | |
|---|---|---|---|
| National Jewish Health (NJH) | 727,988 | 1 | 16.0 |
| Colorado College | 610,445 | 2 | 13.2 |
| Tri County Health (TCH) | 576,027 | 3 | 12.4 |
| Arapaho Community College (ACC) | 557.860 | 4 | 12.0 |
| I-25: Denver | 424,142 | 5 | 8.9 |
| La Casa | 329,290 | 6 | 6.6 |
| Fort Collins - CSU | 304,560 | 7 | 6.1 |
| Greeley - Hospital | 268,382 | 8 | 3.7 |
| Longmont - Municipal Bldg. | 202,531 | 9 | 3.6 |
| Chatfield State Park | 200,454 | 10 | 3.6 |
| Pueblo - Fountain School | 199,837 | 11 | 2.8 |
| Boulder Chamber of Commerce | 164,685 | 12 | 2.6 |
| Grand Junction - Powell Bldg. | 149,998 | 13 | 2.4 |
| I-25: Globeville | 117,284 | 14 | 1.7 |
| CAMP | 109,644 | 15 | 1.5 |
| Platteville - Middle School | 89,562 | 16 | 1.0 |

## 2.9 Emissions Inventory

This analysis ranks sites based on their proximity to point sources of pollution by giving weight to each monitor according to the sum of emissions within its area of representation. Areas of representation for each monitor were determined using a modified Thiessen polygon approach as described in Section 2.7. Point source emissions data was obtained from the 2020 APCD facilities inventory, which lists reported emissions for over 10,000 permitted sources within Colorado. Emissions data for CO, $NO_x$, $SO_2$, volatile organic compounds (VOCs), $PM_{10}$, and $PM_{2.5}$ were spatially located within ArcGIS and then summed within each monitor's Area Served polygon. Polygons with larger total emissions were ranked higher.

### 2.9.1 Carbon Monoxide (CO)

CO point source emissions density is shown for illustration purposes in Figure 22. The highest emissions in the state are associated with public utilities in Colorado Springs and Pueblo. A mining operation in southeast Moffat County is also a large source of CO.

Table 48. CO monitoring sites ranked by total emissions.

| Site Name | Sum of CO Emissions (tons) | Maximum | Rank | Score |
|---|---|---|---|---|
| Greeley - County Tower | 5,023 | 250 | 1 | 7 |
| Welby | 1,394 | 447 | 2 | 2.5 |
| La Casa | 581 | 79 | 3 | 1.5 |
| Highway 24 | 539 | 307 | 4 | 1.4 |
| CAMP | 466 | 151 | 5 | 1.3 |
| Fort Collins - Mason | 385 | 43 | 6 | 1.2 |
| I-25: Denver | 219 | 60 | 7 | 1 |

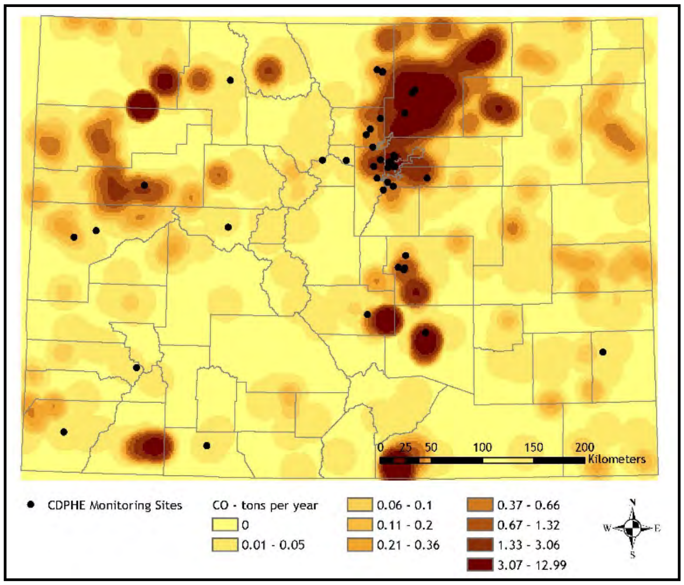


Figure 22. CO emissions density as calculated from point source data using the Kernel Density tool in ArcGIS. Class breaks have been determined using the quantile method.

### 2.9.2 Nitrogen Dioxide ($NO_2$)

$NO_x$ point source emissions density is shown for illustration purposes in Figure 23. The highest emissions in the state are associated with public utilities in Denver, Colorado Springs, Pueblo, and rural counties of Morgan and Routt. Regions of intensive oil and gas extraction in Weld and Garfield counties are also associated with high emissions.

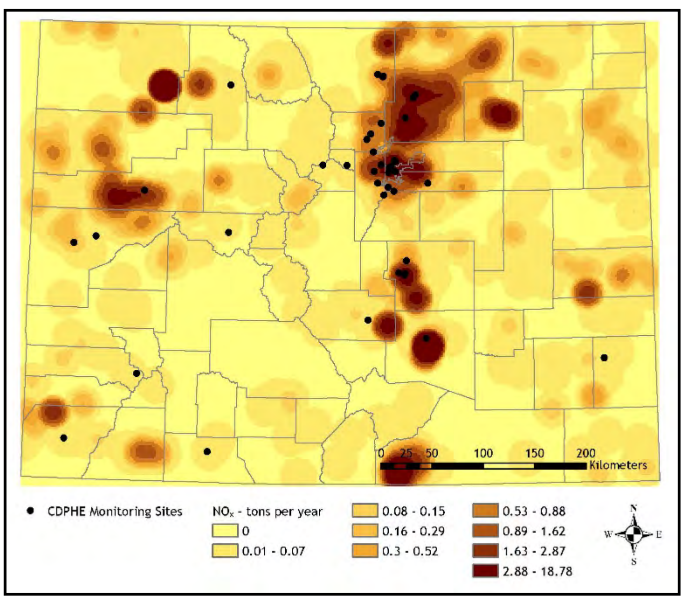


Figure 23. $NO_x$ emissions density as calculated from point source data using the Kernel Density tool in ArcGIS. Class breaks have been determined using the quantile method.

Table 49. $NO_2$ monitoring sites ranked by total $NO_x$ emissions.

| Site Name | Sum of $NO_x$ Emissions (tons) | Max. | Rank | Score |
|---|---|---|---|---|
| I-25 Globeville | 939 | 611 | 1 | 6.0 |
| Welby | 924 | 589 | 2 | 5.9 |
| RFN | 797 | 368 | 3 | 5.0 |
| CAMP | 608 | 179 | 4 | 3.7 |
| I-25 Denver | 305 | 30 | 5 | 1.5 |
| La Casa | 231 | 158 | 6 | 1.0 |

### 2.9.3 Sulfur Dioxide ($SO_2$)

$SO_2$ point source emissions density is shown in Figure 24. The highest emissions in the state are associated with the same public utilities mentioned above. Emissions are particularly concentrated in the Denver Metro area.

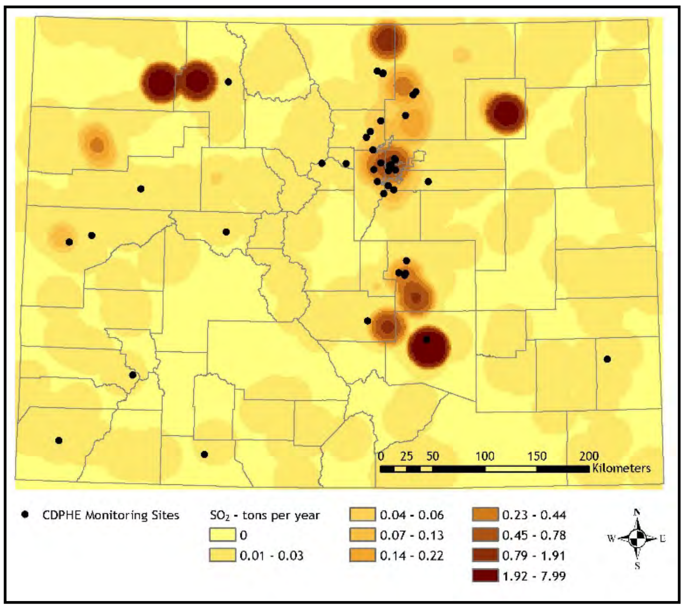


Figure 24. $SO_2$ emissions density as calculated from point source data using the Kernel Density tool in ArcGIS. Class breaks have been determined using the quantile method.

Table 50. $SO_2$ monitoring sites ranked by total emissions.

| Site Name | Sum of $SO_2$ Emissions (tons) | Max. | Rank | Score |
|---|---|---|---|---|
| Welby | 285 | 177 | 1 | 4.0 |
| La Casa | 243 | 122 | 2 | 3.4 |
| Highway 24 | 180 | 151 | 3 | 2.6 |
| CAMP | 69 | 40 | 4 | 1.0 |

### 2.9.4 Ozone ($O_3$)

Tropospheric $O_3$ is a secondary pollutant, meaning that it is not directly emitted, but formed *in-situ* through photochemical reactions involving VOCs and $NO_x$. Furthermore, although $O_3$ requires the presence of $NO_x$ in its formation reaction, it is also scavenged, or destroyed, by $NO_x$ in the atmosphere (Sillman, 1999). Because of its complex source/sink dynamics, $O_3$ concentrations follow much different patterns than other primary pollutants. In the short-term (i.e., several hours or less), $O_3$ will form near its precursor sources and increase in concentration as the plume moves downwind and has more time to react during daylight hours. At night, when photochemical cycling has ceased, $O_3$ concentrations within the urban area will decrease as $NO_x$ compounds in the area scavenge them. However, outside of the urban areas, where $NO_x$ concentrations are typically low, $O_3$ will persist in the environment and can last for weeks before dissipating. This causes $O_3$ concentrations to be much higher in the rural areas downwind of an urban area, especially when viewing concentrations averaged over long temporal periods.

Because of these dynamics, the methodology of ranking $O_3$ monitors in order of the total VOC and $NO_x$ point sources is not entirely valid. It is still practical to use the method established with the other primary pollutants, as the short-term $O_3$ levels can still be high in the area surrounding precursor point sources. However, another method of ranking that considers $O_3$ averages also needs to be adopted. This will be discussed in the following section.

VOC point source emissions density is shown for illustration purposes in Figure 25, while $NO_x$ emissions have been previously discussed and are shown in Figure 23. The highest VOC emission densities in the state occur in the Denver Metro area and in regions of intensive oil and gas extraction in Weld and Garfield counties.

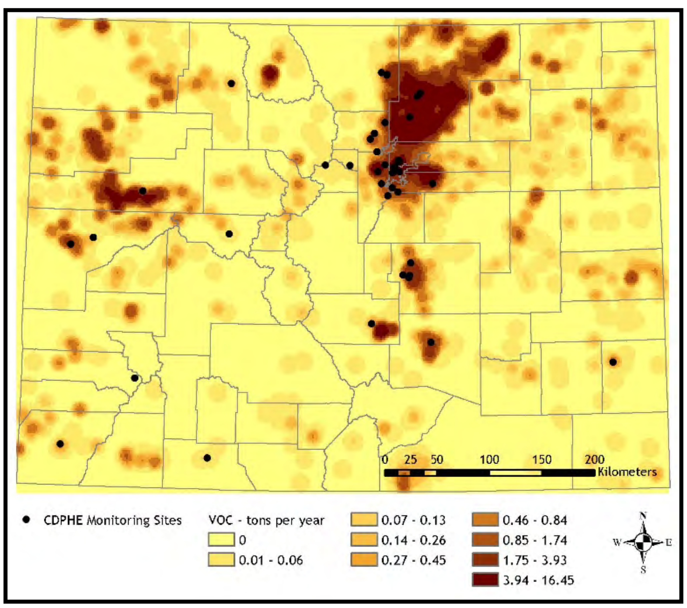


Figure 25. VOC emissions density as calculated from point source data using the Kernel Density tool in ArcGIS. Class breaks have been determined using the quantile method.

The emissions sums and maximum emission sections associated within each $O_3$ monitor are shown for $NO_x$ and VOCs in Table 51 and Table 52 respectively. In Table 53, the $NO_x$- and VOC-based rankings have been averaged to determine an overall ranking for each site.

Table 51. $O_3$ monitoring sites ranked by total $NO_x$ emissions.

| Site Name | Sum of $NO_x$ Emissions (tons) | Max. | Rank |
|---|---|---|---|
| Weld Co. Tower | 11,958 | 769 | 1 |
| Manitou Springs | 11,320 | 5,199 | 2 |
| Rifle - Health Dept. | 4,326 | 214 | 3 |
| Welby | 2,975 | 611 | 4 |
| Aurora East | 1,869 | 604 | 5 |
| Cortez | 1,153 | 866 | 6 |
| Ft. Collins - West | 1,149 | 1,110 | 7 |
| Boulder Reservoir | 1,136 | 293 | 8 |
| Ft. Collins - Mason | 1,048 | 155 | 9 |
| CAMP | 899 | 179 | 10 |
| NREL | 793 | 368 | 11 |
| Highland | 442 | 49 | 12 |
| Palisade | 400 | 33 | 13 |
| USAFA | 285 | 88 | 14 |
| La Casa | 277 | 61 | 15 |
| RFN | 175 | 118 | 16 |
| Chatfield | 109 | 38 | 17 |
| Welch | 12 | 5 | 18 |
| Black Hawk | 3 | 2 | 19 |

Table 52. $O_3$ monitoring sites ranked by total VOC emissions.

| Site Name | Sum of VOC Emissions (tons) | Max. | Rank |
|---|---|---|---|
| Weld Co. Tower | 25,065 | 337 | 1 |
| Welby | 5,361 | 589 | 2 |
| Rifle - Health Dept. | 5,210 | 190 | 3 |
| Aurora East | 2,979 | 192 | 4 |
| Manitou Springs | 2,802 | 243 | 5 |
| Boulder Reservoir | 2,435 | 95 | 6 |
| Ft. Collins - Mason | 2,434 | 255 | 7 |
| NREL | 1,100 | 375 | 8 |
| Palisade | 959 | 90 | 9 |
| CAMP | 898 | 36 | 10 |
| Highland | 757 | 32 | 11 |
| USAFA | 668 | 31 | 12 |
| La Casa | 641 | 84 | 13 |
| Cortez | 321 | 79 | 14 |
| RFN | 309 | 41 | 15 |
| Welch | 194 | 12 | 16 |
| Chatfield | 179 | 24 | 17 |
| Ft. Collins - West | 81 | 31 | 18 |
| Black Hawk | 26 | 8 | 19 |

Table 53. Overall emissions inventory rankings for the $O_3$ monitoring network.

| Site Name | Scores | | Average | Rank |
|---|---|---|---|---|
| | VOC | $NO_x$ | | |
| Greeley - County Tower | 19.0 | 19.0 | 19.0 | 1 |
| Manitou Springs | 3.0 | 18.0 | 10.5 | 2 |
| Rifle - Health Dept. | 4.7 | 7.5 | 6.1 | 3 |
| Welby | 4.8 | 5.5 | 5.2 | 4 |
| Aurora - East | 3.1 | 3.8 | 3.5 | 5 |
| Boulder Reservoir | 2.7 | 2.7 | 2.7 | 6 |
| Fort Collins - Mason | 2.7 | 2.6 | 2.7 | 7 |
| CAMP | 1.6 | 2.3 | 2.0 | 8 |
| NREL | 1.8 | 2.2 | 2.0 | 9 |
| Cortez - Health Dept. | 1.2 | 2.7 | 2.0 | 10 |
| Fort Collins - West | 1.0 | 2.7 | 1.9 | 11 |
| Palisade Water Treatment | 1.7 | 1.6 | 1.6 | 12 |
| Highland Reservoir | 1.5 | 1.7 | 1.6 | 13 |
| U.S. Air Force Academy (USAFA) | 1.5 | 1.4 | 1.4 | 14 |
| La Casa | 1.4 | 1.4 | 1.4 | 15 |
| Rocky Flats - N. | 1.2 | 1.3 | 1.2 | 16 |
| Chatfield State Park | 1.1 | 1.2 | 1.1 | 17 |
| Welch | 1.1 | 1.0 | 1.1 | 18 |
| Black Hawk | 1.0 | 1.0 | 1.0 | 19 |

### 2.9.5 $PM_{10}$

$PM_{10}$ point source emissions density is shown in Figure 26. The highest emissions in the state are associated with a large coal mining operation in southern Moffat County.

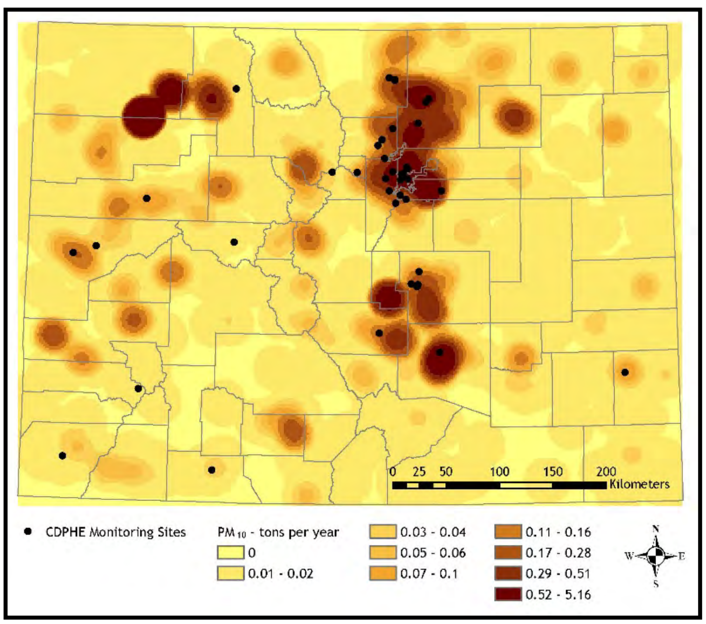


Figure 26. $PM_{10}$ emissions density as calculated from point source data using the Kernel Density tool in ArcGIS. Class breaks have been determined using the quantile method.



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Department of Public Health & Environment

Table 54. $PM_{10}$ monitoring sites ranked by total emissions.

| Site Name | Sum of $PM_{10}$ Emissions (tons) | Max. | Rank | Score |
|---|---|---|---|---|
| Pueblo - Fountain School | 498 | 246 | 1 | 15.0 |
| Tri County Health (TCH) | 435 | 144 | 2 | 13.3 |
| La Casa | 218 | 45 | 3 | 7.1 |
| Colorado College | 166 | 21 | 4 | 5.6 |
| CAMP | 124 | 24 | 5 | 4.4 |
| Longmont - Municipal Bldg. | 98 | 34 | 6 | 3.7 |
| Grand Junction - Powell Bldg. | 93 | 19 | 7 | 3.6 |
| Lamar - Municipal Bldg. | 46 | 24 | 8 | 2.2 |
| Boulder Chamber of Commerce (CC) | 22 | 7 | 9 | 1.6 |
| Welby | 19 | 7 | 10 | 1.5 |
| Pagosa Springs School | 16 | 8 | 11 | 1.4 |
| Cañon City - City Hall | 8 | 7 | 12 | 1.2 |
| Steamboat Springs | 7 | 3 | 13 | 1.1 |
| Aspen | 5 | 5 | 14 | 1.1 |
| Telluride | 2 | 1 | 15 | 1.0 |

### 2.9.6 $PM_{2.5}$

$PM_{2.5}$, like $O_3$, can be considered a secondary pollutant, although it can also be directly emitted to the atmosphere. Nitrate ($NO_3^-$) and sulfate ($SO_4^{2-}$) are particularly important components of secondary $PM_{2.5}$. Because these chemical species originate from the oxidation of $NO_x$ and $SO_2$, respectively, $NO_x$ and $SO_2$ point source emissions are also considered in the ranking of the $PM_{2.5}$ sites.

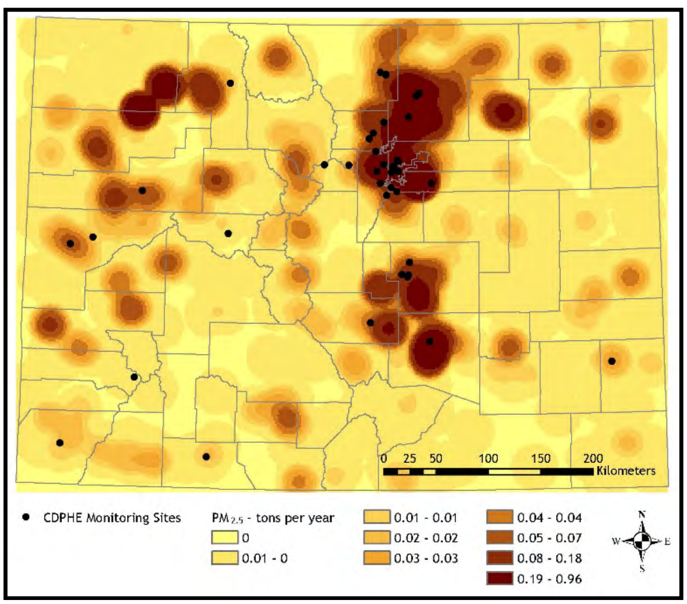


Figure 27. $PM_{2.5}$ emissions density as calculated from point source data using the Kernel Density tool in ArcGIS. Class breaks have been determined using the quantile method.

$PM_{2.5}$ point source emissions density is shown for illustration purposes in Figure 27, while $NO_x$ and $SO_2$ emissions have been previously discussed and are shown in Figure 23 and Figure 24, respectively. The highest $PM_{2.5}$ emission densities in the state occur in the Denver Metro area and in Weld County. Other large point sources include a landfill in Arapahoe County, coal mining operations in southern Moffet County, a refinery locate in the Denver metro area, and a power plant in Pueblo.

Table 55. $PM_{2.5}$ monitoring sites ranked by total $PM_{2.5}$ emissions.

| Site Name | Sum of $PM_{2.5}$ Emissions (tons) | Max. | Rank |
|---|---|---|---|
| Pueblo | 521 | 142 | 1 |
| Greeley - Hospital | 368 | 101 | 2 |
| Tri County Health | 302 | 121 | 3 |
| Platteville | 281 | 60 | 4 |
| Longmont - Municipal Bldg. | 199 | 84 | 5 |
| I-25 Globeville | 118 | 34 | 6 |
| Colorado College | 102 | 14 | 7 |
| I-25 Denver | 84 | 36 | 8 |
| La Casa | 70 | 41 | 9 |
| NJH | 64 | 13 | 10 |
| Ft. Collins - CSU | 54 | 10 | 11 |
| ACC | 43 | 9 | 12 |
| Chatfield | 40 | 13 | 13 |
| GJ - Powell Bldg. | 37 | 3 | 14 |
| Boulder - Chamber of Comm. | 16 | 3 | 15 |
| CAMP | 11 | 4 | 16 |

Table 56. $PM_{2.5}$ monitoring sites ranked by total $NO_x$ emissions.

| Site Name | Sum of $NO_x$ Emissions (tons) | Max. | Rank |
|---|---|---|---|
| Pueblo | 6,763 | 5,199 | 1 |
| Platteville | 2,874 | 510 | 2 |
| Greeley - Hospital | 2,697 | 226 | 3 |
| Colorado College | 1,696 | 1,294 | 4 |
| Tri County Health | 1,486 | 611 | 5 |
| Longmont - Municipal Bldg. | 755 | 293 | 6 |
| NJH | 529 | 116 | 7 |
| ACC | 418 | 49 | 8 |
| CAMP | 373 | 179 | 9 |
| Ft. Collins - CSU | 373 | 121 | 9 |
| La Casa | 293 | 158 | 10 |
| I-25 Globeville | 274 | 61 | 11 |
| I-25 Denver | 234 | 30 | 12 |
| Chatfield | 115 | 38 | 13 |
| Boulder - Chamber of Comm. | 103 | 43 | 14 |
| GJ - Powell Bldg. | 89 | 33 | 15 |

Table 57. $PM_{2.5}$ monitoring sites ranked by total $SO_2$ emissions.

| Site Name | Sum of $SO_2$ Emissions (tons) | Max. | Rank |
|---|---|---|---|
| Pueblo | 4,295 | 4,186 | 1 |
| Tri County Health | 293 | 177 | 2 |
| Colorado College | 186 | 151 | 3 |
| Greeley - Hospital | 157 | 132 | 4 |
| La Casa | 140 | 122 | 5 |
| I-25 Globeville | 119 | 45 | 6 |
| Platteville | 99 | 63 | 7 |
| ACC | 81 | 40 | 8 |
| Longmont - Municipal Bldg. | 63 | 21 | 9 |
| GJ - Powell Bldg. | 53 | 29 | 10 |
| I-25 Denver | 46 | 27 | 11 |
| Chatfield | 24 | 14 | 12 |
| Ft. Collins - CSU | 20 | 12 | 13 |
| NJH | 19 | 6 | 14 |
| Boulder - Chamber of Comm. | 7 | 4 | 15 |
| CAMP | 3 | 1 | 16 |

Table 58. Overall emissions inventory rankings for the $PM_{2.5}$ monitoring network.

| Site Name | Scores | | | Average | Rank |
|---|---|---|---|---|---|
| | $PM_{2.5}$ | $NO_x$ | $SO_2$ | | |
| Pueblo - Fountain School | 16.0 | 16.0 | 16.0 | 16.0 | 1 |
| Greeley - Hospital | 11.5 | 6.9 | 1.5 | 6.6 | 2 |
| Platteville - Middle School | 8.9 | 7.3 | 1.3 | 5.8 | 3 |
| Tri County Health (TCH) | 9.6 | 4.1 | 2.0 | 5.2 | 4 |
| Longmont - Municipal Bldg. | 6.5 | 2.5 | 1.2 | 3.4 | 5 |
| Colorado College | 3.7 | 4.6 | 1.6 | 3.3 | 6 |
| I-25: Globeville | 4.1 | 1.4 | 1.4 | 2.3 | 7 |
| La Casa | 2.7 | 1.5 | 1.5 | 1.9 | 8 |
| National Jewish Health (NJH) | 2.6 | 2.0 | 1.1 | 1.9 | 9 |
| I-25: Denver | 3.1 | 1.3 | 1.1 | 1.9 | 10 |
| Fort Collins - CSU | 2.3 | 1.6 | 1.1 | 1.7 | 11 |
| Arapaho Community College | 1.9 | 1.7 | 1.3 | 1.7 | 12 |
| Chatfield State Park | 1.9 | 1.1 | 1.1 | 1.3 | 13 |
| Grand Junction - Powell Bldg. | 1.8 | 1.0 | 1.2 | 1.3 | 14 |
| CAMP | 1.0 | 1.6 | 1.0 | 1.2 | 15 |
| Boulder Chamber of Commerce | 1.2 | 1.0 | 1.0 | 1.1 | 16 |

### 2.9.7 Lead (Pb)

Lead point sources required for monitoring are based on emissions are listed in the 2017 National Emissions Inventory, which is the most current version. The sources from the inventory with greater than 0.25 tons per year (500 pounds per year) are shown in Table 59.

Table 59. Major lead sources in Colorado.

| Name | Location | Emissions (lbs/year) |
|---|---|---|
| Rocky Mountain Bottle Co. | Wheat Ridge | 3127.10 |
| Centennial Airport | Denver | 1548.75 |
| US Army - Fort Carson | Colorado Springs | 816.00 |
| Greeley-Weld County Airport | Greeley | 794.81 |
| CF & I Steel Mill | Pueblo | 778.50 |
| Pueblo Memorial Airport | Pueblo | 739.64 |
| Clean Harbors Envir. Services | Sterling | 621.00 |
| Jeffco Airport | Denver | 597.71 |
| Fort Collins-Loveland Airport | Fort Collins/Loveland | 584.02 |
| Erie Municipal Airport | Erie | 526.48 |
| Buckley Air Force Base | Aurora | 510.38 |

## 2.10 Traffic Counts

Point sources typically account for only a portion of the pollution emissions within an area. The Traffic Count analysis considers transportation and mobile source emissions. This analysis evaluates the mobile source emissions within the influence of a monitoring site; these data, along with point source data from the Emissions Inventory analysis described in Section 2.9, are used to assess the total effect of emissions within each site's area of representation (i.e., Area Served polygon).

Emissions from mobile sources can vary greatly; factors which can affect the amount of pollution released include road type (e.g., fast-moving vehicles on a freeway generally emit less pollution per unit distance than vehicles on arterial roads and collectors), vehicle type (e.g., diesel vs. gasoline powered vehicles), traffic congestion, age and size of vehicles, etc. Ideally, a method which attempts to account for traffic emissions would account for all of these variables in a spatially resolved model. Unfortunately, such traffic modeling is outside of the scope of this network assessment. Instead, traffic counts and road density are used in this analysis as proxies for mobile source pollution.

Annual average daily traffic (AADT) counts were obtained from the Colorado Department of Transportation for 2018, the most recent year with available data. The dataset includes counts for highways and major roads with comprehensive sample location coverage; however, it is difficult to ascertain if AADT sample locations include all arterial roads with the same density (see Figure 28) and it is likely that additional new roads were not sampled. To account for variations in sampling density in different parts of the state, the total AADT counts within each site's Area Served polygon were normalized by the average distance between sampling locations. The rankings based on normalized AADT counts were then averaged together with rankings based on road density and each site was ranked based on this overall score. To further normalize the AADT counts, this analysis also considers the road density within each site's Area Served polygon when calculating the final rankings.

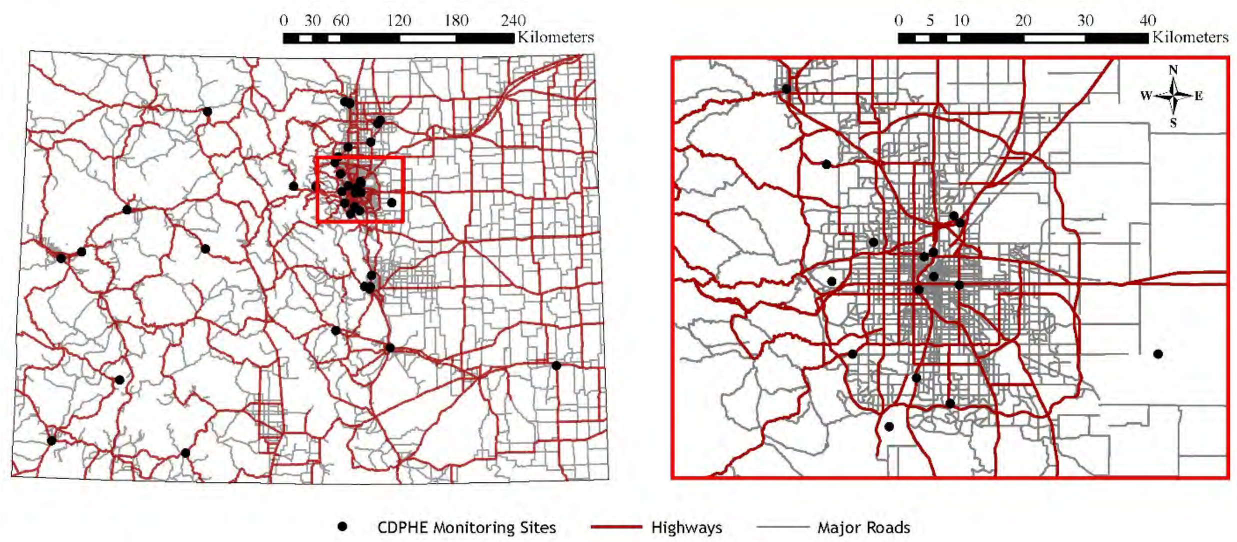


Figure 28. Highways and major roads in Colorado.

### 2.10.1 Carbon Monoxide (CO)

Table 60. CO monitoring sites ranked by traffic counts.

| Site Name | Sum of AADT Counts | | Total Normalized | Score |
|---|---|---|---|---|
| | Major Roads | Highways | AADT Counts | |
| La Casa | 15,574,690 | 88,911,100 | 87,996 | 7.0 |
| CAMP | 64,106,000 | 252,744,500 | 85,239 | 6.8 |
| Welby | 41,610,850 | 138,160,000 | 82,840 | 6.5 |
| I-25 Denver | 45,816,850 | 173,687,600 | 80,221 | 6.3 |
| HWY 24 | 50,868,570 | 69,037,000 | 63,716 | 4.8 |
| Ft. Collins - Mason | 12,863,130 | 25,089,400 | 33,120 | 2.1 |
| Weld County Tower | 6,148,900 | 19,632,560 | 20,672 | 1.0 |

Table 61. CO monitoring sites ranked by road density.

| Site Name | Size of Area Served Polygon ($km^2$) | Total Road Length (km) | Road Density ($m/km^2$) | Score |
|---|---|---|---|---|
| CAMP | 181 | 335 | 1,850 | 7.0 |
| La Casa | 186 | 250 | 1,344 | 4.8 |
| I-25 Denver | 406 | 525 | 1,293 | 4.7 |
| Welby | 536 | 455 | 848 | 2.8 |
| HWY 24 | 829 | 526 | 634 | 1.9 |
| Ft. Collins - Mason | 855 | 376 | 440 | 1.1 |
| Weld County Tower | 855 | 366 | 428 | 1.0 |

Table 62. Overall traffic counts rankings for the CO monitoring network.

| Site Name | Scores | | | Rank |
|---|---|---|---|---|
| | Traffic Counts | Road Density | Average | |
| CAMP | 6.8 | 7.0 | 6.9 | 1 |
| La Casa | 7.0 | 4.8 | 5.9 | 2 |
| I-25: Denver | 6.3 | 4.7 | 5.5 | 3 |
| Welby | 6.5 | 2.8 | 4.7 | 4 |
| Highway 24 | 4.8 | 1.9 | 3.4 | 5 |
| Fort Collins - Mason | 2.1 | 1.1 | 1.6 | 6 |
| Greeley - County Tower | 1.0 | 1.0 | 1.0 | 7 |

## 2.10.2 Nitrogen Dioxide ($NO_2$)

Table 63. $NO_2$ monitoring sites ranked by traffic counts.

| Site Name | Sum of AADT Counts | | Total Normalized AADT Counts | Score |
|---|---|---|---|---|
| | Major Roads | Highways | | |
| I-25: Globeville | 5,105,400 | 56,474,800 | 120,409 | 6.0 |
| La Casa | 10,559,420 | 53,775,000 | 83,900 | 3.8 |
| CAMP | 52,068,600 | 54,289,000 | 81,985 | 3.7 |
| Welby | 39,942,910 | 118,872,400 | 81,967 | 3.7 |
| I-25: Denver | 47,811,950 | 182,373,700 | 80,173 | 3.6 |
| Rocky Flats - N. | 16,111,980 | 53,057,300 | 36,416 | 1.0 |

Table 64. $NO_2$ monitoring sites ranked by road density.

| Site Name | Size of Area Served Polygon ($km^2$) | Total Road Length (km) | Road Density ($m/km^2$) | Score |
|---|---|---|---|---|
| CAMP | 181 | 323 | 1,785 | 6.0 |
| I-25: Globeville | 104 | 166 | 1,596 | 5.7 |
| La Casa | 430 | 548 | 1274 | 5.3 |
| I-25: Denver | 501 | 411 | 820 | 4.0 |
| Welby | 772 | 417 | 540 | 2.1 |
| Rocky Flats - N. | 394 | 68 | 172 | 1.0 |

Table 65. Overall traffic counts rankings for the $NO_2$ monitoring network.

| Site Name | Scores | | | Rank |
|---|---|---|---|---|
| | Traffic Counts | Road Density | Average | |
| I-25: Globeville | 6.0 | 5.7 | 5.9 | 1 |
| CAMP | 3.7 | 6.0 | 4.9 | 2 |
| La Casa | 3.8 | 5.3 | 4.5 | 3 |
| I-25: Denver | 3.6 | 4.0 | 3.8 | 4 |
| Welby | 3.7 | 2.1 | 2.9 | 5 |
| Rocky Flats - N. | 1.0 | 1.0 | 1.0 | 6 |

### 2.10.3 Sulfur Dioxide ($SO_2$)

Table 66. $SO_2$ monitoring sites ranked by traffic counts.

| Site Name | Sum of AADT Counts | | Total Normalized | Score |
|---|---|---|---|---|
| | Major Roads | Highways | AADT Counts | |
| Welby | 24,708,340 | 99,336,200 | 93,342 | 4.0 |
| CAMP | 69,706,760 | 122,384,000 | 92,118 | 3.8 |
| La Casa | 14,432,090 | 90,498,200 | 87,953 | 3.2 |
| Highway 24 | 36,457,460 | 50,075,000 | 72,530 | 1.0 |

Table 67. $SO_2$ monitoring sites ranked by road density.

| Site Name | Size of Area Served Polygon ($km^2$) | Total Road Length (km) | Road Density ($m/km^2$) | Score |
|---|---|---|---|---|
| CAMP | 228 | 458 | 2,008 | 4.0 |
| La Casa | 148 | 230 | 1,554 | 2.8 |
| Welby | 286 | 265 | 927 | 1.1 |
| Highway 24 | 408 | 365 | 895 | 1.0 |

Table 68. Overall traffic counts rankings for the $SO_2$ monitoring network.

| Site Name | Scores | | | Rank |
|---|---|---|---|---|
| | Traffic Counts | Road Density | Average | |
| CAMP | 3.8 | 4.0 | 3.9 | 1 |
| La Casa | 3.2 | 2.8 | 3.0 | 3 |
| Welby | 4.0 | 1.1 | 2.5 | 2 |
| Highway 24 | 1.0 | 1.0 | 1.0 | 4 |

### 2.10.4 Ozone ($O_3$)

Table 69. $O_3$ monitoring sites ranked by traffic counts.

| Site Name | Sum of AADT Counts | | Total Normalized | Score |
|---|---|---|---|---|
| | Major Roads | Highways | AADT Counts | |
| CAMP | 80,462,440 | 128,011,000 | 93,615 | 19.0 |
| La Casa | 12,431,670 | 79,874,200 | 91,692 | 18.6 |
| Highland Reservoir | 36,922,740 | 139,269,000 | 85,371 | 17.3 |
| Welby | 51,094,450 | 148,853,500 | 67,596 | 13.7 |
| NREL | 7,375,950 | 58,215,300 | 52,114 | 10.6 |
| Welch | 7,628,360 | 38,280,800 | 40,754 | 8.3 |
| Rocky Flats - N. | 8,624,450 | 36,069,100 | 37,028 | 7.5 |
| Fort Collins - Mason | 14,767,610 | 41,685,100 | 30,234 | 6.1 |
| USAFA | 32,514,320 | 44,457,090 | 28,904 | 5.9 |
| Boulder Reservoir | 15,945,310 | 54,106,000 | 26,434 | 5.4 |
| Chatfield State Park | 3,244,140 | 21,193,900 | 26,197 | 5.3 |
| Manitou Springs | 33,950,770 | 99,359,830 | 22,394 | 4.6 |
| Rifle - Health Dept. | 2,567,750 | 34,755,580 | 14,475 | 3.0 |
| Greeley - County Tower | 7,551,270 | 49,089,840 | 12,754 | 2.6 |
| Aurora - East | 6,725,290 | 18,634,800 | 10,440 | 2.1 |
| Black Hawk | 104,400 | 17,129,440 | 10,059 | 2.1 |
| Palisade Water Treatment | 12,500,880 | 34,657,160 | 9,580 | 2.0 |
| Fort Collins - West | 1,214,500 | 7,199,340 | 5,816 | 1.2 |
| Cortez - Health Dept. | 458,560 | 8,126,240 | 4,838 | 1.0 |

Table 70. $O_3$ monitoring sites ranked by road density.

| Site Name | Size of Area Served Polygon (km$^2$) | Total Road Length (km) | Road Density (m/km$^2$) | Score |
|---|---|---|---|---|
| CAMP | 272 | 510 | 1,875 | 19.0 |
| La Casa | 111 | 185 | 1,667 | 17.0 |
| NREL | 351 | 223 | 635 | 6.6 |
| Highland Reservoir | 915 | 493 | 539 | 5.6 |
| Welby | 1,199 | 624 | 520 | 5.5 |
| Rocky Flats - N. | 501 | 240 | 479 | 5.0 |
| Welch | 547 | 244 | 446 | 4.7 |
| Boulder Reservoir | 2,288 | 656 | 286 | 3.1 |
| Fort Collins - Mason | 2,182 | 537 | 246 | 2.7 |
| USAFA | 4,844 | 988 | 204 | 2.3 |
| Black Hawk | 1,376 | 256 | 186 | 2.1 |
| Manitou Springs | 7,207 | 1,323 | 183 | 2.1 |
| Greeley - County Tower | 9,085 | 1347 | 148 | 1.7 |
| Chatfield State Park | 1,954 | 260 | 133 | 1.6 |
| Aurora - East | 8,496 | 846 | 100 | 1.2 |
| Palisade Water Treatment | 10,145 | 1,008 | 99 | 1.2 |
| Fort Collins - West | 4,451 | 413 | 93 | 1.2 |
| Cortez - Health Dept. | 6,083 | 519 | 85 | 1.1 |
| Rifle - Health Dept. | 9,389 | 705 | 75 | 1.0 |

Table 71. Overall traffic counts rankings for the $O_3$ monitoring network.

| Site Name | Scores | | | Rank |
|---|---|---|---|---|
| | Traffic Counts | Road Density | Average | |
| CAMP | 19.0 | 19.0 | 19.0 | 1 |
| La Casa | 18.6 | 17.0 | 17.8 | 2 |
| Highland Reservoir | 17.3 | 5.6 | 11.5 | 3 |
| Welby | 13.7 | 5.5 | 9.6 | 4 |
| NREL | 10.6 | 6.6 | 8.6 | 5 |
| Welch | 8.3 | 4.7 | 6.5 | 6 |
| Rocky Flats - N. | 7.5 | 5.0 | 6.3 | 7 |
| Fort Collins - Mason | 6.1 | 2.7 | 4.4 | 8 |
| Boulder Reservoir | 5.4 | 3.1 | 4.2 | 9 |
| USAFA | 5.9 | 2.3 | 4.1 | 10 |
| Chatfield State Park | 5.3 | 1.6 | 3.5 | 11 |
| Manitou Springs | 4.6 | 2.1 | 3.3 | 12 |
| Greeley - County Tower | 2.6 | 1.7 | 2.2 | 13 |
| Black Hawk | 2.1 | 2.1 | 2.1 | 14 |
| Rifle - Health Dept. | 3.0 | 1.0 | 2.0 | 15 |
| Aurora - East | 2.1 | 1.2 | 1.7 | 16 |
| Palisade Water Treatment | 2.0 | 1.2 | 1.6 | 17 |
| Fort Collins - West | 1.2 | 1.2 | 1.2 | 18 |
| Cortez - Health Dept. | 1.0 | 1.1 | 1.1 | 19 |

### 2.10.5 $PM_{10}$

Table 72. $PM_{10}$ monitoring sites ranked by traffic counts.

| Site Name | Sum of AADT Counts | | Total Normalized AADT Counts | Score |
|---|---|---|---|---|
| | Major Roads | Highways | | |
| Welby | 17,875,340 | 68,052,000 | 98,895 | 15.0 |
| CAMP | 68,655,560 | 117,790,000 | 91,089 | 13.8 |
| La Casa | 14,367,290 | 90,245,200 | 89,295 | 13.6 |
| Tri County Health (TCH) | 9,577,300 | 39,514,400 | 88,323 | 13.4 |
| Colorado College | 42,049,630 | 53,813,000 | 76,306 | 11.6 |
| Longmont - Municipal Bldg. | 7,350,980 | 20,029,000 | 37,086 | 5.8 |
| Boulder Chamber of Commerce | 8,489,980 | 23,649,400 | 35,226 | 5.5 |
| Pueblo - Fountain School | 9,574,660 | 15,260,100 | 23,110 | 4.4 |
| Grand Junction - Powell Bldg. | 137,450 | 2,660,900 | 14,285 | 3.7 |
| Aspen | 321,650 | 3,387,700 | 13,312 | 2.4 |
| Steamboat Springs | 31,800 | 2,187,200 | 8,678 | 2.3 |
| Pagosa Springs School | 415,850 | 714,600 | 8,635 | 1.6 |
| Cañon City - City Hall | 2,884,320 | 28,296,900 | 8,048 | 1.6 |
| Lamar - Municipal Bldg. | 231,940 | 1,817,020 | 6,310 | 1.2 |
| Telluride | 13,200 | 648,600 | 4,877 | 1.0 |

Table 73. $PM_{10}$ monitoring sites ranked by road density.

| Site Name | Size of Area Served Polygon ($km^2$) | Total Road Length (km) | Road Density ($m/km^2$) | Score |
|---|---|---|---|---|
| CAMP | 218 | 447 | 2,050 | 15.0 |
| La Casa | 146 | 229 | 1,568 | 11.5 |
| Welby | 170 | 189 | 1,112 | 8.3 |
| Colorado College | 408 | 396 | 971 | 7.2 |
| Tri County Health (TCH) | 144 | 104 | 722 | 5.4 |
| Pueblo - Fountain School | 408 | 265 | 650 | 4.9 |
| Longmont - Municipal Bldg. | 403 | 228 | 566 | 4.3 |
| Grand Junction - Powell Bldg. | 408 | 213 | 522 | 4.0 |
| Boulder Chamber of Commerce | 403 | 210 | 521 | 4.0 |
| Lamar - Municipal Bldg. | 408 | 90 | 220 | 1.8 |
| Steamboat Springs | 408 | 78 | 191 | 1.6 |
| Cañon City - City Hall | 213 | 33 | 155 | 1.3 |
| Telluride | 254 | 37 | 146 | 1.2 |
| Aspen | 408 | 47 | 115 | 1.0 |
| Pagosa Springs School | 408 | 37 | 91 | 1.0 |

Table 74. Overall traffic counts rankings for the $PM_{10}$ monitoring network.

| Site Name | Scores | | | Rank |
|---|---|---|---|---|
| | Traffic Counts | Road Density | Average | |
| CAMP | 13.8 | 15.0 | 14.4 | 1 |
| La Casa | 13.6 | 11.5 | 12.6 | 2 |
| Welby | 15.0 | 8.3 | 11.6 | 3 |
| Colorado College | 11.6 | 7.2 | 9.4 | 4 |
| Tri County Health (TCH) | 13.4 | 5.4 | 9.4 | 5 |
| Longmont - Municipal Bldg. | 5.8 | 4.3 | 5.0 | 6 |
| Boulder Chamber of Commerce (CC) | 5.5 | 4.0 | 4.7 | 7 |
| Pueblo - Fountain School | 4.4 | 4.9 | 4.7 | 8 |
| Grand Junction - Powell Bldg. | 3.7 | 4.0 | 3.8 | 9 |
| Steamboat Springs | 2.3 | 1.6 | 1.9 | 10 |
| Aspen | 2.4 | 1.0 | 1.7 | 11 |
| Lamar - Municipal Bldg. | 1.2 | 1.8 | 1.5 | 12 |
| Cañon City - City Hall | 1.6 | 1.3 | 1.4 | 13 |
| Pagosa Springs School | 1.6 | 1.0 | 1.3 | 14 |
| Telluride | 1.0 | 1.2 | 1.1 | 15 |

### 2.10.6 $PM_{2.5}$

Table 75. $PM_{2.5}$ monitoring sites ranked by traffic counts.

| Site Name | Sum of AADT Counts | | Total Normalized AADT Counts | Score |
|---|---|---|---|---|
| | Major Roads | Highways | | |
| I-25: Globeville | 4,784,300 | 54,815,200 | 126,430 | 16.0 |
| CAMP | 15,311,680 | 9,122,000 | 122,712 | 15.5 |
| National Jewish Health (NJH) | 57,624,220 | 100,443,200 | 97,045 | 11.9 |
| Arapaho Community College | 29,321,440 | 109,409,700 | 87,546 | 10.5 |
| I-25: Denver | 26,052,540 | 100,075,300 | 77,998 | 9.2 |
| La Casa | 14,445,920 | 63,126,700 | 77,395 | 9.1 |
| Tri County Health (TCH) | 36,402,930 | 91,000,000 | 70,605 | 8.2 |
| Colorado College | 53,649,580 | 74,193,000 | 64,037 | 7.2 |
| Longmont - Municipal Bldg. | 8,746,460 | 33,861,100 | 38,131 | 3.6 |
| Chatfield State Park | 3,374,560 | 20,866,300 | 35,223 | 3.2 |
| Fort Collins - CSU | 13,517,540 | 26,335,400 | 33,390 | 2.9 |
| Boulder Chamber of Commerce | 11,281,970 | 37,669,200 | 30,632 | 2.8 |
| Pueblo - Fountain School | 5,411,540 | 29,301,300 | 24,286 | 1.7 |
| Platteville - Middle School | 1,167,320 | 11,420,800 | 20,626 | 1.2 |
| Greeley - Hospital | 5,931,560 | 17,074,560 | 19,970 | 1.1 |
| Grand Junction - Powell Bldg. | 9,741,610 | 17,803,860 | 19,496 | 1.0 |

Table 76. $PM_{2.5}$ monitoring sites ranked by road density.

| Site Name | Size of Area Served Polygon ($km^2$) | Total Road Length (km) | Road Density ($m/km^2$) | Score |
|---|---|---|---|---|
| CAMP | 16 | 80 | 5,000 | 16.0 |
| I-25: Globeville | 36 | 61 | 1,694 | 5.6 |
| I-25: Denver | 211 | 291 | 1,379 | 4.5 |
| National Jewish Health (NJH) | 293 | 391 | 1,334 | 4.3 |
| La Casa | 193 | 241 | 1,248 | 4.1 |
| Arapaho Community College | 354 | 370 | 1,045 | 3.5 |
| Tri County Health (TCH) | 494 | 391 | 791 | 2.6 |
| Colorado College | 906 | 558 | 615 | 2.1 |
| Boulder Chamber of Commerce | 711 | 328 | 461 | 1.8 |
| Longmont - Municipal Bldg. | 918 | 396 | 431 | 1.6 |
| Fort Collins - CSU | 796 | 336 | 422 | 1.5 |
| Greeley - Hospital | 843 | 353 | 419 | 1.4 |
| Pueblo - Fountain School | 918 | 341 | 371 | 1.3 |
| Grand Junction - Powell Bldg. | 914 | 291 | 318 | 1.1 |
| Chatfield State Park | 610 | 175 | 287 | 1.0 |
| Platteville - Middle School | 759 | 216 | 284 | 1.0 |

Table 77. Overall traffic counts rankings for the $PM_{2.5}$ monitoring network.

| Site Name | Scores | | | Rank |
|---|---|---|---|---|
| | Traffic Counts | Road Density | Average | |
| CAMP | 15.5 | 16.0 | 15.7 | 1 |
| I-25: Globeville | 16.0 | 5.6 | 10.8 | 2 |
| National Jewish Health (NJH) | 11.9 | 4.3 | 8.1 | 3 |
| Arapaho Community College (ACC) | 10.5 | 3.5 | 7.0 | 4 |
| I-25: Denver | 9.2 | 4.5 | 6.9 | 5 |
| La Casa | 9.1 | 4.1 | 6.6 | 6 |
| Tri County Health (TCH) | 8.2 | 2.6 | 5.4 | 7 |
| Colorado College | 7.2 | 2.1 | 4.7 | 8 |
| Longmont - Municipal Bldg. | 3.6 | 1.6 | 2.6 | 9 |
| Boulder Chamber of Commerce (CC) | 2.8 | 1.8 | 2.3 | 10 |
| Fort Collins - CSU | 2.9 | 1.5 | 2.2 | 11 |
| Chatfield State Park | 3.2 | 1.0 | 2.1 | 12 |
| Pueblo - Fountain School | 1.7 | 1.3 | 1.5 | 13 |
| Greeley - Hospital | 1.1 | 1.4 | 1.3 | 14 |
| Platteville - Middle School | 1.2 | 1.0 | 1.1 | 15 |
| Grand Junction - Powell Bldg. | 1.0 | 1.1 | 1.1 | 16 |

## 2.11 Results

The purpose of using many different, often competing, indicators is to provide a comprehensive evaluation technique that attempts to address all of the APCD's monitoring objectives, which are themselves often conflicting; e.g., the assessment of population exposure in areas of maximum pollutant concentrations and the determination of background concentrations are fundamentally different objectives requiring separate monitoring strategies. However, the various indicators used are not necessarily of equal importance to the overall analysis and the relative importance of each indicator should be expected to vary between pollutants. For example, the Measured Concentration indicator is widely believed to be the most relevant to the Network Assessment (Pope and Wu, 2014). However, in the case of the APCD $PM_{10}$ network, an overreliance on the Measured Concentration indicator would result in an analysis that is highly biased toward sites that are impacted by regional dust storms. Because these are exceptional events beyond the division's control, the APCD feels that the Deviation from the NAAQS indicator is a more appropriate metric by which to assess the $PM_{10}$ network. Furthermore, while traffic volume and point source density (i.e., "source-oriented" indicators) may be highly correlated with $SO_2$ and $NO_2$ concentrations in ambient air (Gulliver et al., 2011; Beelen et al., 2013), these sources are less relevant in determining the concentration of $O_3$, a secondary pollutant whose concentration is often reduced via $NO_x$ titration in areas immediately surrounding pollution sources (Sillman, 1999). Therefore, the APCD feels that these indicators should be deemphasized in the case of $O_3$.

Another point that must be considered is that many of the indicators used in the site-to-site comparsion analysis are spatially collocated and therefore correlated. For example, population density, traffic volume, and point source emissions all tend to be highest in areas of maximum economic activity (e.g., the central business distrcit). To simply combine these indicators without weighting factors would result in an analysis that is biased heavily toward urban areas. This would be particularly problematic in the case of $O_3$, the pollutant of most concern within Colorado, which typically reaches its highest concentrations at suburban, rural, and high elevation sites. To reflect the variability among the factors addressed in the assessment, APCD has determined weights of relative importance to use when combining the individual indicators for each parameter assessed. These weighting factors were then used to produce a weighted score from the raw rankings derived from each analysis.

The weighting factors chosen for the CO, $NO_2$, $SO_2$, $O_3$, $PM_{10}$, and $PM_{2.5}$ networks are shown in the following tables.

Table 78. Weighting factors applied to the site-to-site comparison results for each network.

| Analysis | CO Weight | $NO_2$ Weight | $SO_2$ Weight | $O_3$ Weight | $PM_{10}$ Weight | $PM_{2.5}$ Weight |
|---|---|---|---|---|---|---|
| Number of Parameters Monitored | 12.6% | 12.7% | 7.0% | 5.0% | 3.8% | 6.6% |
| Trends Impact | 9.2% | 8.9% | 7.4% | 7.0% | 8.7% | 8.9% |
| Measured Concentration | 24.2% | 23.3% | 25.6% | 21.0% | 25.3% | 21.8% |
| Deviation from the NAAQS | - | - | - | 13.0% | - | - |
| Monitor-to-Monitor Correlation | 7.4% | 2.0% | 2.8% | 16.0% | 8.3% | 6.3% |
| Removal Bias | - | - | - | 12.0% | 8.6% | 7.4% |
| Area Served | 4.4% | 6.0% | 5.7% | 16.0% | 11.0% | 9.7% |
| Population Served | 17.1% | 16.7% | 18.9% | 5.0% | 17.4% | 15.0% |
| Point Source Emissions | 7.4% | 17.4% | 28.4% | 3.0% | 11.7% | 16.0% |
| Traffic Counts | 17.7% | 13.0% | 4.2% | 2.0% | 5.2% | 8.3% |

### 2.11.1 Parameter Details

In this section, the raw rankings derived from each analysis are converted to scores. For each monitoring network, the number of possible points is equivalent to the number of sites in the network (e.g., for the CO network, the maximum possible score is seven). Sites ranking first in a given analysis are assigned the maximum number of points (e.g., seven for the CO network), while the other sites are given scores that scale linearly between one and the maximum.

The following figures and tables show the results of the overall analysis for each pollutant network. The final rankings are based on the weighted average score, with the highest scoring monitor being given a one, the second highest scoring monitor being given a two, etc.

#### *2.11.1.1 Carbon Monoxide (CO)*

Table 79. Raw scores and weighted averages for the CO site-to-site comparison analyses.

| Site Name | Parameters Monitored | Trends Impact | Measured Concentration | Monitor-to-Monitor Correlation | Area Served | Population Served | Point Source Emissions | Traffic Counts | Weighted Total Score | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| CAMP | 7.0 | 7.0 | 7.0 | 2.6 | 1.0 | 5.2 | 1.3 | 6.9 | 5.6 | 1 |
| Welby | 5.5 | 6.0 | 3.0 | 4.1 | 4.2 | 5.8 | 2.5 | 4.7 | 4.4 | 2 |
| I-25: Denver | 2.5 | 1.2 | 5.5 | 1.0 | 3.0 | 7.0 | 1.0 | 5.5 | 4.2 | 3 |
| La Casa | 7.0 | 1.2 | 4.7 | 1.0 | 1.1 | 2.7 | 1.5 | 5.9 | 3.9 | 4 |
| Highway 24 | 1.0 | 3.0 | 4.4 | 7.0 | 6.8 | 5.3 | 1.4 | 3.4 | 3.8 | 5 |
| Fort Collins - Mason | 1.0 | 5.2 | 3.3 | 4.6 | 7.0 | 2.1 | 1.2 | 1.6 | 2.7 | 6 |
| Greeley - County Tower | 1.0 | 1.0 | 1.0 | 6.1 | 7.0 | 1.0 | 7.0 | 1.0 | 2.0 | 7 |
| **Weight** | 13% | 9% | 24% | 7% | 4% | 17% | 7% | 18% | | |

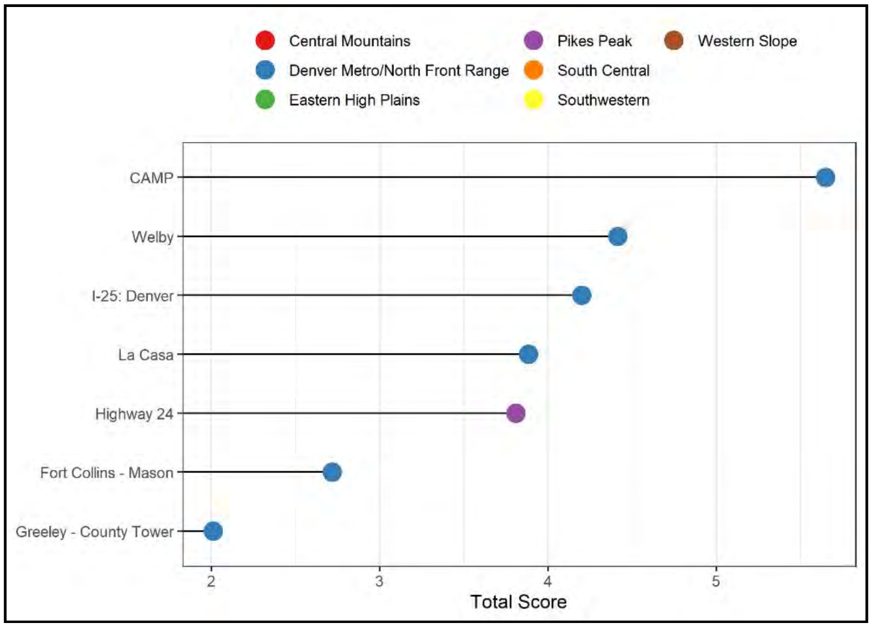


Figure 29. Cleveland dot plot showing the weighted total score for each site in the CO monitoring network.

### *2.11.1.2 Sulfur Dioxide ($SO_2$)*

Table 80. Raw scores and weighted averages for the $SO_2$ site-to-site comparison analyses.

| Site Name | Parameters Monitored | Trends Impact | Measured Concentration | Monitor-to-Monitor Correlation | Area Served | Population Served | Point Source Emissions | Traffic Counts | Weighted Total Score | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| Welby | 3.3 | 3.5 | 1.5 | 2.8 | 2.6 | 1.9 | 4.0 | 2.5 | 2.6 | 1 |
| CAMP | 4.0 | 4.0 | 1.0 | 1.0 | 1.9 | 4.0 | 1.0 | 3.9 | 2.6 | 2 |
| La Casa | 4.0 | 1.0 | 2.1 | 1.0 | 1.0 | 1.0 | 3.4 | 3.0 | 2.3 | 3 |
| Highway 24 | 1.0 | 1.0 | 4.0 | 4.0 | 4.0 | 1.6 | 2.6 | 1.0 | 2.3 | 4 |
| **Weight** | 7% | 7% | 26% | 3% | 6% | 19% | 28% | 4% | | |

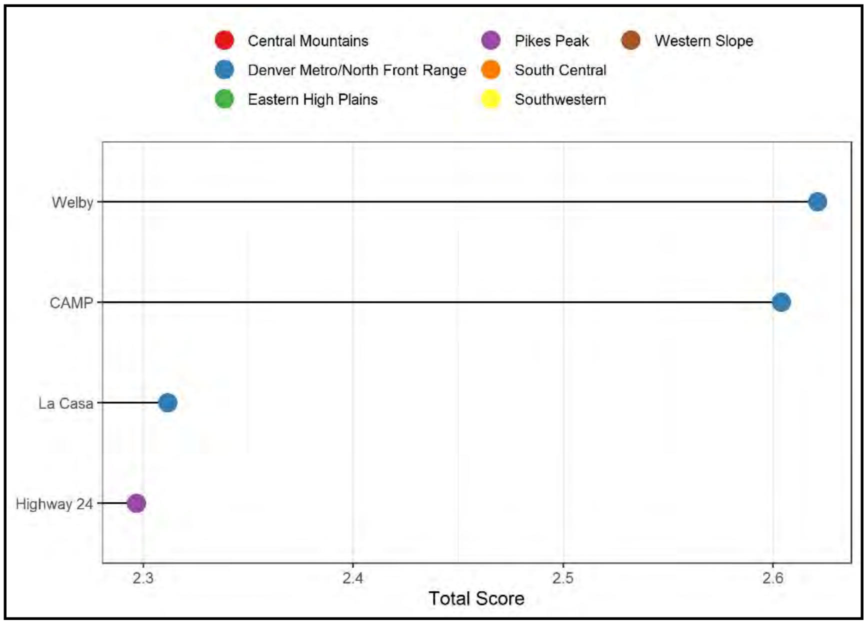


Figure 30. Cleveland dot plot showing the weighted total score for each site in the $SO_2$ monitoring network.

### *2.11.1.3 Nitrogen Dioxide ($NO_2$)*

Table 81. Raw scores and weighted averages for the $NO_2$ site-to-site comparison analyses.

| **Site Name** | **Parameters Monitored** | **Trends Impact** | **Measured Concentration** | **Monitor-to-Monitor Correlation** | **Area Served** | **Population Served** | **Point Source Emissions** | **Traffic Counts** | **Weighted Total Score** | **Rank** |
|---|---|---|---|---|---|---|---|---|---|---|
| Welby | 4.8 | 4.9 | 4.9 | 1.5 | 4.2 | 4.4 | 5.9 | 2.9 | 4.8 | 1 |
| CAMP | 6.0 | 6.0 | 5.7 | 1.1 | 2.0 | 4.6 | 3.7 | 4.9 | 4.5 | 2 |
| I-25: Globeville | 1.0 | 1.0 | 6.0 | 1.0 | 1.0 | 1.0 | 6.0 | 5.9 | 3.9 | 3 |
| I-25: Denver | 2.3 | 1.2 | 5.5 | 1.0 | 3.7 | 6.0 | 1.5 | 3.8 | 3.6 | 4 |
| Rocky Flats - N. | 1.0 | 3.0 | 1.0 | 6.0 | 6.0 | 3.3 | 5.0 | 1.0 | 3.2 | 5 |
| La Casa | 6.0 | 1.1 | 4.7 | 1.1 | 1.4 | 2.0 | 1.0 | 4.5 | 2.7 | 6 |
| **Weight** | 13% | 9% | 23% | 2% | 6% | 17% | 17% | 13% | | |

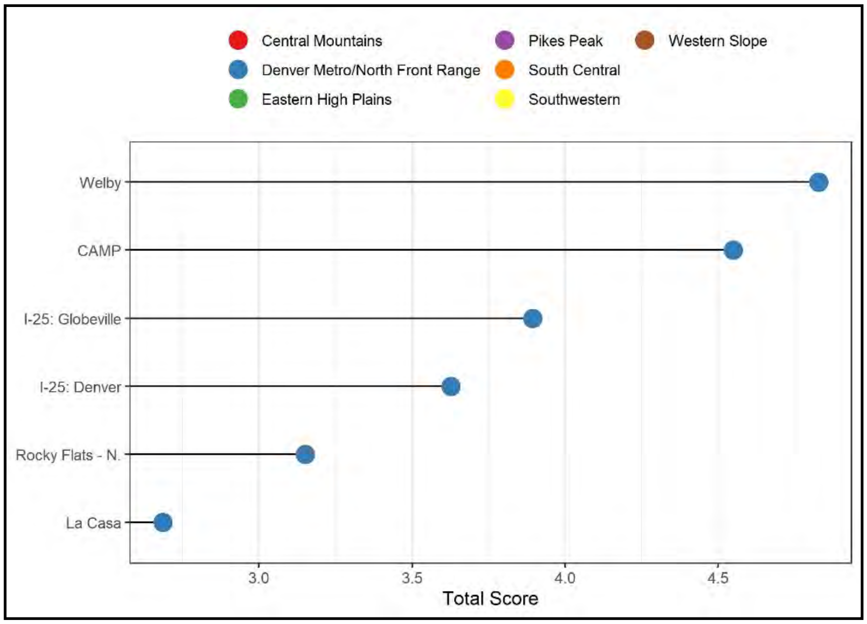


Figure 31. Cleveland dot plot showing the weighted total score for each site in the $NO_2$ monitoring network.

### *2.11.1.4 Ozone ($O_3$)*

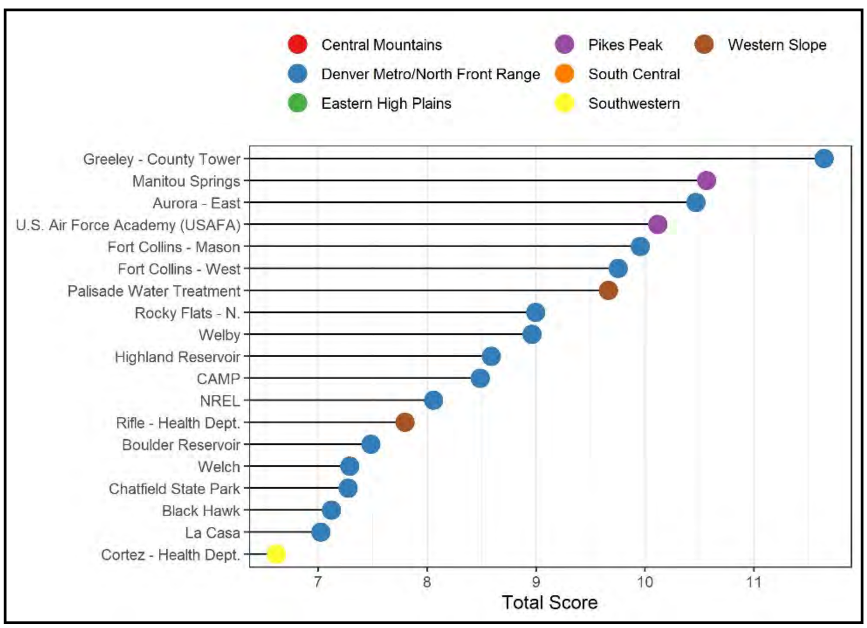


Figure 32. Cleveland dot plot showing the weighted total score for each site in the $O_3$ monitoring network.

Table 82. Raw scores and weighted averages for the $O_3$ site-to-site comparison analyses.

| Site Name | Parameters Monitored | Trends Impact | Measured Concentration | Deviation from the NAAQS | Monitor-to-Monitor Correlation | Removal Bias | Area Served | Population Served | Point Source Emissions | Traffic Counts | Weighted Total Score | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Greeley - County Tower | 7.0 | 7.5 | 10.7 | 19.0 | 8.7 | 8.2 | 17.1 | 6.7 | 19.0 | 2.2 | 11.6 | 1 |
| Manitou Springs | 1.0 | 6.7 | 9.3 | 16.5 | 9.5 | 9.7 | 13.7 | 13.5 | 10.5 | 3.3 | 10.6 | 2 |
| Aurora - East | 4.0 | 4.8 | 9.7 | 17.1 | 6.0 | 13.9 | 16.0 | 6.8 | 3.5 | 1.7 | 10.5 | 3 |
| U.S. Air Force Academy | 1.0 | 9.8 | 9.7 | 17.1 | 12.5 | 8.2 | 9.5 | 9.9 | 1.4 | 4.1 | 10.1 | 4 |
| Fort Collins - Mason | 7.0 | 15.9 | 8.0 | 14.0 | 8.7 | 19.0 | 4.7 | 7.8 | 2.7 | 4.4 | 10.0 | 5 |
| Fort Collins - West | 1.0 | 6.0 | 16.3 | 8.4 | 5.5 | 18.7 | 8.8 | 2.8 | 1.9 | 1.2 | 9.8 | 6 |
| Palisade Water Treatment | 4.0 | 5.2 | 6.0 | 10.3 | 12.2 | 9.7 | 19.0 | 5.3 | 1.6 | 1.6 | 9.7 | 7 |
| Rocky Flats - N. | 7.0 | 11.3 | 16.7 | 7.8 | 4.5 | 15.7 | 1.7 | 6.1 | 1.2 | 6.3 | 9.0 | 8 |
| Welby | 16.0 | 18.6 | 6.3 | 10.9 | 9.0 | 9.2 | 3.0 | 14.8 | 5.2 | 9.6 | 9.0 | 9 |
| Highland Reservoir | 4.0 | 16.7 | 14.7 | 11.6 | 3.6 | 4.8 | 2.4 | 16.4 | 1.6 | 11.5 | 8.6 | 10 |
| CAMP | 19.0 | 19.0 | 9.0 | 15.9 | 1.9 | 3.0 | 1.3 | 19.0 | 2.0 | 19.0 | 8.5 | 11 |
| NREL | 1.0 | 10.6 | 17.7 | 6.0 | 3.8 | 12.2 | 1.4 | 5.2 | 2.0 | 8.6 | 8.1 | 12 |
| Rifle - Health Dept. | 1.0 | 5.2 | 1.0 | 1.0 | 12.2 | 15.8 | 17.6 | 2.8 | 6.1 | 2.0 | 7.8 | 13 |
| Boulder Reservoir | 4.0 | 2.1 | 13.7 | 13.4 | 4.1 | 4.0 | 4.9 | 8.4 | 2.7 | 4.2 | 7.5 | 14 |
| Welch | 4.0 | 11.7 | 11.7 | 17.1 | 4.1 | 1.0 | 1.8 | 7.3 | 1.1 | 6.5 | 7.3 | 15 |
| Chatfield State Park | 7.0 | 6.7 | 19.0 | 3.5 | 3.6 | 3.7 | 4.3 | 3.9 | 1.1 | 3.5 | 7.3 | 16 |
| Black Hawk | 1.0 | 1.0 | 4.7 | 7.8 | 19.0 | 10.8 | 3.3 | 1.5 | 1.0 | 2.1 | 7.1 | 17 |
| La Casa | 19.0 | 3.3 | 9.0 | 15.9 | 3.2 | 4.1 | 1.0 | 6.3 | 1.4 | 17.8 | 7.0 | 18 |
| Cortez - Health Dept. | 1.0 | 5.2 | 2.7 | 4.1 | 15.8 | 4.8 | 11.7 | 1.0 | 2.0 | 1.1 | 6.6 | 19 |
| **Weight** | 5% | 7% | 21% | 13% | 16% | 12% | 16% | 5% | 3% | 2% | | |

### *2.11.1.5 PM$_{10}$*

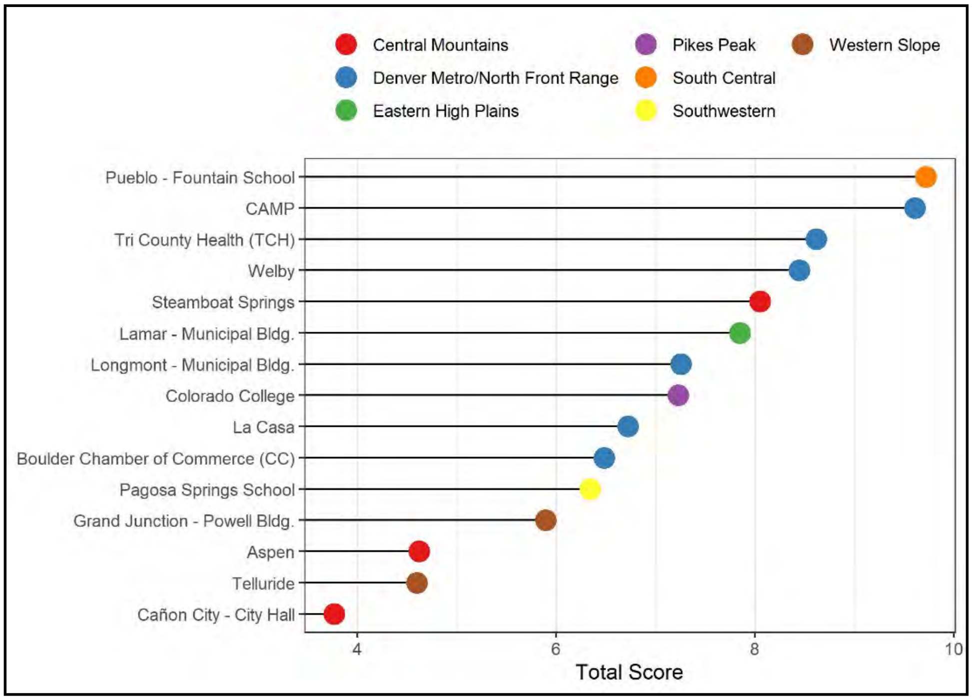


Figure 33. Cleveland dot plot showing the weighted total score for each site in the PM$_{10}$ monitoring network.

Table 83. Raw scores and weighted averages for the PM$_{10}$ site-to-site comparison analyses.

| Site Name | Parameters Monitored | Trends Impact | Measured Concentration | Monitor-to-Monitor Correlation | Removal Bias | Area Served | Population Served | Point Source Emissions | Traffic Counts | Weighted Total Score | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pueblo - Fountain School | 3.3 | 4.2 | 15.0 | 13.1 | 1.0 | 15.0 | 3.8 | 15.0 | 4.7 | 9.7 | 1 |
| CAMP | 15.0 | 14.5 | 10.5 | 1.0 | 7.1 | 4.9 | 15.0 | 4.4 | 14.4 | 9.6 | 2 |
| Tri County Health (TCH) | 3.3 | 1.0 | 14.5 | 7.1 | 15.0 | 1.0 | 4.0 | 13.3 | 9.4 | 8.6 | 3 |
| Welby | 12.7 | 14.5 | 7.9 | 13.3 | 14.0 | 2.4 | 7.7 | 1.5 | 11.6 | 8.4 | 4 |
| Steamboat Springs | 1.0 | 14.5 | 12.6 | 11.9 | 5.7 | 15.0 | 1.2 | 1.1 | 1.9 | 8.1 | 5 |
| Lamar - Municipal Bldg. | 1.0 | 14.5 | 12.1 | 13.1 | 2.7 | 15.0 | 1.1 | 2.2 | 1.5 | 7.8 | 6 |
| Longmont - Municipal | 3.3 | 15.0 | 5.8 | 10.9 | 5.1 | 14.7 | 4.0 | 3.7 | 5.0 | 7.3 | 7 |
| Colorado College | 3.3 | 4.6 | 3.0 | 11.5 | 5.0 | 15.0 | 10.3 | 5.6 | 9.4 | 7.2 | 8 |
| La Casa | 15.0 | 2.8 | 7.0 | 4.5 | 10.0 | 1.1 | 7.4 | 7.1 | 12.6 | 6.7 | 9 |
| Boulder Chamber | 3.3 | 10.9 | 4.4 | 10.9 | 5.8 | 14.7 | 4.9 | 1.6 | 4.7 | 6.5 | 10 |
| Pagosa Springs School | 1.0 | 15.0 | 6.2 | 14.4 | 2.0 | 15.0 | 1.0 | 1.4 | 1.3 | 6.3 | 11 |
| Grand Junction - Powell | 3.3 | 7.3 | 2.2 | 14.4 | 6.0 | 15.0 | 3.5 | 3.6 | 3.8 | 5.9 | 12 |
| Aspen | 1.0 | 1.5 | 2.4 | 11.9 | 9.4 | 15.0 | 1.1 | 1.1 | 1.7 | 4.6 | 13 |
| Telluride | 1.0 | 12.7 | 4.1 | 12.2 | 3.4 | 6.8 | 1.0 | 1.0 | 1.1 | 4.6 | 14 |
| Cañon City - City Hall | 1.0 | 6.4 | 1.0 | 15.0 | 8.5 | 4.6 | 1.2 | 1.2 | 1.4 | 3.8 | 15 |
| **Weight** | 4% | 9% | 25% | 8% | 9% | 11% | 17% | 12% | 5% | | |

### *2.11.1.6 $PM_{2.5}$*

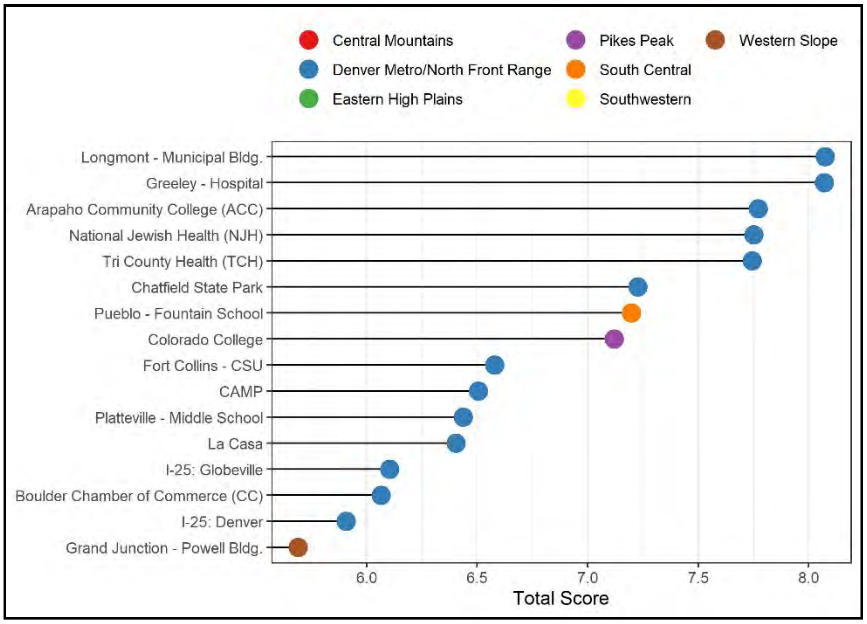


Figure 34. Cleveland dot plot showing the weighted total score for each site in the $PM_{2.5}$ monitoring network.

Table 84. Raw scores and weighted averages for the $PM_{2.5}$ site-to-site comparison analyses.

| Site Name | Parameters Monitored | Trends Impact | Measured Concentration | Monitor-to-Monitor Correlation | Removal Bias | Area Served | Population Served | Point Source Emissions | Traffic Counts | Weighted Total Score | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Longmont - Municipal | 3.5 | 16.0 | 14.3 | 2.2 | 8.1 | 12.6 | 3.6 | 3.4 | 2.6 | 8.1 | 1 |
| Greeley - Hospital | 1.0 | 16.0 | 10.6 | 6.8 | 9.1 | 14.8 | 3.7 | 6.6 | 1.3 | 8.1 | 2 |
| Arapaho CC | 1.0 | 16.0 | 8.9 | 3.9 | 11.3 | 6.6 | 12.0 | 1.7 | 7.0 | 7.8 | 3 |
| National Jewish Health | 1.0 | 16.0 | 9.4 | 1.0 | 2.8 | 5.6 | 16.0 | 1.9 | 8.1 | 7.8 | 4 |
| Tri County Health (TCH) | 3.5 | 1.0 | 11.3 | 4.6 | 8.9 | 8.9 | 12.4 | 5.2 | 5.4 | 7.7 | 5 |
| Chatfield State Park | 6.0 | 10.7 | 16.0 | 4.1 | 1.0 | 10.9 | 3.6 | 1.3 | 2.1 | 7.2 | 6 |
| Pueblo - Fountain School | 3.5 | 7.2 | 1.0 | 10.4 | 11.0 | 16.0 | 2.8 | 16.0 | 1.5 | 7.2 | 7 |
| Colorado College | 3.5 | 8.1 | 2.8 | 8.9 | 7.6 | 15.8 | 13.2 | 3.3 | 4.7 | 7.1 | 8 |
| Fort Collins - CSU | 1.0 | 16.0 | 6.6 | 5.5 | 4.8 | 16.0 | 6.1 | 1.7 | 2.2 | 6.6 | 8 |
| CAMP | 16.0 | 16.0 | 8.5 | 2.6 | 2.2 | 1.0 | 1.5 | 1.2 | 15.7 | 6.5 | 9 |
| Platteville - Middle School | 1.0 | 16.0 | 7.3 | 7.4 | 5.2 | 13.3 | 1.0 | 5.8 | 1.1 | 6.4 | 10 |
| La Casa | 16.0 | 4.5 | 8.1 | 1.0 | 11.5 | 3.9 | 6.6 | 1.9 | 6.6 | 6.4 | 11 |
| I-25: Globeville | 6.0 | 1.9 | 12.2 | 4.8 | 13.4 | 1.3 | 1.7 | 2.3 | 10.8 | 6.1 | 12 |
| Boulder Chamber | 3.5 | 16.0 | 6.7 | 6.6 | 16.0 | 6.6 | 2.6 | 1.1 | 2.3 | 6.1 | 13 |
| I-25: Denver | 8.5 | 2.8 | 9.9 | 2.1 | 2.4 | 4.2 | 8.9 | 1.9 | 6.9 | 5.9 | 14 |
| Grand Junction - Powell | 3.5 | 13.4 | 3.2 | 16.0 | 4.7 | 15.9 | 2.4 | 1.3 | 1.1 | 5.7 | 15 |
| **Weight** | 7% | 9% | 22% | 6% | 7% | 10% | 15% | 16% | 8% | | |

#### *2.11.1.7 Lead (Pb)*

While there is no comparative weighting analysis needed for lead as there is no current specific monitoring, one non-airport point source is identified in the 2017 National Emissions Inventory that is over 0.5 tons per year of lead. There are no airports with emissions over 1.0 tons per year of lead.

## 3 SUITABILITY MODELING

Suitability modeling and analysis is a common and valuable application of Geographic Information Systems (GIS) in the field of environmental planning and management. Broadly defined, suitability analysis aims to identify the most appropriate spatial pattern for a particular land use or activity according to specific requirements, preferences, or predictors. Suitability analysis is applied in a wide variety of fields including ecology, agriculture, and commerce, but its use is most widespread in environmental management and urban and regional planning (Malczewski, 2004). The most commonly used approaches are based on the concept of overlay analysis, in which multiple evaluation criteria map layers ("input maps") are combined to obtain a composite suitability map ("output map"). For example, an agricultural suitability model may combine data pertaining to elevation, slope, aspect, precipitation, and soil chemistry to identify the most appropriate areas for planting a particular crop. Suitability models in the field of air pollution monitoring typically consider data related to population exposure and the source/sink relationships determining the concentration of pollutants in ambient air (Pope and Wu, 2014).

In this section, suitability analysis is used to identify areas where the existing APCD monitoring network does not adequately represent potential air pollution problems, and where additional sites are potentially needed. This has been accomplished using a weighted linear combination (WLC) technique, which is based on the concept of a weighted average. In this approach, technical experts and program managers at the APCD directly assigned weights of relative importance to a series of attribute map layers ("indicator maps"). The maps were then reclassified into a congruous ranking system (1-10 scale) and organized into three purpose areas: source-oriented, population-oriented, and spatially-oriented. The spatially averaged suitability map was then obtained by the multiplying the importance weight assigned to each attribute by that attribute's value. This spatial average was then used to determine the optimal locations at which new monitors should be deployed.

In general, the results of these analyses indicate where monitors are best located based on specific objectives and expected pollutant behavior. However, the development of a useful suitability model relies on a thorough understanding of the phenomena that cause reduced air quality. The various indicator maps used in this section were introduced in Section 1.5 (see Table 5) and are described below.

### 3.1 Description of Indicators

Indicators maps have been grouped into three categories: source-oriented, population-oriented, and spatially oriented. This categorization has been used to simplify the assignment of weights and to make the weighting process transparent. Different weighting schemes have been used in the evaluation of each network due to the unique characteristics of each pollutant. For example, emissions inventory data can be used to determine the areas of maximum expected concentrations of pollutants directly emitted (i.e., primary emissions). However, emission inventory data are less useful to understand secondary pollutants formed in the atmosphere (i.e., $O_3$ and $PM_{2.5}$). Therefore, the emissions inventory indicator map was assigned a lower weight in the case of secondary pollutants (see Section 3.2).

### 3.1.1 Source-Oriented

#### *3.1.1.1 Emissions Inventory*

In this analysis, raster maps of point emission sources were created for each pollutant network using APCD emissions inventory data (see Section 2.9). Emission sources for each pollutant were spatially aggregated in ArcGIS using a 4 $km^2$ fishnet grid and the sum of emissions in each sector ("emission section") was used as the raster value in the resulting indicator map. For CO, $SO_2$, and $PM_{10}$, only primary emission sources of these species were considered. For $NO_2$, emissions of both NO and $NO_2$ (i.e., $NO_x$) were considered. For $O_3$, both $NO_x$ and VOC emissions were considered. For $PM_{2.5}$, $NO_x$, $SO_2$, and primary $PM_{2.5}$ emissions were considered. When reclassifying the raster maps, the entire distribution of emission sections was divided into 10 classes using the Jenks classification method and assigned a score of 1-10 with 10 being the highest score. This same approach was taken in the reclassification of all the indicator maps described below.

#### *3.1.1.2 Traffic Counts*

The association of road traffic and air pollution, particularly CO and $NO_2$, is a well-known phenomenon (Briggs et al., 2000). In this analysis, the normalized AADT counts derived in Section 2.10 were spatially aggregated using a 4 $km^2$ fishnet grid and the sum of normalized AADT in each sector was then used to create a raster map. The same AADT indicator map was used in the suitability model for each pollutant network.

#### *3.1.1.3 Road Density*

Similar to the approach discussed in Section 2.10, this analysis uses CDOT spatial data for highways and major roads within Colorado to create a raster map of road density using a 4 $km^2$ fishnet grid. The same road density indicator map was used in the suitability model for each pollutant network.

### 3.1.2 Population-Oriented

#### *3.1.2.1 Population Density*

In this analysis, a population density map was created using 2014-2018 ACS data (see Section 1.4.5). The population density of each census tract was calculated as the total population divided by the area of the census tract and this value was used in the resulting raster map. The same population density indicator map was then used in the suitability model for each pollutant network.

### 3.1.3 Spatially-Oriented

#### *3.1.3.1 Distance from an Existing Monitor*

This indicator calculates and spatially assigns scores based on the ground distance between existing monitoring sites. The assumption underlying this analysis is that it is more desirable to have a new monitoring site located farther away from an existing site. The score increases the farther away in space that the location is from existing monitoring sites.

#### *3.1.3.2 Interpolation Map*

This analysis uses pollutant interpolation maps generated with monitoring data to account for actual (i.e., measured) pollutant concentration surfaces.

#### *3.1.3.4 Elevation*

As discussed in Section 2.6.1, $O_3$ in Colorado exhibits a strong positive correlation with elevation. The observation of enhanced $O_3$ concentrations with elevation in Colorado has been attributed to the low availability of nitric oxide (NO), which reacts with $O_3$, and the increased importance of stratospheric $O_3$ transport at high elevation (Jaffe, 2010; Musselman and Korfmacher, 2014). Because of this relationship, we have used a digital elevation model (DEM) as a weighted indicator map in the $O_3$ suitability model.

## 3.2 Results for All Parameters

In the following sections, the weights of relative importance assigned to the indicator maps in each pollutant suitability model are presented and a brief justification of the chosen weighting scheme is provided. The final weighted suitability model for each network is then presented in the form of a raster map with a spatial resolution of 4 km. Values of the raster maps are suitability scores, which represent the suitability of the location for the addition of a new monitoring site.

### 3.2.1 Carbon Monoxide (CO)

Table 85. Weights applied in the CO suitability model.

| Analysis | Weight Percentage |
|---|---|
| ***Source-Oriented*** | ***42.5%*** |
| Point Source Emissions | 11.7% |
| Traffic Counts | 18.3% |
| Road Density | 12.5% |
| ***Population-Oriented*** | ***28.2%*** |
| Population Density | 28.2% |
| ***Spatially-Oriented*** | ***29.3%*** |
| Distance from an Existing Monitor | 11.8% |
| Interpolated Concentration | 17.5% |

CO is generally non-reactive, thus concentrations are directly correlated to emission sources. The source-oriented indicators have therefore been given a large relative weighting in the CO suitability model. The majority of CO emissions to ambient air originate from mobile sources (i.e., transportation), particularly in urban areas, where as much as 85% of all CO emissions may come from automobile exhaust. Therefore, the mobile source indicators (i.e., Traffic Counts and Road Density) have been assigned almost three times the total weight given to the point source indicator.

Correlations between CO monitoring sites decrease rapidly with distance between sites (Figure 5). This suggests that CO sites can be located relatively close together without producing redundant data. Therefore, the Distance from an Existing Monitor indicator was given a relatively low weight. The Interpolated Concentration indicator was given a relatively large weight, as this represents the best available estimate of the spatial variability in CO at unmonitored locations.

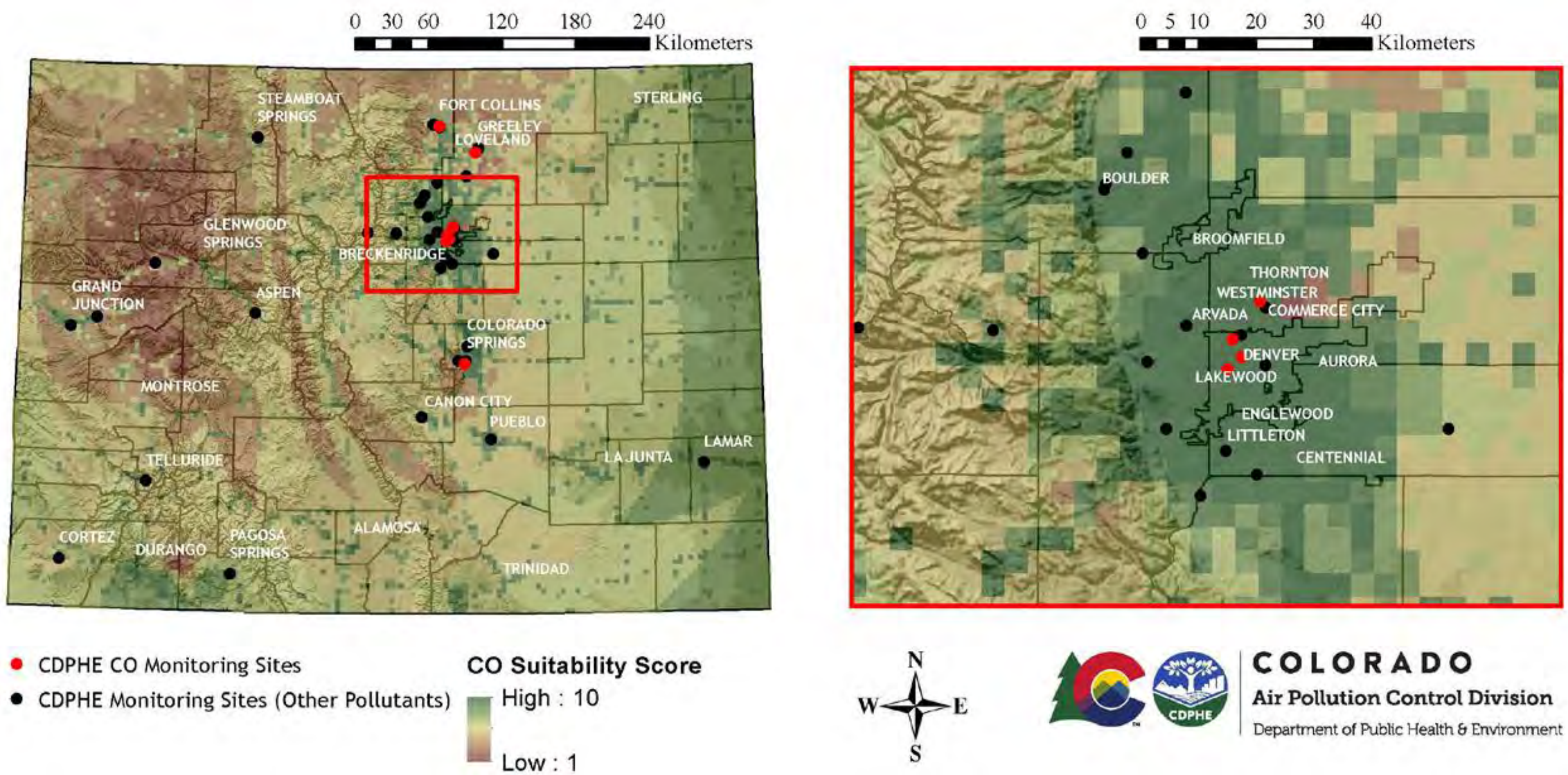


Figure 35. Results of the CO suitability model showing the entire state of Colorado as well as the Denver metropolitan area. Criteria pollutant monitoring sites operated by the APCD and listed in Table 6 are symbolized with black circles. Detailed site information, including AQS identification numbers, site descriptions and histories, addresses and coordinates, monitoring start dates, site elevations, site orientation/scale designations, etc., can be found in Appendix A.

### 3.2.2 Nitrogen Dioxide ($NO_2$)

Table 86. Weights applied in the $NO_2$ suitability model.

| Analysis | Weight Percentage |
|---|---|
| ***Source-Oriented*** | ***48.3%*** |
| Point Source Emissions | 20.8% |
| Traffic Counts | 16.7% |
| Road Density | 10.8% |
| ***Population-Oriented*** | ***19.7%*** |
| Population Density | 19.7% |
| ***Spatially-Oriented*** | ***32.0%*** |
| Distance from an Existing Monitor | 14.5% |
| Interpolated Concentration | 17.5% |

$NO_2$ emissions are associated with both point sources (mostly fuel combustion) and mobile sources (i.e., transportation), and $NO_2$ concentrations in ambient air are directly correlated with emission sources (Briggs et al., 2000). For this reason, the source-oriented indicators were given almost half of the total weight in the $NO_2$ suitability model, with the mobile source indicators being given a higher total weight (27.5%) than the point source indicator (20.8%).

$NO_2$ is a public health concern and it is an objective of the APCD to maximize the number of citizens represented by each $NO_2$ monitor. However, $NO_2$ is also an important precursor to $O_3$, which tends to have a greater impact on regions of lower population density (see Section 3.1.3.2). The collocation of $NO_2$ and $O_3$ monitors at high $O_3$ sites could provide useful information regarding the balance between ozone production and destruction, which can be used to assess and validate model predictions and further optimize the network's configuration. Therefore, the Population Density indicator was assigned a lower weight in the $NO_2$ suitability model (19.7%) as compared to the CO suitability model (28.2%).

As with CO, the monitor-to-monitor correlation study described in Section 2.5 suggests that $NO_2$ sites can be located relatively close together without producing redundant data. Therefore, the Distance from an Existing Monitor indicator was given a relatively low weight. The Interpolated Concentration indicator was given a relatively large weight.

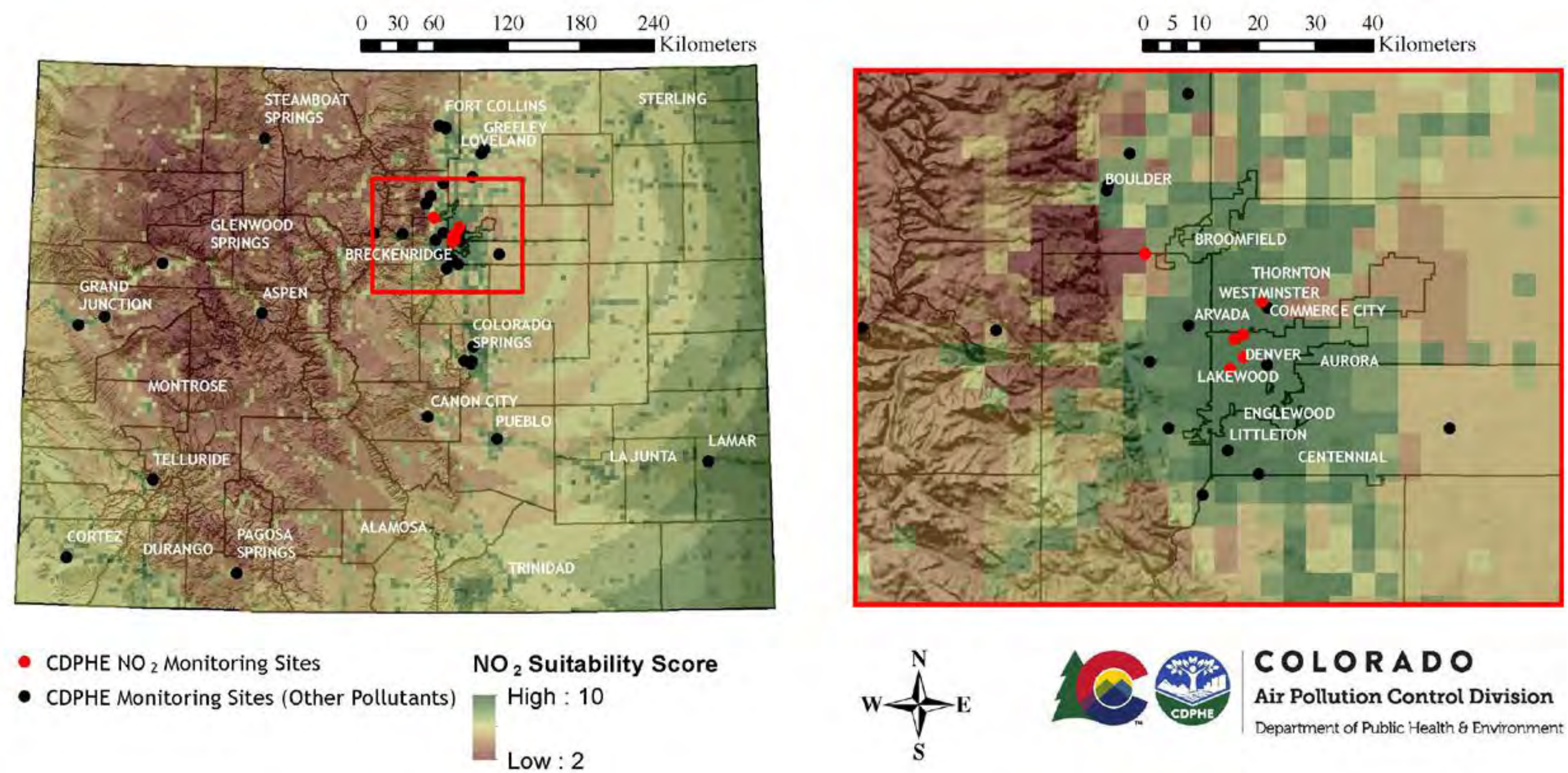


Figure 36. Results of the $NO_2$ suitability model showing the entire state of Colorado as well as the Denver metropolitan area. Criteria pollutant monitoring sites operated by the APCD and listed in Table 6 are symbolized with black circles. Detailed site information, including AQS identification numbers, site descriptions and histories, addresses and coordinates, monitoring start dates, site elevations, site orientation/scale designations, etc., can be found in Appendix A.

### 3.2.3 Sulfur Dioxide ($SO_2$)

Table 87. Weights applied in the $SO_2$ suitability model.

| Analysis | Weight Percentage |
|---|---|
| ***Source-Oriented*** | ***45.8%*** |
| Point Source Emissions | 30.8% |
| Traffic Counts | 8.3% |
| Road Density | 6.7% |
| ***Population-Oriented*** | ***20.8%*** |
| Population Density | 20.8% |
| ***Spatially-Oriented*** | ***33.3%*** |
| Distance from an Existing Monitor | 10.8% |
| Interpolated Concentration | 22.5% |

The largest sources of $SO_2$ emissions in Colorado are from fossil fuel combustion at power plants, while mobile sources contribute less than 1 percent.[4] For this reason, the point source indicator was assigned a relatively high weight in the $SO_2$ suitability model (30.8%), while the mobile source indicators were assigned a relatively low total weight (15.0%).

The monitor-to-monitor correlation study described in Section 2.5 showed very low correlations among the three $SO_2$ sites located in central Denver ($r^2$ = 0.09-0.20), suggesting that $SO_2$ sites can be located relatively close together without producing redundant data. Therefore, the Distance from an Existing Monitor indicator was given a relatively low weight in the $SO_2$ suitability model. The Interpolated Concentration indicator was given a relatively large weight.

[4] http://www.epa.gov/air/emissions/

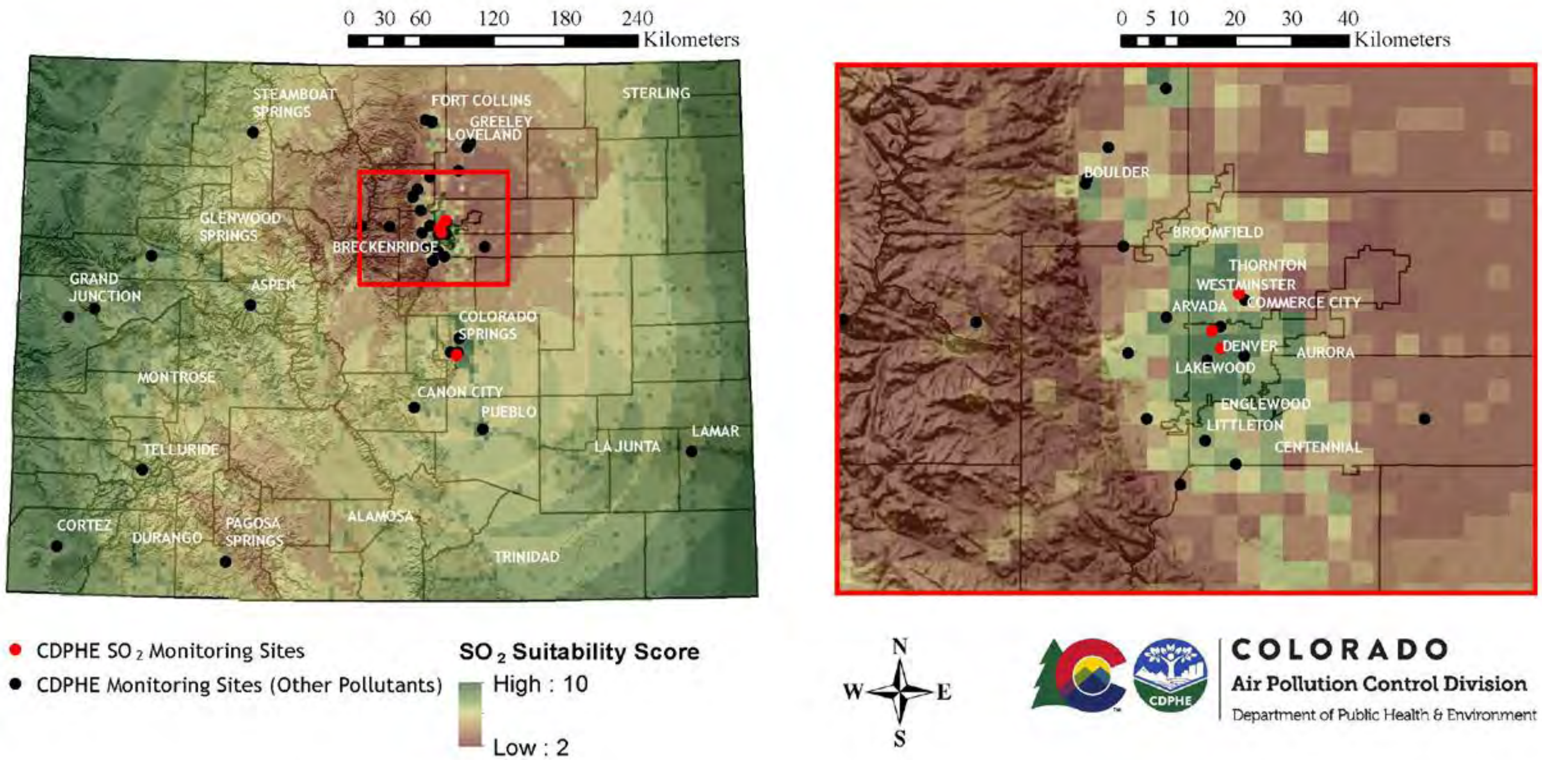


Figure 37. Results of the $SO_2$ suitability model showing the entire state of Colorado as well as the Denver metropolitan area. Criteria pollutant monitoring sites operated by the APCD and listed in Table 6 are symbolized with black circles. Detailed site information, including AQS identification numbers, site descriptions and histories, addresses and coordinates, monitoring start dates, site elevations, site orientation/scale designations, etc., can be found in Appendix A.

### 3.2.4 Ozone ($O_3$)

Table 88. Weights applied in the $O_3$ suitability model.

| Analysis | Weight Percentage |
|---|---|
| ***Source-Oriented*** | ***22.6%*** |
| Point Source Emissions | 10.8% |
| Traffic Counts | 6.5% |
| Road Density | 5.3% |
| ***Population-Oriented*** | ***15.7%*** |
| Population Density | 15.7% |
| ***Spatially-Oriented*** | ***61.7%*** |
| Distance from an Existing Monitor | 18.4% |
| Interpolated Concentration | 38.0% |
| Elevation | 5.3% |

As discussed in Section 2.9.4, $O_3$ is a secondary pollutant and its spatial variability is only indirectly related to precursor emissions sources. Therefore, the source-oriented indicators were assigned a relatively small weight in the $O_3$ suitability model. Similarly, because $O_3$ concentrations tend to be reduced via $NO_x$ titration in heavily populated areas, the population indicator was also assigned a lower weight compared to the other pollutant models.

$O_3$ monitoring sites tend to be well correlated over distances of approximately 90 km (see Section 2.5.4, Figure 7). This suggests that a dense network of $O_3$ monitoring sites is an inefficient use of resources as it will produce redundant data. Therefore, the Distance from an Existing Monitor indicator was given a relatively high weight in the $O_3$ suitability model. Because the Interpolated Concentration indicator in this case is based on maximum 8-hr values (see Section 3.1.3.2), which are more relevant from a regulatory perspective, this input was assigned a higher weight compared to the modeled concentration indicator.

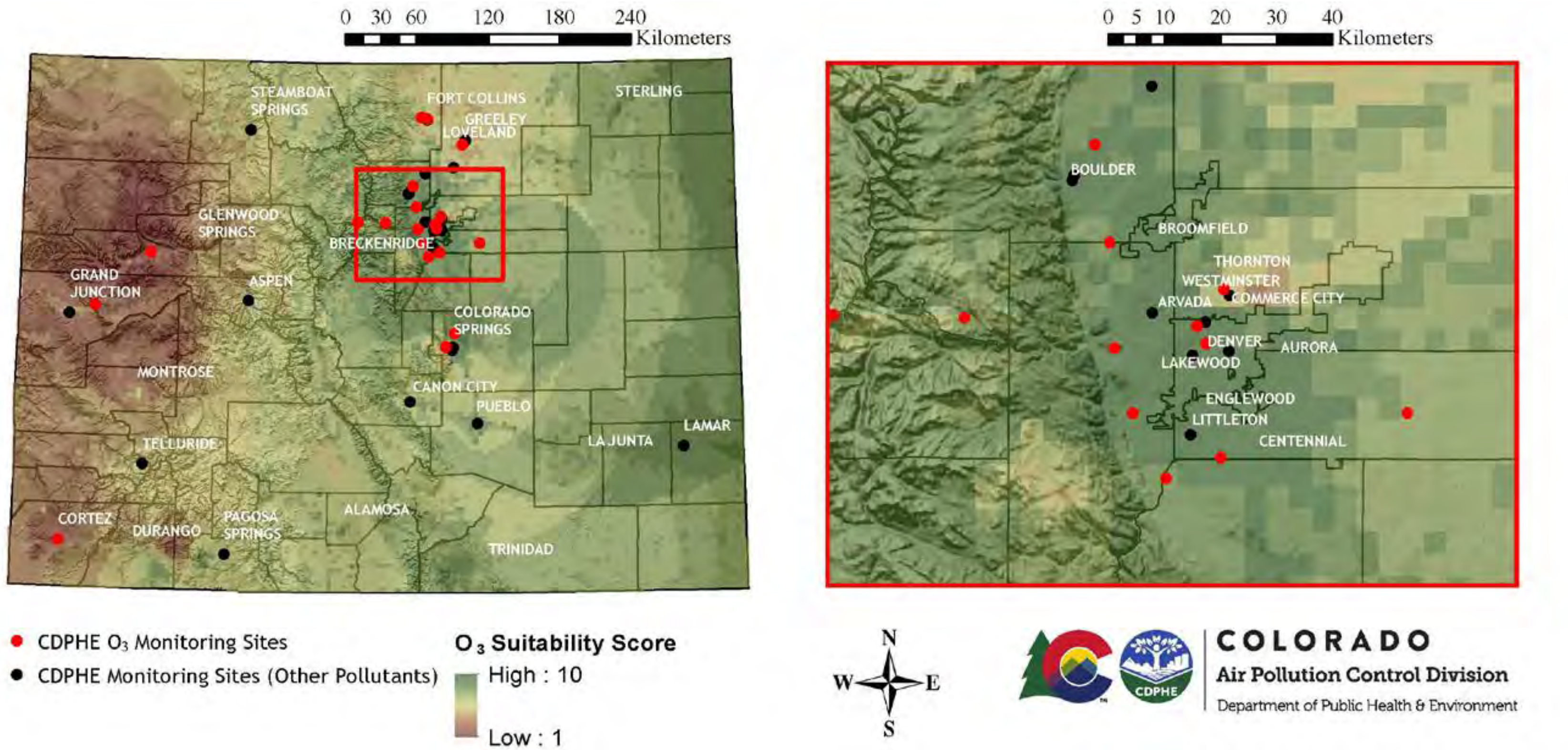


Figure 38. Results of the $O_3$ suitability model showing the entire state of Colorado as well as the Denver metropolitan area. Criteria pollutant monitoring sites operated by the APCD and listed in Table 6 are symbolized with black circles. Detailed site information, including AQS identification numbers, site descriptions and histories, addresses and coordinates, monitoring start dates, site elevations, site orientation/scale designations, etc., can be found in Appendix A.

### 3.2.5 $PM_{10}$

Table 89. Weights applied in the $PM_{10}$ suitability model.

| Analysis | Weight Percentage |
|---|---|
| ***Source-Oriented*** | ***36.2%*** |
| Point Source Emissions | 20.0% |
| Traffic Counts | 8.8% |
| Road Density | 7.4% |
| ***Population-Oriented*** | ***22.8%*** |
| Population Density | 22.8% |
| ***Spatially-Oriented*** | ***41.0%*** |
| Distance from an Existing Monitor | 14.0% |
| Interpolated Concentration | 27.0% |

$PM_{10}$ concentrations typically have a strong relationship with point sources. Furthermore, dust from paved and unpaved roads is a particular problem in Colorado and the western U.S. in general. For this reason, the point and mobile source indicators were assigned relatively high weights, with the point source indicator being given a slightly larger weight than the mobile source indicators.

As with CO and $NO_2$, the monitor-to-monitor correlation study described in Section 2.5 suggests that $PM_{10}$ sites can be located relatively close together without producing redundant data. Therefore, the Distance from an Existing Monitor indicator was given a relatively low weight.

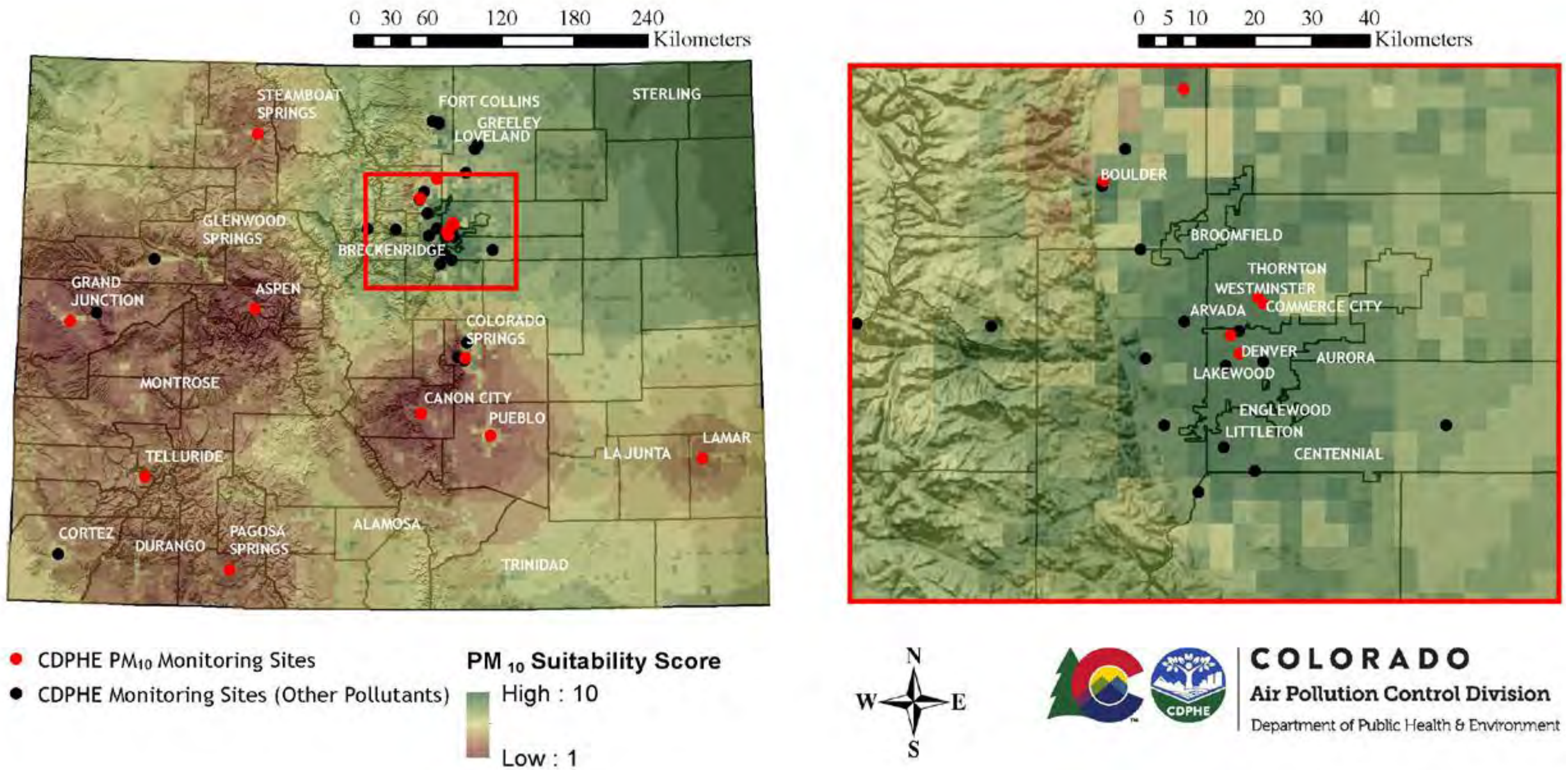


Figure 39. Results of the $PM_{10}$ suitability model showing the entire state of Colorado as well as the Denver metropolitan area. Criteria pollutant monitoring sites operated by the APCD and listed in Table 6 are symbolized with black circles. Detailed site information, including AQS identification numbers, site descriptions and histories, addresses and coordinates, monitoring start dates, site elevations, site orientation/scale designations, etc., can be found in Appendix A.

### 3.2.6 $PM_{2.5}$

Table 90. Weights applied in the $PM_{2.5}$ suitability model.

| Analysis | Weight Percentage |
|---|---|
| ***Source-Oriented*** | ***25.0%*** |
| Point Source Emissions | 10.0% |
| Traffic Counts | 9.0% |
| Road Density | 6.0% |
| ***Population-Oriented*** | ***21.2%*** |
| Population Density | 21.2% |
| ***Spatially-Oriented*** | ***53.8%*** |
| Distance from an Existing Monitor | 12.0% |
| Interpolated Concentration | 41.8% |

Like $O_3$, $PM_{2.5}$ is a secondary pollutant and its spatial variability is only indirectly related to precursor emissions sources. Therefore, the source-oriented indicators were assigned a relatively small weight in the $PM_{2.5}$ suitability model, with the mobile source indicators being given a slightly larger weight than the point source indicators.

As with $PM_{10}$, the monitor-to-monitor correlation study described in Section 2.5 suggests that $PM_{2.5}$ sites can be located relatively close together without producing redundant data. Therefore, the Distance from an Existing Monitor indicator was given a relatively low weight in the $PM_{2.5}$ suitability model. The Interpolated Concentration indicator was given a relatively large weight.

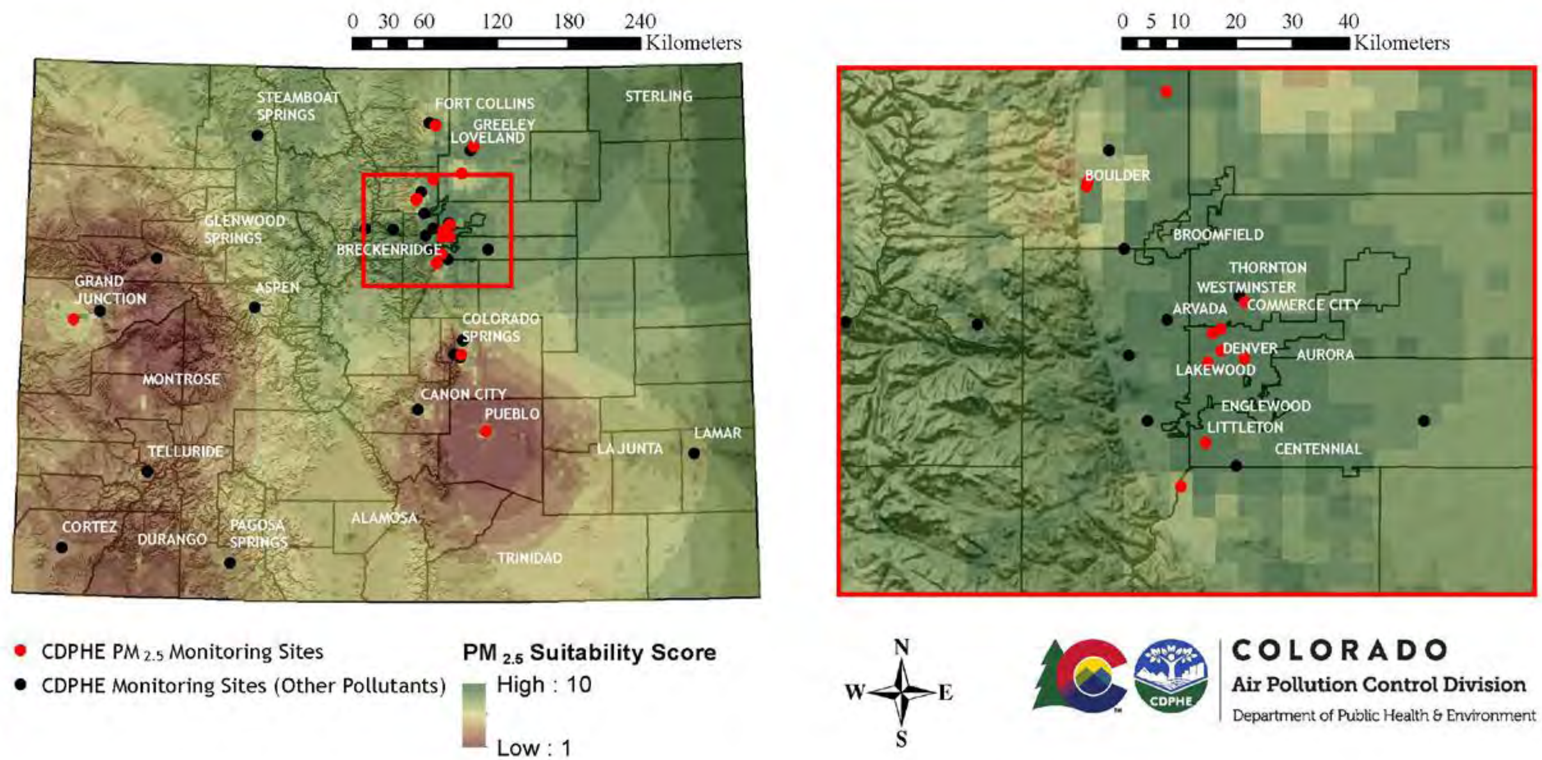


Figure 40. Results of the $PM_{2.5}$ suitability model showing the entire state of Colorado as well as the Denver metropolitan area. Criteria pollutant monitoring sites operated by the APCD and listed in Table 6 are symbolized with black circles. Detailed site information, including AQS identification numbers, site descriptions and histories, addresses and coordinates, monitoring start dates, site elevations, site orientation/scale designations, etc., can be found in Appendix A.

## 4. CONCLUSIONS AND RECOMMENDATIONS

Colorado's ambient air monitoring network has been and will continue to be in a constant state of flux. Change within the network is most notably driven by changes to the NAAQS, changes in population demographics, and changes in land use. For example, the EPA lowered the ozone NAAQS standard from 75 ppb to 70 ppb in 2015, which has required the APCD to enhance its ozone monitoring, identify potential precursor sources, and to refine its scientific understanding of Colorado's ozone problems. To further understand regional background ozone concentrations, several special studies have been conducted and additional ozone monitoring in Pueblo is being considered.[5]

The following section contains suggestions for modifications to the APCD monitoring network to be considered over the next five years. Results of the analyses presented in previous sections are used to suggest the addition, removal, or relocation of individual monitors or monitoring sites. These suggestions are ultimately based upon the EPA requirements for monitoring sites (e.g., site objective and number of required sites) and the objectives and priorities of the APCD as stated in Section 1.5.3.

### 4.1 Parameter-Specific Recommendations

#### 4.1.1 Carbon Monoxide (CO)

The current CO monitoring network configuration adequately supports APCD monitoring objectives and meets all federal requirements. CO concentrations are typically well below the NAAQS and no state-operated monitor has recorded a violation of the 8-hour standard since 1996. For this reason, it is the opinion of APCD program managers and technical experts that CO monitoring should be deemphasized and funds shifted to monitoring objectives of higher priority (e.g., increased $O_3$ precursor monitoring). Most Colorado CO monitoring sites are currently in place in support of SIP maintenance plans, which necessitate that monitoring activities continue until these plans expire.[6] However, we recommend the removal of the lowest value sites (e.g., Greeley, Fort Collins, and Highway 24) once they have achieved their monitoring objectives.

#### 4.1.2 Nitrogen Dioxide ($NO_2$)

The current $NO_2$ monitoring network meets all federal requirements and adequately supports most APCD monitoring objectives. $NO_2$ concentrations are typically well below the NAAQS. No state-operated monitor has recorded a violation of the annual standard since 1977 and the one-hour standard has not been violated since it was promulgated in 2010. However, despite the decreased relevance of $NO_2$ as an ambient air pollutant, the APCD feels that the monitoring network should be expanded due to the importance of $NO_2$ as an $O_3$ precursor. Furthermore, the collocation of $O_3$ and $NO_2$ monitors can be very helpful in understanding ozone dynamics at a particular site. Total oxidant, or "odd oxygen," estimates can be derived by simply adding $NO_2$ and $O_3$ concentrations. These estimates provide an important indicator of the $O_3$ production potential at a location, and help to differentiate low $O_3$ production potential from $NO_x$ scavenging. As such, they can shed light on the meaning of day-of-week differences in $O_3$ concentrations which can be an important step in understanding what areas may be $NO_x$ or VOC limited. Therefore, we recommend adding supplemental $NO_2$ monitoring at high-concentration ozone monitoring sites in the Front Range. $NO_2$ monitoring is already underway at Rocky Flats - North, a suggestion from

[5] https://www.colorado.gov/airquality/tech_doc_repository.aspx?action=open&file=PuebloOzoneDynamics2015.pdf
[6] https://www.colorado.gov/pacific/cdphe/state-implementation-plans-sips

the 2015 Network Assessment.[7] The $NO_2$ suitability model presented here (see Figure 36) suggests that Fort Collins - West and NREL are the best other candidates for the addition of an $NO_2$ monitor. The APCD is currently developing a $NO_2/O_3$ monitoring site in Platteville (PAO), an area of high oil and gas related emissions that also has a high suitability score, as shown in Figure 36.

### 4.1.3 Sulfur Dioxide ($SO_2$)

The current $SO_2$ monitoring network meets all federal requirements and adequately supports APCD monitoring objectives. All sites have 2019 one-hour design values less than 20% of the NAAQS standard.

### 4.1.4 Ozone ($O_3$)

The current $O_3$ monitoring network supports the APCD's monitoring objectives reasonably well. Areas of high concentrations, as well as background concentration areas have been monitored all along the Front Range, the Continental Divide, and in several areas on the Western Slope. The network may expand in the future, with sites currently being planned for Platteville and Pueblo.

The monitor-to-monitor correlation study presented in Section 2.5.4 suggests that $O_3$ monitors sited less than approximately 90 km apart are likely to produce redundant data. This is a concern in the Denver Metro / North Front Range region, where $O_3$ monitors are highly concentrated and several are separated by distances of less than 10 km. This is an inefficient use of resources that could be employed elsewhere; therefore, we recommend that some urban sites be considered for closure or relocation. The Welch site has been slated for closure and relocation to the community of Evergreen. The Welch site shows a high level of redundancy with other sites in the Denver Metro region (see Table 30) and was ranked 15th out of the 19 existing $O_3$ sites considered in the site-to-site comparison analysis.

Cortez was ranked lowest in the $O_3$ site-to-site comparison analysis. We recommend that this site be closed or relocated to a more suitable area in the Southwestern region.

### 4.1.5 $PM_{10}$

The current $PM_{10}$ monitoring network meets all federal requirements and adequately supports APCD monitoring objectives. The APCD has decreased the size of its $PM_{10}$ monitoring network over the past 10-15 years and removed the monitors deemed to be of lowest value. This was done to make funding available for other monitoring networks of higher priority within the state of Colorado (e.g., $O_3$ and $PM_{2.5}$). Many of the lowest ranked sites in the site-to-site comparison analysis presented here (e.g., Canon City, Aspen, and Telluride) are associated with SIP maintenance plans and cannot be removed or relocated; however, we recommend that these sites be considered for closure once they have met their monitoring objectives.

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[7] https://www.colorado.gov/airquality/tech_doc_repository.aspx?action=open&file=2015_CO_5yr_Network_Assessment.pdf

### 4.1.6 $PM_{2.5}$

The current $PM_{2.5}$ monitoring network meets all federal requirements and adequately supports APCD monitoring objectives. However, we do recommend that the I-70 corridor in the region near Vail/Eagle-Vail be evaluated for the possible addition of a $PM_{2.5}$ monitor.

### 4.1.7 Lead (Pb)

There is no current lead-specific monitoring in Colorado. Based on the 2017 National Emissions Inventory, monitoring requirements are not being met. There is one non-airport point source that is over 0.5 tons per year of air emissions (Rocky Mountain Bottle Co.). Thus, a monitor is required to be placed near the site to determine compliance with the NAAQS. Alternatively, modeling is possible as a scientifically justifiable method to ensure compliance with the NAAQS.

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# APPENDIX A

## Monitoring site descriptions

## APPENDIX A: MONITORING SITE DESCRIPTIONS

This appendix provides detailed information for all monitoring sites considered in this Data Report. **Table A-1** summarizes the locations and monitoring parameters of each site currently in operation, by county, alphabetically. The shaded lines in the table list the site AQS identification numbers, address, site start-up date, elevation, and longitude and latitude coordinates. Beneath each site description the table lists each monitoring parameter in operation at that site, the orientation and spatial scale, which national monitoring network it belongs to, the type of monitor in use, and the sampling frequency. The parameter date is the date when valid data were first collected.

The following abbreviations are used in **Table A-1** below, with orientation (Orient) referring to the monitoring objective and scale referring to the size of the area that concentrations from the monitor represent.

**Orientation**
P.O. - Population oriented
Back - Background orientation
SPM - Special Purpose Monitor
H.C. - Highest Concentration
POC - Parameter Occurrence Code
SLAMS - State or Local Air Monitoring Stations

**Scale (Area Represented)**[1]
Micro - Micro-scale (several m – 100 m)
Middle - Middle Scale (100 – 500 m)
Neigh - Neighborhood Scale (0.5 – 4 km)
Urban - Urban Scale (4 – 50 km)
Region - Regional Scale (50 – hundreds of km)

**Table A-1. Monitoring Locations and Parameters Monitored**

| AQS # | *Site Name* | *Address* | | *Site Start* | *Elevation (m)* | *Latitude* | *Longitude* |
|---|---|---|---|---|---|---|---|
| | **Parameter** | **POC** | **Start** | **Orient/Scale** | **Monitor** | **Type** | **Sample** |
| | | | | **Adams** | | | |
| *08 001 0008* | *Tri County Health* | *4201 E 72nd Ave.* | | *Jul-16* | *1,574* | *39.82835* | *-104.93836* |
| | PM10 | 1 | Jul-16 | P.O. Neigh | R&P PARTISOL 2025 | SLAMS | 1 in 1 |
| | $PM_{2.5}$ | 2 | Jul-16 | P.O. Neigh | R&P PARTISOL 2025 | SLAMS | 1 in 6 |
| | $PM_{2.5}$ | 3 | Jul-16 | P.O. Neigh | GRIMM EDM 180 | SPM | Continuous |
| | $PM_{2.5}$ Speciation | 5 | Jul-16 | P.O. Neigh | SASS | Trends Spec. | 1 in 6 |
| | $PM_{2.5}$ Carbon | 5 | Jul-16 | P.O. Neigh | URG 3000N | Trends Spec. | 1 in 6 |
| *08 001 3001* | *Welby* | *3174 E. 78th Ave.* | | *Jul-73* | *1,554* | *39.838119* | *-104.94984* |
| | CO (Trace) | 1 | Jul-73 | P.O. Neigh | THERMO 48i-TLE | SLAMS | Continuous |
| | $SO_2$ | 2 | Jul-73 | P.O. Neigh | TAPI 100E | SLAMS | Continuous |
| | $NO/NO_x$ | 2 | Jan-76 | P.O. Urban | TAPI 200UP | SPM | Continuous |
| | $NO_2$ | 1 | Jan-76 | P.O. Urban | TAPI 200EU | SLAMS | Continuous |
| | $O_3$ | 2 | Jul-73 | P.O. Neigh | TAPI 400E | SLAMS | Continuous |
| | WS/WD/Temp | 1 | Jan-75 | P.O. Neigh | MET-ONE | SPM | Continuous |
| | $PM_{10}$ | 1 | Feb-92 | P.O. Neigh | SA/GMW 1200 | SLAMS | 1 in 6 |
| | $PM_{10}$ | 3 | Jun-90 | P.O. Neigh | TEOM 1400AB | SLAMS | Continuous |
| | | | | **Arapahoe** | | | |
| *08 005 0002* | *Highland Reservoir* | *8100 S. University Blvd* | | *Jun-78* | *1,747* | *39.567887* | *-104.957193* |
| | $O_3$ | 1 | Jun-78 | P.O. Neigh | TAPI 400E | SLAMS | Continuous |
| | WS/WD/Temp | 1 | Jul-78 | P.O. Neigh | MET-ONE | SPM | Continuous |

[1] "Appendix D to Part 58 – Network Design Criteria for Ambient Air Quality Monitoring," 40 Federal Register 58 (15 January 2015).

| AQS # | Site Name | Address | | Site Start | Elevation (m) | Latitude | Longitude |
|---|---|---|---|---|---|---|---|
| | Parameter | POC | Start | Orient/Scale | Monitor | Type | Sample |
| 08 005 0005 | *Arapahoe Community College (ACC)* | *6190 S. Santa Fe Dr.* | | *Dec-98* | *1,636* | *39.604399* | *-105.019526* |
| | $PM_{2.5}$ | 1 | Mar-99 | P.O. Neigh | R&P PARTISOL 2025 | SLAMS | 1 in 3 |
| 08 005 0006 | *Aurora - East* | *36001 E. Quincy Ave.* | | *Apr-11* | *1,552* | *39.63854* | *-104.56913* |
| | $O_3$ | 1 | Apr-09 | P.O. Region | TAPI 400E | SLAMS | Continuous |
| | WS/WD/Temp | 1 | Jun-09 | P.O. Neigh | MET-ONE | SPM | Continuous |
| **Archuleta** | | | | | | | |
| 08 007 0001 | *Pagosa Springs School* | *309 Lewis St.* | | *Aug-75* | *2,165* | *37.26842* | *-107.009659* |
| | $PM_{10}$ | 3 | Sep-90 | P.O. Neigh | SA/GMW 1200 | SLAMS | 1 in 1 |
| **Boulder** | | | | | | | |
| 08 013 0003 | *Longmont - Municipal Bldg.* | *350 Kimbark St.* | | *Jun-85* | *1,520* | *40.164576* | *-105.100856* |
| | $PM_{10}$ | 2 | Sep-85 | P.O. Neigh | SA/GMW 1200 | SLAMS | 1 in 6 |
| | $PM_{10}$ Collocated | 2 | Sep-14 | P.O. Micro | SA/GMW 1200 | SLAMS | 1 in 6 |
| | $PM_{2.5}$ | 1 | Jan-99 | P.O. Neigh | R&P PARTISOL 2025 | SLAMS | 1 in 3 |
| | $PM_{2.5}$ | 3 | Nov-05 | P.O. Neigh | TEOM 1400AB | SPM | Continuous |
| 08 013 0012 | *Boulder Chamber of Commerce* | *2440 Pearl St.* | | *Dec-94* | *1,619* | *40.021097* | *-105.263382* |
| | $PM_{10}$ | 1 | Oct-94 | P.O. Neigh | SA/GMW 1200 | SLAMS | 1 in 6 |
| | $PM_{2.5}$ | 1 | Jan-99 | P.O. Middle | R&P PARTISOL 2025 | SLAMS | 1 in 3 |
| 08 013 0014 | *Boulder Reservoir* | *5565 N. 51st* | | *Sep-16* | *1,586* | *40.070016* | *-105.220238* |
| | $O_3$ | 1 | Sep-16 | H.C. Urban | TAPI 400E | SLAMS | Continuous |
| | WS/WD/Temp/RH | 1 | Sep-16 | H.C. Urban | RM YOUNG | SPM | Continuous |
| 08 013 1001 | *Boulder - CU Athens* | *2102 Athens St.* | | *Dec-80* | *1,622* | *40.012969* | *-105.264212* |
| | $PM_{2.5}$ | 3 | Feb-04 | H.C. Urban | TEOM FDMS | SPM | Continuous |
| **Clear Creek** | | | | | | | |
| 08-019-0006 | *Mines Peak* | *Mines Peak Road* | | *Jun-14* | *3,807* | *39.794376* | *-105.763993* |
| | $O_3$ | 1 | Jun-14 | Other | TAPI 400 | SPM | Continuous |

| AQS # | Site Name | Address | | Site Start | Elevation (m) | Latitude | Longitude |
|---|---|---|---|---|---|---|---|
| | **Parameter** | **POC** | **Start** | **Orient/Scale** | **Monitor** | **Type** | **Sample** |
| **Denver** | | | | | | | |
| *08 031 0002* | *CAMP* | *2105 Broadway* | | *Jan-65* | *1,593* | *39.751184* | *-104.987625* |
| | CO (Trace) | 2 | Jan-71 | P.O. Micro | THERMO 48i-TLE | SLAMS | Continuous |
| | $SO_2$ | 1 | Jan-67 | P.O. Neigh | TAPI 100E | SLAMS | Continuous |
| | $O_3$ | 6 | Mar-12 | P.O. Neigh | TAPI 400E | SLAMS | Continuous |
| | $NO/NO_x$ | 1 | Jan-73 | Other | TAPI 200EU | Other | Continuous |
| | $NO_2$ | 1 | Jan-73 | P.O. Neigh | TAPI 200EU | SLAMS | Continuous |
| | WS/WD/Temp | 1 | Jan-65 | P.O. Neigh | MET-ONE | SPM | Continuous |
| | $PM_{10}$ | 1 | Aug-86 | P.O. Micro | SA/GMW 1200 | SLAMS | 1 in 6 |
| | $PM_{10}$ Collocated | 2 | Dec-87 | P.O. Micro | SA/GMW 1200 | SLAMS | 1 in 6 |
| | $PM_{10}$ | 3 | Apr-13 | P.O. Micro | GRIMM EDM 180 | SLAMS | Continuous |
| | $PM_{2.5}$ | 1 | Jan-99 | P.O. Micro | R&P PARTISOL 2025 | SLAMS | 1 in 1 |
| | $PM_{2.5}$ Collocated | 2 | Sep-01 | P.O. Micro | R&P PARTISOL 2025 | SLAMS | 1 in 6 |
| | $PM_{2.5}$ | 3 | Apr-13 | P.O. Micro | GRIMM EDM 180 | SPM | Continuous |
| *08 031 0013* | *National Jewish Health* | *14$^{th}$ Ave. & Albion St.* | | *Jan-83* | *1,620* | *39.738578* | *-104.939925* |
| | $PM_{2.5}$ | 3 | Oct-03 | P.O. Neigh | TAPI T640 | SPM | Continuous |
| | $PM_{10}$ | 3 | Mar-18 | P.O. Neigh | TAPI T640 | SPM | Continuous |
| *08 031 0016* | *DESCI* | *1901 E. 13$^{th}$ Ave.* | | *Dec-90* | *1,623* | *39.7357* | *-104.9582* |
| | Transmissometer | 1 | Dec-89 | Other | OPTEC LPV-3 | SPM | Continuous |
| | Nephelometer | 1 | Dec-00 | Other | OPTEC NGN-2 | SPM | Continuous |
| | Relative Humidity | 1 | Dec-89 | Other | RM YOUNG | SPM | Continuous |

| AQS # | Site Name | Address | | Site Start | Elevation (m) | Latitude | Longitude |
|---|---|---|---|---|---|---|---|
| | **Parameter** | **POC** | **Start** | **Orient/Scale** | **Monitor** | **Type** | **Sample** |
| 08 031 0026 | *La Casa* | *4587 Navajo St.* | | *Oct-13* | *1,594* | *39.779429* | *-105.005174* |
| | CO (Trace) | 1 | Oct-12 | P.O. Neigh | THERMO 48i-TLE | NCore | Continuous |
| | $SO_2$ (Trace) | 1 | Oct-12 | P.O. Neigh | TAPI 100EU | NCore | Continuous |
| | $NO_Y$ | 1 | Oct-12 | P.O. Neigh | TAPI 200EU | NCore | Continuous |
| | CAPS $NO_2$ | 1 | Jul-14 | P.O. Neigh | TAPI 500U | NCore | Continuous |
| | $O_3$ | 1 | Oct-12 | Neigh/Urban | TAPI 400E | NCore | Continuous |
| | WS/WD/Temp | 1 | Oct-12 | P.O. Neigh | MET-ONE | NCore | Continuous |
| | Relative Humidity | 1 | Oct-12 | P.O. Neigh | MET-ONE | NCore | Continuous |
| | Total Solar Radiation | 1 | Apr-18 | P.O. Neigh | KIPP & ZONEN | NCore | Continuous |
| | Temp Differential (Upper/Lower) | 2 | Oct-12 | P.O. Neigh | MET-ONE | NCore | Continuous |
| | $PM_{10}$ | 1 | Oct-12 | P.O. Neigh | R&P PARTISOL 2025 | SLAMS | 1 in 3 |
| | $PM_{10}$ Collocated | 2 | Oct-12 | P.O. Neigh | R&P PARTISOL 2025 | SLAMS | 1 in 6 |
| | $PM_{10}$ | 3 | Feb-14 | P.O. Neigh | GRIMM EDM 180 | SLAMS | Continuous |
| | $PM_{2.5}$ | 1 | Oct-12 | P.O. Neigh | R&P PARTISOL 2025 | NCore | 1 in 3 |
| | $PM_{2.5}$ | 3 | Feb-14 | P.O. Neigh | GRIMM EDM 180 | SLAMS | Continuous |
| | $PM_{2.5}$ Speciation | 5 | Oct-12 | P.O. Neigh | SASS | Supplem. Speciation | 1 in 3 |
| | $PM_{2.5}$ Carbon | 5 | Oct-12 | P.O. Neigh | URG 3000N | Supplem. Speciation | 1 in 3 |
| 08 031 0027 | *I-25: Denver* | *971 W. Yuma Street* | | *Jun-13* | *1,586* | *39.732146* | *-105.015317* |
| | CO (Trace) | 1 | Jun-13 | Near Road | THERMO 48i-TLE | SLAMS | Continuous |
| | $NO_2$ | 1 | Jun-13 | Near Road | TAPI 200E | SLAMS | Continuous |
| | $NO/NO_x$ | 1 | Jun-13 | Near Road | TAPI 200E | SPM | Continuous |
| | WS/WD/Temp | 1 | Jun-13 | Near Road | MET-ONE | SPM | Continuous |
| | $PM_{10}$ | 3 | Dec-13 | Near Road | GRIMM EDM 180 | SLAMS | Continuous |
| | $PM_{2.5}$ | 1 | Jan-14 | Near Road | R&P PARTISOL 2025 | SLAMS | 1 in 6 |
| | $PM_{2.5}$ | 3 | Dec-13 | Near Road | GRIMM EDM 180 | SLAMS | Continuous |
| | $PM_{2.5}$ Carbon | 5 | Oct-13 | Near Road | API 633 | SPM | Continuous |
| 08 031 0028 | *I-25: Globeville* | *4905 Acoma Street* | | *10/1/2015* | *1,587* | *39.785823* | *-104.988857* |
| | $NO_2$ | 1 | 10/1/2015 | Near Road | TAPI 200E | SLAMS | Continuous |
| | $NO/NO_x$ | 1 | 10/1/2015 | Near Road | TAPI 200E | SPM | Continuous |
| | WS/WD/Temp/RH | 1 | 10/1/2015 | Near Road | RM YOUNG | SPM | Continuous |
| | $PM_{10}$ | 3 | 10/1/2015 | Near Road | GRIMM EDM 180 | SLAMS | Continuous |
| | $PM_{2.5}$ | 3 | 10/1/2015 | Near Road | GRIMM EDM 180 | SLAMS | Continuous |

| AQS # | Site Name | Address | | Site Start | Elevation (m) | Latitude | Longitude |
|---|---|---|---|---|---|---|---|
| | Parameter | POC | Start | Orient/Scale | Monitor | Type | Sample |
| **Douglas** | | | | | | | |
| 08 035 0004 | *Chatfield State Park* | *11500 N. Roxborough Pk. Rd* | | *Apr-04* | *1,676* | *39.534488* | *-105.070358* |
| | $O_3$ | 1 | May-05 | H.C. Urban | TAPI 400E | SLAMS | Continuous |
| | WS/WD/Temp | 1 | Apr-04 | P.O. Neigh | MET-ONE | SPM | Continuous |
| | $PM_{2.5}$ | 1 | Jul-05 | P.O. Neigh | R&P PARTISOL 2025 | SPM | 1 in 3 |
| | $PM_{2.5}$ | 3 | May-04 | P.O. Neigh | TAPI T640 | SPM | Continuous |
| | $PM_{10}$ | 3 | Jun-17 | P.O. Neigh | TAPI T640 | SPM | Continuous |
| **El Paso** | | | | | | | |
| 08 041 0013 | *U. S. Air Force Academy* | *USAFA Rd. 640* | | *May-96* | *1,971* | *39.958341* | *-104.817215* |
| | $O_3$ | 1 | Jun-96 | H.C. Urban | TAPI 400E | SLAMS | Continuous |
| 08 041 0015 | *Highway 24* | *690 W. Hwy. 24* | | *Nov-98* | *1,824* | *39.830895* | *-104.839243* |
| | CO (Trace) | 1 | Nov-98 | P.O. Micro | THERMO 48i-TLE | SLAMS | Continuous |
| | $SO_2$ | 1 | Jan-13 | P.O. Micro | TAPI 100EU | SLAMS | Continuous |
| | WS/WD/Temp | 1 | Aug-14 | P.O. Micro | RM YOUNG | SPM | Continuous |
| | Relative Humidity | 1 | Aug-14 | P.O. Micro | RM YOUNG | SPM | Continuous |
| 08 041 0016 | *Manitou Springs* | *101 Banks Pl.* | | *Apr-04* | *1,955* | *38.853097* | *-104.901289* |
| | $O_3$ | 1 | Apr-04 | H.C. Neigh | TAPI 400E | SLAMS | Continuous |
| 08 041 0017 | *Colorado College* | *130 W. Cache La Poudre* | | *Dec-07* | *1,832* | *38.848014* | *-104.828564* |
| | $PM_{10}$ | 1 | Dec-07 | P.O. Neigh | R&P PARTISOL 2025 | SLAMS | 1 in 6 |
| | $PM_{10}$ | 3 | Jun-16 | P.O. Neigh | GRIMM EDM 180 | SLAMS | Continuous |
| | $PM_{2.5}$ | 3 | Dec-07 | P.O. Neigh | GRIMM EDM 180 | SLAMS | Continuous |
| **Fremont** | | | | | | | |
| 08 043 0003 | *Cañon City - City Hall* | *128 Main St.* | | *Oct-04* | *1,626* | *38.43829* | *-105.24504* |
| | $PM_{10}$ | 1 | Oct-04 | P.O. Neigh | SA/GMW 1200 | SLAMS | 1 in 6 |
| **Garfield** | | | | | | | |
| 08 045 0012 | *Rifle - Health Dept.* | *195 W. 14th Ave.* | | *Jun-08* | *1,629* | *39.54182* | *-107.784125* |
| | $O_3$ | 1 | Jun-08 | P.O. Neigh | TAPI 400E | SLAMS | Continuous |
| **Gilpin** | | | | | | | |
| 08-047-0003 | *Black Hawk* | *831 Miners Mesa Rd.* | | *Jul-19* | *2,633* | *39.792519* | *-105.491272* |
| | $O_3$ | 1 | Jul-19 | P.O. Micro | TAPI 400E | SPM | Continuous |
| **Jefferson** | | | | | | | |
| 08 059 0002 | *Arvada* | *9101 W. 57th Ave.* | | *Jan-73* | *1,640* | *39.800333* | *-105.099973* |
| | WS/WD/Temp | 1 | Jan-75 | P.O. Neigh | MET-ONE | SPM | Continuous |

| AQS # | Site Name | Address | | Site Start | Elevation (m) | Latitude | Longitude |
|---|---|---|---|---|---|---|---|
| | **Parameter** | **POC** | **Start** | **Orient/Scale** | **Monitor** | **Type** | **Sample** |
| *08 059 0005* | *Welch* | *12400 W. Hwy. 285* | | *Aug-91* | *1,742* | *39.638781* | *-105.13948* |
| | $O_3$ | 1 | Aug-91 | P.O. Urban | TAPI 400E | SLAMS | Continuous |
| | WS/WD/Temp | 1 | Nov-91 | P.O. Neigh | MET-ONE | SPM | Continuous |
| *08 059 0006* | *Rocky Flats North* | *16600 W. Hwy. 128* | | *Jun-92* | *1,802* | *39.912799* | *-105.188587* |
| | $NO_Y$ | 1 | Oct-20 | P.O. Neigh | TAPI 200EU | PAMS | Continuous |
| | CAPS $NO_2$ | 1 | Jul-20 | P.O. Neigh | TAPI 500U | PAMS | Continuous |
| | $O_3$ | 1 | Sep-92 | H.C. Urban | TAPI 400E | PAMS | Continuous |
| | Precipitation | 1 | Jul-19 | P.O. Neigh | RM Young | PAMS | Continuous |
| | Relative Humidity | 1 | Jul-19 | P.O. Neigh | RM Young | PAMS | Continuous |
| | Total Solar Radiation | 1 | Jul-19 | P.O. Neigh | KIPP & ZONEN | PAMS | Continuous |
| | WS/WD/Temp | 1 | Sep-92 | P.O. Neigh | RM Young | PMAS | Continuous |
| *08 059 0011* | *NREL* | *2054 Quaker St.* | | *Jun-94* | *1,832* | *39.743724* | *-105.177989* |
| | $O_3$ | 1 | Jun-94 | H.C. Urban | TAPI 400E | SLAMS | Continuous |
| **Larimer** | | | | | | | |
| *08 069 0009* | *Fort Collins - CSU* | *251 Edison Dr.* | | *Dec-98* | *1,524* | *40.571288* | *-105.079693* |
| | $PM_{10}$ | 3 | Jun-15 | P.O. Neigh | GRIMM EDM 180 | SPM | Continuous |
| | $PM_{2.5}$ | 3 | Jun-15 | P.O. Neigh | GRIMM EDM 180 | SPM | Continuous |
| *08 069 0011* | *Fort Collins - West* | *3416 La Porte Ave.* | | *May-06* | *1,571* | *40.592543* | *-105.141122* |
| | $O_3$ | 1 | May-06 | H.C. Urban | TAPI 400E | SLAMS | Continuous |
| *08 069 1004* | *Fort Collins - Mason* | *708 S. Mason St.* | | *Dec-80* | *1,524* | *40.57747* | *-105.07892* |
| | CO (Trace) | 1 | Dec-80 | P.O. Neigh | THERMO 48i-TLE | SLAMS | Continuous |
| | $O_3$ | 1 | Dec-80 | P.O. Neigh | TAPI 400E | SLAMS | Continuous |
| | WS/WD/Temp | 1 | Jan-81 | P.O. Neigh | MET-ONE | SPM | Continuous |
| **Mesa** | | | | | | | |
| *08 077 0017* | *Grand Junction - Powell Bldg.* | *650 South Ave.* | | *Feb-02* | *1,398* | *39.063798* | *-108.561173* |
| | $PM_{10}$ & NATTS Metals | 3 | Jan-05 | P.O. Neigh | R&P PARTISOL 2025 | SLAMS | 1 in 3 |
| | $PM_{10}$ Collocated & NATTS | 4 | Mar-05 | P.O. Neigh | R&P PARTISOL 2025 | SLAMS | 1 in 6 |
| | $PM_{10}$ | 3 | Jan-14 | P.O. Neigh | GRIMM EDM 180 | SPM | Continuous |
| | $PM_{2.5}$ | 3 | Jan-14 | P.O. Neigh | GRIMM EDM 180 | SPM | Continuous |
| *08 077 0018* | *Grand Junction - Pitkin* | *645 1/4 Pitkin Ave.* | | *Jan-04* | *1,398* | *39.064289* | *-108.56155* |
| | WS/WD/Temp | 1 | Jan-04 | P.O. Neigh | RM YOUNG | SPM | Continuous |
| | Relative Humidity | 1 | Jan-04 | P.O. Neigh | RM YOUNG | SPM | Continuous |

| AQS # | *Site Name* | *Address* | | *Site Start* | *Elevation (m)* | *Latitude* | *Longitude* |
|---|---|---|---|---|---|---|---|
| | **Parameter** | **POC** | **Start** | **Orient/Scale** | **Monitor** | **Type** | **Sample** |
| *08 077 0020* | *Palisade Water Treatment* | *Rapid Creek Rd.* | | *May-08* | *1,512* | *39.130575* | *-108.313853* |
| | $O_3$ | 1 | Apr-08 | P.O. Urban | TAPI 400E | SLAMS | Continuous |
| | WS/WD/Temp | 1 | Apr-08 | P.O. Neigh | RM YOUNG | SPM | Continuous |
| **Montezuma** | | | | | | | |
| *08 083 0006* | *Cortez - Health Dept.* | *106 W. North St.* | | *Jun-06* | *1,890* | *37.350054* | *-108.592337* |
| | $O_3$ | 1 | Jun-08 | P.O. Urban | TAPI 400E | SLAMS | Continuous |
| **Pitkin** | | | | | | | |
| *08 097 0006* | *Aspen* | *215 N. Garmisch St.* | | *Jan-15* | *2,408* | *39.192958* | *-106.823257* |
| | $PM_{10}$ | 1 | Feb-15 | P.O. Neigh | SA/GMW 1200 | SLAMS | 1 in 3 |
| **Prowers** | | | | | | | |
| *08 099 0002* | *Lamar - Municipal Bldg.* | *104 E. Parmenter St.* | | *Dec-76* | *1,107* | *38.084688* | *-102.618641* |
| | $PM_{10}$ | 2 | Mar-87 | P.O. Neigh | SA/GMW 1200 | SLAMS | 1 in 1 |
| **Pueblo** | | | | | | | |
| *08 101 0015* | *Pueblo - Fountain School* | *925 N. Glendale Ave.* | | *Jun-11* | *1,433* | *38.276099* | *-104.597613* |
| | $PM_{10}$ | 1 | Apr-11 | P.O. Neigh | SA/GMW 1200 | SLAMS | 1 in 3 |
| | $PM_{2.5}$ | 1 | Apr-11 | P.O. Neigh | R&P PARTISOL 2025 | SLAMS | 1 in 3 |
| **Routt** | | | | | | | |
| *08 107 0003* | *Steamboat Springs* | *136 6th St.* | | *Sep-75* | *2,054* | *40.485201* | *-106.831625* |
| | $PM_{10}$ | 2 | Mar-87 | P.O. Neigh | SA/GMW 1200 | SLAMS | 1 in 1 |
| **San Miguel** | | | | | | | |
| *08 113 0004* | *Telluride* | *333 W. Colorado Ave.* | | *Mar-90* | *2,684* | *37.937872* | *-107.813061* |
| | $PM_{10}$ | 1 | Mar-90 | P.O. Neigh | SA/GMW 1200 | SLAMS | 1 in 3 |
| **Weld** | | | | | | | |
| *08 123 0006* | *Greeley - Hospital* | *1516 Hospital Rd.* | | *Apr-67* | *1,441* | *40.414877* | *-104.70693* |
| | $PM_{10}$ | 2 | Feb-99 | P.O. Neigh | GRIMM EDM 179 | SPM | Continuous |
| | $PM_{2.5}$ | 3 | Feb-99 | P.O. Neigh | GRIMM EDM 180 | SPM | Continuous |
| *08 123 0008* | *Platteville - Middle School* | *1004 Main St.* | | *Dec-98* | *1,469* | *40.209387* | *-104.82405* |
| | $PM_{2.5}$ | 1 | Aug-99 | P.O. Region | R&P PARTISOL 2025 | SLAMS | 1 in 3 |
| | $PM_{2.5}$ Speciation | 5 | Aug-99 | P.O. Region | SASS | Spec. Trends | 1 in 6 |
| | $PM_{2.5}$ Carbon | 5 | Apr-11 | P.O. Neigh | URG 3000N | Spec. Trends | 1 in 6 |
| *08 123 0009* | *Greeley - County Tower* | *3101 35th Ave.* | | *Jun-02* | *1,484* | *40.386368* | *-104.73744* |
| | $O_3$ | 1 | Jun-02 | H.C. Neigh | TAPI 400E | SLAMS | Continuous |
| | WS/WD/Temp | 1 | Feb-12 | P.O. Neigh | MET-ONE | SPM | Continuous |
| | CO (Trace) | 1 | Apr-16 | P.O. Neigh | THERMO 48i-TLE | SLAMS | Continuous |

**Tri County Health Dept. - Commerce City, 4201 E. 72nd Ave. (08 001 0008):**

Tri County Health Dept. - Commerce City site is in a predominantly residential area with a large commercial and industrial district. It is located north of the Denver Central Business District (CBD) near the Platte River Valley, downstream from the Denver urban air mass. There are three schools in the immediate vicinity, an elementary school to the south, a middle school to the north, and a high school to the southeast. There is a large industrial area to the south and east, and gravel pits about a kilometer to the west and northwest.

This is a replacement site for the Alsup Elementary school (08-001-0006) site which was dismantled due to a roofing project on the building.

$PM_{10}$ and $PM_{2.5}$ monitoring began in August of 2016. There is a collocated $PM_{2.5}$ FRM along with a continuous $PM_{2.5}$ GRIMM EDM dust monitor, a filter based low volume $PM_{10}$ monitor, a trends speciation monitor, and a $PM_{2.5}$ carbon monitor all in operation.

**Welby, 3174 E. 78th Avenue (08 001 3001):**

Located 8 miles north-northeast of the Denver Central Business District (CBD) on the bank of the South Platte River, this site is ideally located to measure nighttime drainage of the air mass from the Denver metropolitan area and the thermally driven, daytime upriver flows. The monitoring shows that high CO levels are associated with winds from the south-southwest. While this is the direction of five of the six major sources in the area, it is also the direction of the primary drainage winds along the South Platte River. This monitor is in the SLAMS network, and is population oriented for a neighborhood scale.

CO monitoring began in 1973 and continued through the spring of 1980. Monitoring was stopped from the spring of 1980 until October 1986 when it began again as a special study. Welby has not recorded an exceedance of either the one-hour or eight-hour CO standard since January 1988. In the last few years, its primary value has been as an indicator of changes in the air quality index (AQI).

$O_3$ monitoring began at Welby in July of 1973. The Welby monitor has not recorded an exceedance of the old one-hour $O_3$ standard since 1998. However, the trend in the 3-year average of the 4th maximum eight-hour average has been increasing since 2002.

The Welby $NO_2$ monitor began operation in July 1976. The site's location provides an indication of possible exceedance events before they hit the Denver-Metro area. The site serves as a good drainage location, but it may be a target for deletion or relocation farther down the South Platte River Valley from Denver due to growth in trees that are not allowed to be removed.

The Welby $SO_2$ monitor began operation in July of 1973.

$PM_{10}$ monitoring began at Welby in June and July of 1990 with a high volume $PM_{10}$ monitor and a $PM_{10}$ continuous TEOM monitor. Meteorological monitoring began in January of 1975.

**Highland Reservoir, 8100 S. University Boulevard (08 005 0002):**

The Highlands site began operation in June of 1978. It was intended to be a background location. However, with urban growth and the construction of C-470, it has become a long-term trend site that monitors changes in the air quality of the area. It is currently believed to be near the southern edge of the high urban $O_3$ concentrations although it may not be in the area of maximum concentrations. This is a population oriented neighborhood scale SLAMS monitor.

Meteorological monitoring began in July of 1978.

In September of 2010 the site and meteorological tower were relocated to the east by approximately 30 meters to allow for the construction of an emergency generator system. This emergency generator system is located approximately 20 meters northwest of the new site location. The Highlands monitoring site had to be shut down from approximately Oct. of 2013 to Sept. of 2015 due to major construction activities on the property. The site is currently back up and monitoring for ozone and meteorological parameters.

**Arapahoe Community College (ACC), 6190 S. Santa Fe Drive (08 005 0005):**

The ACC site is located in south suburban metropolitan Denver. It is located on the south side of the Arapahoe Community College in a distant parking lot. The site is near the bottom of the Platte River Valley along Santa Fe Drive

(Hwy. 85) in the city of Littleton. It is also near the city of Englewood. There is a large residential area located to the east across the railroad and Light Rail tracks. The $PM_{2.5}$ monitor is located on a mobile shelter in the rarely used South parking lot. Located at 6190 S. Santa Fe Drive, this small trailer is close to the Platte River and the monitor has excellent $360^0$ exposure. Based on the topography and meteorology of the area ACC is in an area where $PM_{2.5}$ emissions may collect. This location may capture high concentrations during periods of upslope flow and temperature inversion in the valley. However, since it is further south in a more sparsely populated area, the concentrations are usually not as high as other Denver locations.

Winds are predominately out of the south-southwest and south, with secondary winds out of the north and north-northeast (upslope). Observed distances and traffic estimates easily fall into the neighborhood scale in accordance with federal guidelines found in the 40 CFR, Part 58, Appendix D. The site meets all other neighborhood scale criteria, making the monitor a population oriented neighborhood scale SLAMS monitor on a 1 in 3 day sample schedule.

**Aurora – East, 36001 Quincy Ave (08 005 0006):**

The Aurora East site began operation in June 2009. It is intended to act as a regional site and aid in the determination of the eastern most extent of the high urban $O_3$ concentrations. It is located along the eastern edge of the former Lowry bombing range, on a flat, grassy plains area. This site is currently outside of the rapid urban growth area taking place around Aurora Reservoir. This was a special purpose monitor (SPM) for a regional scale, and became a SLAMS monitor in 2013.

**Pagosa Springs School, 309 Lewis Street (08 007 0001):**

The Pagosa Springs site was located on the roof of the Town Hall from April 24, 2000 through May 2001. When the Town Hall building was planned to be demolished, the $PM_{10}$ monitor was relocated to the Pagosa Springs Middle School and the first sample was collected on June 7, 2001.

The Pagosa Springs School site is located next to Highway 160 near the center of town. Pagosa Springs is a small town spread over a large area. The San Juan River runs through the south side of town. The town sits in a small bowl like setting with hills all around. A small commercial strip area along Highway 160 and single-family homes surrounds this location. It is representative of residential neighborhood exposure. Pagosa Springs was a $PM_{10}$ nonattainment area and a SIP was implemented for this area. $PM_{10}$ concentrations were exceeded a few times in the late 1990s.

Winds for this area predominantly blow from the north, with secondary winds from the north-northwest and the south. The predominant wind directions closely follow the valley topography in this rugged terrain. McCabe Creek, which is very near the meteorological station that was on the Town Hall building, runs north-south through this area. However, the highest wind gusts come from the west and southwest during regional dust storms. This is a population oriented neighborhood scale SLAMS monitor on a daily sampling schedule.

**Longmont – Municipal Bldg., 350 Kimbark Street (08 013 0003):**

The town of Longmont is a growing, medium sized Front Range community. Longmont is located between the Denver/Boulder Metro-area and Fort Collins. Longmont is both suburban and rural in nature. The town of Longmont is located approximately 30 miles north of Denver along the St. Vrain Creek and is about six miles east of the foothills. Longmont is partly a bedroom community for the Denver-Boulder area. The elevation is 4978 feet. The Front Range peaks rise to an elevation of 14,000 feet just to the west of Longmont. In general, the area experiences low relative humidity, light precipitation and abundant sunshine.

The station began operations in 1985 with the installation of $PM_{10}$ followed by $PM_{2.5}$ monitors in 1999.

Longmont's predominant wind direction is from the north through the west due to winds draining from the St. Vrain Creek Canyon. The $PM_{10}$ site is near the center of the city near both commercial and residential areas. This location provides the best available monitoring for population exposure to particulate matter. The distance and traffic estimate for the controlling street easily falls into the neighborhood scale in accordance with federal guidelines found in 40 CFR, Part 58, and Appendix D. This is a population oriented neighborhood scale SLAMS monitor on a 1 in 6 day sample schedule. In September of 2014 APCD installed a collocated sampler at the site to meet EPA $PM_{10}$ high volume collocation requirements.

**Boulder Chamber of Commerce, 2440 Pearl Street (08 013 0012):**

The city of Boulder is located on the eastern edge of the Rocky Mountain foothills. Most of the city sits on rolling plains. The Boulder $PM_{2.5}$ site is approximately 7,000 feet east of the base of the Front Range foothills and about 50 feet south of a small branch of Boulder Creek, the major creek that runs through Boulder.

$PM_{10}$ monitoring began at this site in December of 1994, while the $PM_{2.5}$ monitoring did not begin until January of 1999.

The predominant wind direction at the APCD's closest meteorological site (Rocky Flats – North) is from the west with secondary maximum frequencies from the west-northwest and west-southwest. The distance and traffic estimate for Pearl Street and Folsom Street falls into the middle scale, but the site has been justified to represent a neighborhood scale site in accordance with federal guidelines found in 40 CFR, Part 58 and Appendix D. This is a population oriented neighborhood scale SLAMS monitoring site on a 1 in 6 day sample schedule.

**Boulder Reservoir, 5545 Reservoir Road (08 013 0014):**

The city of Boulder is located about 30 miles to the northwest of Denver. The Boulder Reservoir is a 700 acre multi-use recreation and water storage facility owned and managed by the city of Boulder. It is operated as a water supply by the Northern Colorado Water Conservancy District. The Reservoir is located about 5.5 miles to the North East of the city of Boulder. This site is a replacement site for the South Boulder Creek site which was shut down January 1st, 2016 due to large trees that had grown over the years that could not be removed, making the site no longer meet siting criteria.

The Boulder Reservoir is a highest concentration oriented urban scale SLAMS monitor. The site monitors for ozone and meteorological parameters and has been sampling since September of 2016.

**Boulder – CU - Athens, 2102 Athens Street (08 013 1001):**

The Boulder - CU site is located at the edge of a low usage parking lot to the immediate north of the site and south of the University of Colorado football practice fields. This location provides a good neighborhood representation for particulates. The site houses a continuous TEOM particulate monitor inside the shelter. The site began operation in November 2004. A dome is erected each fall over the practice field and remains inflated until early spring when it is removed for the summer months.

**Mines Peak – Mines Peak Rd. (08 019 0006):**

The Mines Peak ozone monitor began operation in June 2014 in support of the FRAPPE and Discover-AQ studies. The site is located in a Colorado Office of Information and Technology communication tower atop Mines Peak at an elevation of 3,807 meters.

The site resides in Clear Creek County approximately 1200 meters east southeast of Berthoud Pass along US Hwy 40. This site was retained in operation as a special purpose site after the FRAPPE and Discover-AQ studies for its unique attribute to measure local and regional background ozone concentrations. This site has proven to be very informative in identifying and quantifying stratospheric ozone events in the North Front Range area. Because of its unique location and limited year round access, the ozone analyzer cannot be operated to meet regulatory requirements, and thus the site has been classified as "non-regulatory" and cannot be used to show attainment of National Ambient Air Quality Standards.

**CAMP, 2105 Broadway (08 031 0002):**

The City and County of Denver is located approximately 30 miles east of the foothills of the Rocky Mountains. Denver sits in a basin, and the terrain of the city is characterized as gently rolling hills, with the Platte River running from southwest to northeast, just west of the downtown area. The CAMP site is located in downtown Denver.

CO monitoring began in February 1965 as a part of the Federal Continuous Air Monitoring Program. It was established as a maximum concentration (micro-scale), population-oriented monitor. The CAMP site measures the exposure of the people who work or reside in the central business district (CBD). Its location in a high traffic street canyon causes this site to record most of the high pollution episodes in the metro area. The street canyon effect at CAMP results in variable wind directions for high CO levels and as a result wind direction is less relevant to high concentrations than wind speed. Wind speeds less than 1 mph, especially up-valley, combined with temperature inversions trap the pollution in the area. The CO monitor was updated to a Thermo 48iTLE trace level monitor in April 2017 to better characterize lower level concentrations seen in recent years.

Sampling for all parameters at the site was discontinued from June of 1999 to July of 2000 for the construction of a new building.

The $NO_2$ monitor began operation in January 1973 at this location.

The $SO_2$ monitor began operation in January 1967.

$O_3$ monitoring began originally in 1972 and has been intermittently monitored through January 2008. The current $O_3$ monitor began operation in February 2012.

The $PM_{10}$ monitoring began in 1986 with the installation of collocated monitors, and was furthered by the addition of a continuous monitor in 1988.

The $PM_{2.5}$ monitoring began in 1999 with a sequential filter based FRM monitor. A continuous TEOM FEM $PM_{2.5}$ monitor was installed in February of 2001 and an FDMS was installed on the instrument November 1, 2003. In April 2013, the TEOM/FDMS was replaced with a GRIMM EDM 180 continuous monitor, which concurrently measures both $PM_{10}$ and $PM_{2.5}$.

Meteorological monitoring began at this site in January of 1965.

## National Jewish Health, 14th Avenue & Albion Street (08 031 0013):

This site is located three miles east of the Denver CBD, close to a very busy intersection (Colorado Boulevard and Colfax Avenue). The current site began operations in 1982. Two previous sites were located just west of the current location. The first operated for only a few months before it was moved to a new site in the corner of the laboratory building at the corner of Colorado Boulevard and Colfax Avenue. Data from this continuous TEOM particulate monitor is not compared with the NAAQS. It is used for short term forecasting and public notifications. The monitor here is a population oriented middle scale special project monitor.

## DESCI:

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. 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 station also monitors relative humidity in order to resolve low visibility because of fog or rain.

## La Casa, 4587 Navajo Street (08 031 0026):

The La Casa site was established in January of 2013 as a replacement for the Denver Municipal Animal Shelter (DMAS) site when a land use change forced the relocation of the site. The La Casa location has been established as the NCore site for the Denver Metropolitan area. In late 2012 the DMAS site was decommissioned and moved to the La Casa site in northwest Denver and includes a trace gas/precursor-level CO analyzer, and a NOy analyzer, in addition to the trace level $SO_2$, $O_3$, meteorology, and particulate monitors are located here. La Casa has been certified in 2013 as an NCore-compliant site by the EPA. The site represents a population oriented neighborhood scale monitoring area.

The trace level $SO_2$, CO, and NOy analyzers began operation in January 2013.

The meteorological monitoring began at La Casa in January 2013.

$PM_{10}$ monitoring began at La Casa in January 2013. Currently, there is a pair of collocated low volume $PM_{10}$ samplers, and a Lo-Vol $PM_{2.5}$ on the shelter roof. The Lo-vol $PM_{10}$ concentrations are very useful as they are used in conjunction with the $PM_{2.5}$ measurements to calculate $PM_{10-2.5}$ or coarse PM.

$PM_{2.5}$ monitoring began at La Casa in January 2013 with an FRM filter-based monitor, a continuous TEOM/FDMS FEM instrument, a supplemental $PM_{2.5}$ speciation monitor, and a carbon speciation monitor. In early 2015, the TEOM/FDMS was replaced with a GRIMM EDM 180 continuous monitor, which concurrently measures both $PM_{10}$ and $PM_{2.5}$.

$PM_{10}$/lead monitoring began in January 2013. Lead monitoring at La Casa was discontinued December 31st, 2015 due to extremely low concentrations measured at the site. EPA has removed the lead monitoring requirement from all NCore sites due to the low concentrations measured throughout the country. Ambient lead concentrations will still be measured at the $PM_{2.5}$ speciation and IMPROVE sites throughout the state, as well as on the $PM_{10}$ sampler at Grand Junction Powell (08 077 0017) as part of the National Air Toxics Trends Stations project.

**I-25 Denver, 913 Yuma Street (08 031 0027):**

The I-25 Denver site is an EPA-required near roadway $NO_2$ monitoring site. It was established in June 2013. It is measuring $NO/NO_2/NO_x$ by chemiluminescence. Trace level CO, Teledyne API Model 633 Black Carbon Aethalometer, $PM_{2.5}$ with a filter based sequential FRM on a 1 and 6 day schedule, continuous $PM_{10}$ & $PM_{2.5}$ (with a GRIMM EDM 180), and meteorological parameters are also measured here.

**I-25 Globeville, 4905 Acoma Street (08 031 0028):**

The I-25 Globeville site is a second EPA-required near roadway $NO_2$ monitoring site. It was established Oct. 1st, 2015. It is measuring $NO/NO_2/NO_x$ by chemiluminescence. The site is also equipped with sensors to measure meteorological parameters and continuous $PM_{10}$ and $PM_{2.5}$ with a GRIMM EDM 180 instrument.

**Chatfield State Park, 11500 N. Roxborough Park Road (08 035 0004):**

The Chatfield State Park location was established as the result of the 1993 Summer $O_3$ Study. The original permanent site was located at the campground office. This site was later relocated on the south side of Chatfield State Park at the park offices. This location was selected over the Corps of Engineers Visitor Center across the reservoir because it was more removed from the influence of traffic along C-470. Located in the South Platte River drainage, this location is well suited for monitoring southwesterly $O_3$ formation in the Denver metro area.

$PM_{2.5}$ monitoring began at this site in 2004 with the installation of a continuous monitor, and was furthered by the addition of an FRM sequential filter based monitor in 2005. Meteorological monitoring began in April of 2004.

**Colorado Springs, USAFA Road 640 (08 041 0013):**

The United States Air Force Academy site was installed as a replacement maximum concentration $O_3$ monitor for the Chestnut Street (08 041 0012) site. Modeling in the Colorado Springs area indicates that high $O_3$ concentrations should generally be found along either the Monument Creek drainage to the north of the Colorado Springs central business district (CBD), or to a lesser extent along the Fountain Creek drainage to the west of the CBD. The decision was made to locate this site near the Monument Creek drainage, approximately 9 miles north of the CBD. This location is near the south entrance of the Air Force Academy but away from any roads. This is a population oriented urban scale SLAMS monitor.

**Colorado Springs Hwy-24, 690 W. Highway 24 (08 041 0015):**

The Highway 24 site is located just to the west of I-25 and just to the east of the intersection of U.S. Highway 24 and 8th Street, approximately 0.8 miles to the west of the Colorado Springs CBD. Commencing operation in November 1998, this site is a replacement for the Tejon Street (08 041 0004) CO monitor. The site is located in the Fountain Creek drainage and is in one of the busiest traffic areas of Colorado Springs. Additionally, traffic is prone to back-up along Highway 24 due to a traffic light at 8th Street. Thus, this site is well suited for the SLAMS network to monitor maximum concentrations of CO in the area both from automotive sources and also from nearby industry, which includes a power plant. It also provides a micro-scale setting for the Colorado Springs area, which has not been possible in the past.

In January of 2013 an $SO_2$ monitor was added to Highway 24 to meet monitoring criteria for an increased population found during the 2010 census. To supplement $SO_2$ monitoring at the site, APCD added an RM Young meteorological tower in August of 2014, which also includes an RH sensor.

**Manitou Springs, 101 Banks Place (08 041 0016):**

The Manitou Springs ozone site is located 4 miles west of Colorado Springs. It was established because of concern that the high concentration urban $O_3$ area was traveling farther up the Fountain Creek drainage and the current monitoring network was not adequate. The Manitou Springs monitor began operations in April 2004. It is located in the foothills above Colorado Springs in the back of the city maintenance facility. It has not recorded any levels greater than the current standard. This is a population-oriented neighborhood scale SLAMS monitor.

**Colorado College, 130 W. Cache la Poudre Street (08 041 0017):**

The Colorado College monitoring site was established in January, 2007 after the revised particulate regulations required that Colorado Springs have a continuous $PM_{2.5}$ monitor. The APCD elected to collocate the new $PM_{2.5}$ monitor with the corresponding filter-based monitors from the RBD site at the Colorado College location, which included an FRM $PM_{2.5}$ monitor and added a low volume FEM $PM_{10}$ monitor in November, 2007. The continuous monitor began operation in April of 2008. In the summer of 2016 the filter based $PM_{2.5}$ FRM instrument was removed and the GRIMM EDM 180 was designated as the primary sampler used to compare to the $PM_{2.5}$ NAAQS. Currently there is also a low volume filter-based $PM_{10}$ sampler operated on a 1 in 6 day schedule at the site.

The nearest representative meteorological site is located at the Highway 24 monitoring site. Wind flows at the Colorado College site are affected by its proximity to Fountain Creek, so light drainage winds will follow the creek in a north/south direction. The three monitoring sites here are population-oriented neighborhood scale monitors on the SLAMS network ($PM_{10}$ and $PM_{2.5}$).

**Cañon City - City Hall, 128 Main Street (08 043 0003):**

Cañon City is located 39 miles west of Pueblo. Particulate monitoring began on January 2, 1969 with the operation of a TSP monitor located on the roof of the courthouse building at 7th Avenue and Macon Street. The Macon Street site was relocated to the top of the City Hall building in October of 2004.

The Cañon City $PM_{10}$ site began operation in December 1987. On May 6, 1988, the Macon Street monitor recorded a $PM_{10}$ concentration of 172 $\mu g/m^3$. This is the only exceedance of either the 24-hour or annual NAAQS since $PM_{10}$ monitoring was established at Cañon City. This is a population oriented neighborhood scale SLAMS monitor on a 1 in 6 day sample schedule.

**Rifle – Health Dept., 195 14th Ave (08 045 0012):**

The Rifle Health site is located at the Garfield County Health Department building. The site is approximately 1 kilometer to the north of the downtown area and next to the Garfield County fairgrounds. The site is uphill from the downtown area. A small residential area is to the north and a commercial area to the east. This site was established to measure $O_3$ in Rifle, which is the largest population center in the oil and gas impacted area of the Grand Valley. Monitoring commenced in June 2008. This is a SLAMS site with a neighborhood scale.

**Black Hawk, 831 Miners Mesa Rd. (08 047 0003):**

The Black Hawk Site was selected to replace the Aspen Park Site that no longer met EPA siting requirements for tree obstruction. The Black Hawk site was chosen because it was found, during a recent Front Range ozone study, to have elevated ozone concentrations as compared to the other sites in the study. The Black Hawk monitoring location sits at an elevation of 2,633 meters and has been in operation since July of 2019.

**Arvada, 9101 57th Avenue (08 059 0002):**

The city of Arvada is located 15 miles west-northwest of the Denver central business district (CBD). The Arvada site began operation before 1973. It is located to the northwest of the Denver CBD near the western end of the diurnal midday wind flow of the high concentration urban $O_3$ area. As a result, when conditions are proper for daylong $O_3$ production, this site has received some of the highest levels in the city. In the early and mid-1990s, these wind patterns caused Arvada to have the most exceedances in the metro area. In the 5-Year Network Assessment Plan the Arvada site was deemed to be redundant. The last valid $O_3$ sample was taken 12/31/2011, and the instrument was removed shortly after that. Meteorological monitoring began in 1975 and continues today.

### Welch, 12400 W. Highway 285 (08 059 0005):

The APCD conducted a short-term $O_3$ study on the grounds of Chatfield High School from June 14, 1989 until September 28, 1989. The Chatfield High School location was chosen because it sits on a ridge southwest of the Denver CBD. Wind pattern studies showed a potential for elevated $O_3$ levels in the area on mid to late afternoon summer days. There were no exceedances of the NAAQS recorded at the Chatfield High School site, but the levels were frequently higher than those recorded at the other monitoring sites south of the metro area.

One finding of the study was the need for a new, permanent site further north of the Chatfield High School location. As with most Denver locations, the predominant wind pattern is north/south. The southern flow occurs during the upslope, daytime warming period. The northern flow occurs during late afternoon and nighttime when drainage is caused by cooling and settling. The major drainages of Bear Creek and Turkey Creek were selected as target downwind transport corridors. These are the first major topographical features north of the Chatfield High School site. A point midway between the valley floor (Englewood site) and the foothill's hogback ridge was modeled to be the best estimate of the maximum downwind daytime transport area. These criteria were used to evaluate available locations. The Welch site best met these conditions. This site is located off State Highway 285 between Kipling Street and C-470. This is a population oriented urban scale SLAMS monitor.

### Rocky Flats North, 16600 W. Highway 128 (08 059 0006):

The Rocky Flats North (RFN) site is located north-northeast of the former plant on the south side of Colorado Highway 128, approximately 1¼ miles to the west of Indiana Street. The site began operation in June of 1992 with the installation of an $O_3$ monitor and meteorological monitors as a part of the first phase of the APCD's monitoring effort around the Rocky Flats Environmental Technology Site.

$O_3$ monitoring began as a part of the Summer 1993 Ozone Study. The monitor recorded some of the highest $O_3$ levels of any of the sites during that study. Therefore, it was included as a regular part of the APCD $O_3$ monitoring network. The Rocky Flats – N monitor frequently exceeds the current standard. This is a highest concentration-oriented urban scale SLAMS monitor.

The RFN site is now being converted to a Photochemical Assessment Monitoring Station (PAMS). This station, in addition to $O_3$, now monitors for $NO_y$ and $NO_2$. When the PAMS site is complete it will offer extensive meteorological monitoring to include total solar, precipitation, and atmospheric profiling. In addition, the PAMS will monitor for $SO_2$, CO, particulate monitoring ($PM_{10}$ and $PM_{2.5}$), and VOC monitoring by use of an Auto Gas Chromatograph (auto-GC).

### NREL Solar Radiation Research Laboratory, 2054 Quaker Street (08 059 0011):

The National Renewable Energy Laboratory (NREL) site is located on the south rim of South Table Mountain, near Golden, and was part of the Summer 1993 Ozone Study. Based on the elevated concentrations found at this location during the study, it was made a permanent monitoring site in 1994. This site typically records some of the higher eight-hour $O_3$ concentrations in the Denver area. It frequently exceeds the current standard.

### Fort Collins - CSU - Edison, 251 Edison Street (08 069 0009):

Fort Collins does not have the population to require a particulate monitor under Federal regulations. However, it is one of the largest cities along the Front Range. In the summer of 2016 APCD removed the filter based FRM $PM_{2.5}$ sampler and designated the GRIMM EDM 180 continuous particulate monitor as the primary method for $PM_{2.5}$ NAAQS comparisons. On January 1st, 2019, the APCD discontinued Hi-Vol PM10 sampling leaving only a continuous GRIMM EDM 180 that measures $PM_{10}$ and $PM_{2.5}$ at the site.

### Fort Collins - West, 3416 W. La Porte Avenue (08 069 0011):

The Fort Collins-West ozone monitor began operation in May of 2006. The location was established based on modeling and to satisfy permit conditions for a major source in the Fort Collins area. The levels recorded for the first season of operation showed consistently higher concentrations than the 708 S. Mason Street monitor. This is a highest concentration oriented urban scale SLAMS monitor.

**Fort Collins- Mason, 708 S. Mason Street (08 069 1004):**

The 708 S. Mason Street site began operation in December 1980 and is located one block west of College Avenue in the Central Business District. The one-hour CO standard of 35 ppm as a one-hour average has only been exceeded on December 1, 1983, at 4:00 P.M. and again at 5:00 P.M. The values reported were 43.9 ppm and 43.2 ppm respectively. The eight-hour standard of 9 ppm was exceeded one or more times a year from 1980 through 1989. The last exceedances were in 1991 on January 31 and December 6 when values of 9.8 ppm and 10.0 ppm respectively were recorded.

Fort Collins does not have the population to require a CO monitor under Federal regulation. However, it is one of the largest cities along the Front Range and was declared in nonattainment for CO in the mid-1970s after exceeding the eight-hour standard in both 1974 and 1975. In May of 2016 the CO monitor was upgraded to a Thermo 48i-TLE trace level instrument. The current level of monitoring is in part a function of the resulting CO State Maintenance Plan (SMP) for the area. It is a population oriented neighborhood scale SLAMS monitor.

$O_3$ monitoring began in 1980, and continues today.

Meteorological monitoring began at the site January 1st, 1981. In March 2012 the meteorological tower was relocated from a freestanding tower on the west side of the shelter to a shelter mounted tower on the south side of the shelter due to the Mason Street Redevelopment Project.

**Grand Junction - Powell, 650 South Avenue (08 077 0017):**

Grand Junction is the largest city on the western slope. It is located in the broad valley of the Colorado River. The monitors are on county owned buildings in the south side of the city. This site is on the southern end of the central business district and close to the industrial area along the train tracks. It is about a half a mile north of the river and about a quarter mile east of the railroad yard. In the summer of 2016 the primary filter based FRM was removed and the GRIMM EDM 180 continuous particulate monitor was designated as the primary to compare to the $PM_{2.5}$ NAAQS. Currently the GRIMM monitors for continuous $PM_{2.5}$ and $PM_{10}$ and there are also two low volume filter based collocated $PM_{10}$ monitors operated at the site on a 1 in 3 day and 1 in 6 day sample schedule.

**Grand Junction - Pitkin, 645¼ Pitkin Avenue (08 077 0018):**

Meteorological monitors were installed in 2004, and include wind speed, wind direction, and temperature sensors. The meteorological tower was outfitted January 5th, 2015 with RM Young meteorological sensors, including a RH sensor. This site is also part of the National Air Toxics Trends Station Network. This network is a national EPA project to assess levels of urban air toxics around the country.

**Palisade Water Treatment, Rapid Creek Rd (08 077 0020):**

The Palisade site is located at the Palisade Water Treatment Plant. The site is 4 km to the east-northeast of downtown Palisade, just into the De Beque Canyon area. The site is remote from any significant population and was established to measure maximum concentrations of $O_3$ that may result from summertime up-flow conditions into a topographical trap. Ozone and meteorological monitoring commenced in May 2008. This is an urban scale special purpose monitor.

**Cortez, 106 W. North St (08 083 0006):**

The Cortez site is located in downtown Cortez at the Montezuma County Health Department building. Cortez is the largest population center in Montezuma County in the southwest corner of Colorado.

The $O_3$ monitor was established to address community concerns of possible high $O_3$ from oil and gas and power plant emissions in the area. Many of these sources are in New Mexico. Ozone monitoring commenced in May 2008 and the first $PM_{2.5}$ filter was sampled June 20th, 2008. $PM_{2.5}$ monitoring was discontinued at the site in July of 2015 due to the site completing sampling requirements and the site returning low $PM_{2.5}$ concentrations. This site is an urban scale SLAMS monitor.

**Aspen Yellow Brick School, 215 North Garmisch (08 097 0008):**

Aspen is at the upper end of a steep mountain valley. Aspen does not have an interstate highway running through it. Aspen was classified as nonattainment for $PM_{10}$, but it is now under an attainment/maintenance plan. The valley is more restricted at the lower end, and thus forms a tighter trap for pollutants. The transient population due to winter skiing and summer mountain activities greatly increases the population and traffic during these seasons. There is also a large down valley population that commutes to work each day from as far away as the Glenwood Springs area, which is 41 miles to the northeast. Aspen currently has a high volume filter based $PM_{10}$ monitor operated by the CDPHE-APCD, and a continuous $PM_{10}$/$PM_{2.5}$ GRIMM EDM 180 monitor operated by Pitkin County.

The population oriented neighborhood scale SLAMS high volume $PM_{10}$ monitor is operating on a 1 in 3 sample schedule.

**Lamar Municipal Building, 104 Parmenter Street (08 099 0002):**

The Lamar Municipal site was established in January of 1996 as a more population oriented location than the Power Plant. The Power Plant site was located on the northern edge of town (until it was decommissioned in 2012) while the Municipal site is near the center of the town. Both sites have recorded exceedances of the 24-hour standard of 150 $\mu g/m^3$, and both sites regularly record values above 100$\mu g/m^3$ as a 24-hour average. The Power Station site in Lamar has been shut down, because it did not meet siting criteria. The Lamar Municipal Building location houses population oriented neighborhood scale SLAMS high-volume $PM_{10}$ monitors on a daily sample schedule.

**Pueblo Fountain School, 925 N. Glendale Ave (08 101 0015):**

Pueblo is the third largest city in the state, not counting communities that are part of Metropolitan Denver. Pueblo is principally characterized by rolling plains and moderate slopes with elevations ranging from 4,474 feet to 4,814 feet (1,364 to 1,467 m). The Rocky Mountain Front Range is about 25 miles (40 km) west and the sight of Pikes Peak is easily visible on a clear day.

Meteorologically, Pueblo can be described as having mild weather with an average of about 300 days of sunshine per year. Generally, wind blows up valley from the southeast during the day and down valley from the west at night. Pueblo experiences average wind speed ranges from 7 miles per hour in the fall and early winter to 11 miles per hour in the spring.

This site was formerly located on the roof of the Public Works Building at 211 E. D St., in a relatively flat area found two blocks northeast of the Arkansas River. At the end of June in 2011 the Public Works site was shut down and moved to the Magnet School site as the construction of a new multi-story building caused a major change in the flow dynamics of the site. The new site began operations in 2011. The distance and traffic estimate for the surrounding streets falls into the middle scale in accordance with federal guidelines found in 40 CFR, Part 58, and Appendix D.

**Steamboat Springs, 136 6th Street (08 107 0003):**

Like other ski towns, Steamboat Springs has problems with wintertime inversions, high traffic density, wood smoke, and street sand. These problems are exacerbated by temperature inversions that trap the pollution in the valleys.

The first site began operation in Steamboat Springs in June 1985 at 929 Lincoln Avenue. It was moved to the current location in October 1986. The 136 6th Street location not only provides a good indication of population exposure, since it is more centrally located, but it has better accessibility than the previous location. This site monitors for $PM_{10}$ with high volume filter based sampling. This is a population oriented neighborhood scale SLAMS monitor on a daily sample schedule.

**Telluride, 333 W. Colorado Avenue (08 117 0002):**

Telluride is a high mountain ski town in a narrow box end valley. The San Miguel River runs through the south end of town, which is only about ½ mile wide from north to south. The topography of this mountain valley regime creates temperature inversions that can last for several days during the winter. Temperature inversions can trap air pollution close to the ground. Telluride sits in a valley that trends mainly east to west, which can trap air pollutants more effectively since the prevailing winds in this latitude are westerly and the San Miguel River Valley is closed off on the east end. This is a population oriented neighborhood scale SLAMS monitor on a 1 in 3 day sample schedule.

**Greeley Hospital, 1516 Hospital Road (08 123 0006):**

The Greeley $PM_{10}$ and $PM_{2.5}$ continuous monitor is located on the roof of a hospital office building at 1516 Hospital Road. In the summer of 2016 the filter Based FRM was removed from the site and the GRIMM EDM 180 continuous particulate monitor was designated as the primary monitor for $PM_{2.5}$ NAAQS comparisons. On January 1st, 2019, the APCD discontinued Hi-Vol PM10 sampling leaving only a continuous GRIMM EDM 180 that measures $PM_{10}$ and $PM_{2.5}$ at the site. This is a population-oriented neighborhood scale SLAMS site. Greeley Central High School is located immediately to the east of the monitoring site. Overall, this is in an area of mixed residential and commercial development that makes it a good population-exposure, neighborhood scale monitor. The distance and traffic estimate for the most controlling street easily falls into the neighborhood scale in accordance with federal guidelines found in 40 CFR, Part 58.

Winds in this area are primarily out of the northwest, with dominant wind speeds less than 5 mph. Secondary winds are from the north, north-northwest and east-southeast, with the most frequent wind speeds also being less than 5 mph. The most recent available wind data for this station is for the period December 1986 to November 1987. Predominant residential growth patterns are to the west and north with large industrial growth expected to the west. There are two feedlots located about 11 miles east of the town. There was a closer feedlot on the east edge of town, but it was shut down in early 1999, after the town of Greeley purchased the land in 1997.

**Platteville, 1004 Main Street (08 123 0008):**

Platteville is located immediately west of Highway 85 along the Platte River valley bottom approximately five miles east of I-25, at an elevation of 4,825 feet. The area is characterized by relatively flat terrain and is located about one mile east of the South Platte. The National Oceanic and Atmospheric Administration operated the Prototype Regional Observational Forecasting System Mesonet network of meteorological monitors from the early 1990s through the mid-1990s in the northern Colorado Front Range area. Based on this data, the area around Platteville is one of the last places in the wintertime that the cold pool of air that is formed by temperature inversions will burn off. This is due to solar heating. The upslope/down slope Platte River Valley drainage and wind flows between Denver and Greeley make Platteville a good place to monitor $PM_{2.5}$. These characteristics also make it an ideal location for chemical speciation sampling, which began at the end of 2001 and is currently still monitoring.

The Platteville site is located at 1004 Main Street at the South Valley Middle School, located on the south side of town on Main Street. The school is a one-story building and it has a roof hatch from a locked interior room providing easy access to its large flat roof. There is a 2-story gym attached to the building approximately 28 meters to the Northwest of the monitor. The location of the Platteville monitor falls into the regional transport scale in accordance with federal guidelines found in 40 CFR, Part 58, and Appendix D. There are three monitors here. Two are population-oriented regional scale monitors, one of which is on the SLAMS network and the other is for supplemental speciation. The $PM_{2.5}$ filter based FRM SLAMS monitor is operating on a 1 in 3 day sample schedule, while the speciation monitor is operating on a 1 in 6 day schedule. The remaining monitor is a population oriented neighborhood scale supplemental speciation monitor on a 1 in 6 day sample schedule.

**Greeley, Weld County Tower, 3101 35th Avenue (08 123 0009):**

The Weld County Tower $O_3$ monitor began operation in June 2002. The site was established after the 811 15th Street building was sold and was scheduled for conversion to other uses. The Weld County Tower site has generally recorded levels greater than the old site. This is a population-oriented neighborhood scale SLAMS monitor. The Greeley West Annex carbon monoxide monitoring site was dismantled in June of 2015 and moved to the Weld County Tower site. Carbon Monoxide monitoring began at the Weld County Tower site in April of 2015 with a Thermo 48C monitor. The CO monitor at Weld County Tower was upgraded from a Thermo 48C to a Thermo 48iTLE trace level analyzer on April 28th, 2016.

Meteorological monitoring began in February of 2012.

# Appendix B - Public Comments and Responses

This appendix includes information regarding the required public comment period, comments received and APCD responses.

Per 40 CFR 58.10, a 30-day public comment period is required before submitting the Network Assessment to EPA. APCD posted notice of this Network Assessment on May 22, 2020 on the APCD website at: https://www.colorado.gov/pacific/cdphe/air-division-public-comment and https://www.colorado.gov/airquality/tech_doc_repository.aspx. The public comment period was open through June 22, 2020. Notification was also sent out to interested parties, including the Air Quality Control Commission, the Regional Air Quality Council and the Pikes Peak Area Council of Governments, and was sent out to CDPHE listserves. Copies of the notifications are presented below.

The APCD did not receive any comments on the Network Assessment. However, one comment was received for the Annual Network Plan during the public comment period. The APCD appreciates the time and effort that the commenter took to develop their comment. The comment is presented below the notifications, along with the APCD’s response.

## May 22, 2020 Public Comment Notice Posting and Email:



STATE OF COLORADO

**Pierce - CDPHE, Gordon <gordon.pierce@state.co.us>**

### Website update request

2 messages

**Pierce - CDPHE, Gordon** <gordon.pierce@state.co.us> Fri, May 22, 2020 at 1:02 PM
To: APCD Websters <apcd_websters@state.co.us>

We have posted a couple of documents for public comment and would like them linked on the APCD "Public Comment Opportunities" page.

1. A screenshot of the web page that needs to be changed.


2. The URL
   https://www.colorado.gov/pacific/cdphe/air-division-public-comment
3. Exact wording for the change and which part of the web page needs to be changed
   Add 2 new bullets:

   - 2020 Annual Network Monitoring Plan (comments due by 6/22/2020) https://www.colorado.gov/airquality/tech_doc_repository.aspx#network_plan
   - 2020 5-Year Monitoring Network Assessment (comments due by 6/22/2020) https://www.colorado.gov/airquality/tech_doc_repository.aspx#5yr_assess

4. PDFs attached that need to be uploaded
   none
5. Date the change is needed by.
   As soon as possible.

If possible, I would also like the following to be sent out to the permitting actions listserv:

> Pursuant to EPA requirements, the APCD has posted the following documents for a 30-day public comment period, which will end on 6/22/2020:
>
> - 2020 Annual Network Monitoring Plan
> - 2020 5-Year Monitoring Network Assessment
>
> These documents can be found on the Technical Services webpage at: https://www.colorado.gov/airquality/tech_doc_repository.aspx. Final documents will be submitted to the EPA by 7/1/2020. Please send comments to cdphe.commentsapcd@state.co.us.

Thanks,
Gordon

--

Gordon Pierce
Program Manager
Technical Services Program

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

4300 Cherry Creek Drive South, Denver, CO 80246-1530
P 303.692.3238 | F 303.782.5493
gordon.pierce@state.co.us | www.colorado.gov/cdphe/apcd

Are you curious about ground-level ozone in Colorado? Visit our ozone webpage to learn more.

---

**Lazalde - CDPHE, Angel** <angel.lazalde@state.co.us> Fri, May 22, 2020 at 1:20 PM
To: "Pierce - CDPHE, Gordon" <gordon.pierce@state.co.us>
Cc: APCD Websters <apcd_websters@state.co.us>

I am working on this now and will send you an email when I am done.

Angel Lazalde
Program Assistant

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Air Pollution Control Division | Stationary Sources
Telephone: 303.692.3593 | Email: angel.lazalde@state.co.us

**Questions on Air Pollution Control Division operations during COVID-19 response? Visit our FAQ Page.**

[Quoted text hidden]

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**Lazalde - CDPHE, Angel** <angel.lazalde@state.co.us> Fri, May 22, 2020 at 1:40 PM
To: "Pierce - CDPHE, Gordon" <gordon.pierce@state.co.us>

Hi, Gordon,

The webpage has been updated and listserv sent.

Have a great weekend!

Angel Lazalde
Program Assistant

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Air Pollution Control Division | Stationary Sources
Telephone: 303.692.3593 | Email: angel.lazalde@state.co.us

**Questions on Air Pollution Control Division operations during COVID-19 response? Visit our FAQ Page.**

[Quoted text hidden]

STATE OF COLORADO

Pierce - CDPHE, Gordon <gordon.pierce@state.co.us>

## 2020 Network Plan and Network Assessment

1 message

**Pierce - CDPHE, Gordon** <gordon.pierce@state.co.us> Fri, May 22, 2020 at 1:55 PM
To: Gordon Pierce - CDPHE <gordon.pierce@state.co.us>
Bcc: Garry Kaufman <garrison.kaufman@state.co.us>, Mark Mcmillan <mark.mcmillan@state.co.us>, Cindy Copeland <ccopeland@bouldercounty.org>, Cassie Archuleta <carchuleta@fcgov.com>, Gregg Thomas <Gregg.Thomas@denvergov.org>, Brian Hlavacek <bhlavacek@tchd.org>, Richard Payton <Payton.Richard@epa.gov>, Bruce Barker <bbarker@weldgov.com>, "Fallon, Gail" <fallon.gail@epa.gov>, Amanda Brimmer <abrimmer@raqc.org>, Samantha Bailey <sbailey@ppacg.org>

All:

Pursuant to EPA requirements, the APCD has posted the following documents for a 30-day public comment period, which will end on 6/22/2020:

- 2020 Annual Network Monitoring Plan
- 2020 5-Year Monitoring Network Assessment

These documents can be found on the Technical Services webpage at: https://www.colorado.gov/airquality/tech_doc_repository.aspx. Final documents will be submitted to the EPA by 7/1/2020. Please send comments to cdphe.commentsapcd@state.co.us.

--

**Gordon Pierce**
**Program Manager**
Technical Services Program

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

4300 Cherry Creek Drive South, Denver, CO 80246-1530
P 303.692.3238 | F 303.782.5493
gordon.pierce@state.co.us | www.colorado.gov/cdphe/apcd

Are you curious about ground-level ozone in Colorado? Visit our ozone webpage to learn more.

## **Public Comments Received and APCD Responses:**

### **Comment #1:**



STATE OF COLORADO

**Pierce - CDPHE, Gordon <gordon.pierce@state.co.us>**

**Fwd: Comments on Colorado 2020 Annual Network Monitoring Plan and 2020 5-year monitoring network assessment**

**Comments - CDPHE, APCD** <cdphe.commentsapcd@state.co.us> Tue, Jun 23, 2020 at 7:52 AM
To: Gordon Pierce - CDPHE <gordon.pierce@state.co.us>

Hi,
See the email below.

**Regulatory Compliance and Support Unit**
**Planning and Policy Program**

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

P 303.692.3100 | F 303.782.0278
4300 Cherry Creek Drive South, Denver, CO 80246-1530
cdphe.commentsapcd@state.co.us

**Are you curious about ground-level ozone in Colorado? Visit our ozone webpage to learn more.**

---------- Forwarded message ---------
From: **Robert Ukeiley** <RUkeiley@biologicaldiversity.org>
Date: Mon, Jun 22, 2020 at 4:21 PM
Subject: Comments on Colorado 2020 Annual Network Monitoring Plan and 2020 5-year monitoring network assessment
To: cdphe.commentsapcd@state.co.us <cdphe.commentsapcd@state.co.us>
Cc: Morales.Monica@epa.gov <Morales.Monica@epa.gov>, fallon.gail@epa.gov <fallon.gail@epa.gov>

Attached, please find comments requesting the Colorado Air Pollution Control Division add an additional ozone monitor to the foothills of Boulder County.

If you have any questions, please do not hesitate to ask.

Robert Ukeiley

Senior Attorney – Environmental Health

Center for Biological Diversity

1536 Wynkoop St., Ste. 421

Denver, CO 80202

(720) 496-8568

rukeiley@biologicaldiversity.org

CENTER for BIOLOGICAL DIVERSITY Because life is good

VIA EMAIL
cdphe.commentsapcd@state.co.us

June 22, 2020

Colorado Air Pollution Control Division

RE: 2020 Annual Network Monitoring Plan
2020 5-Year Monitoring Network Assessment

To whom it may concern:

On behalf of the Center for Biological Diversity and our thousands of members and supporters who are adversely impacted by air pollution in Colorado, I am writing to submit comments on the 2020 Annual Network Monitoring Plan and the 2020 5-Year Monitoring Network Assessment. We are requesting that an additional ozone monitor be added to the foothills of Boulder county.

In Oltmans, SJ, *et al.* 2019. Boundary layer ozone in the Northern Colorado Front Range in July–August 2014 during FRAPPE and DISCOVER-AQ from vertical profile measurements. Elem Sci Anth, 7: 6. DOI: https://doi.org/10.1525/elementa.345, attached, an esteemed group of researchers, mostly from Colorado, used several vertical profile observing platforms to monitor ozone. *Id.* at 2. The researchers determined that:

> The association of high O3 days at the BAO [Boulder Atmospheric Observatory] tower with transport from sectors with intense oil and natural gas production toward the northeast suggests emissions from this industry were an important source of O3 precursors and are crucial in producing peak O3 events in the NCFR [Northern Colorado Front Range]. Higher elevation locations to the west of the NCFR plains regularly experience higher O3 values than those in the lower elevation NCFR locations. Exposure of populations in these areas is **not captured by the current regulatory network**, and likely underestimated in population O3 exposure assessments.

*Id.* at 1, emphasis added.

In Brodin, M., et al., 2010. Seasonal ozone behavior along an elevation gradient in the Colorado Front Range Mountains, Atmospheric Environment 44 (2010) 5305 -

5315, attached, “Ambient surface ozone was monitored for one year at seven sites along an elevation gradient from 1600 m to 3500 m above sea level (ASL) in Boulder County”. *Id.* at 5305. This paper found that the majority, but not all, studies have found that average concentrations of ozone increase with elevation. *Id.* The study found that during what APCD considers the ozone “season”, that is late April through early September, the highest ozone levels were observed at the middle elevations, that is Betasso, (1943 meters above sea level (m ASL)), Sugarloaf (2399 m ASL), Coughlin (2539 m ASL) and Niwot Ridge (3021 m ASL). *Id.* at 5311. See also Table 3 at 5314. These monitors with worse ozone were all above the City of Boulder monitor which was at 1608 m ASL. The current APCD monitor at Boulder Reservoir is at a similar elevation to the City of Boulder monitor in this study.

Thus, APCD should add an ozone monitor at a site above 1900 m ASL in Boulder County. We would suggest using one of the sites in the Brodin study, that is at Betasso Boulder County Open Space Park, the Sugarloaf fire state or Caughlin meadows. It should be relatively easy for APCD to obtain permission for a suitable site at these locations.

These areas, in addition to being residential neighborhoods, see significant high effort recreational use. Also, the studies indicate that these areas see differences in the times of day when ozone levels are highest. This is important information to protect the health of people in engaged in exercise in these areas. For example, a biker may think it is safe to bike in the morning or evening based on ozone levels at Boulder Reservoir even though that may not be true.

We are not suggesting, however, that APCD should remove the Boulder Reservoir site. As that site is co-located with excellent long term VOC collection, it has significant value.

We appreciate the installation of the Black Hawk ozone monitor and the plan to move a monitor to Evergreen. However, those monitors do not address our concerns.

First, we are not aware of any peer-reviewed literature showing those locations as having worse ozone levels than the locations of the current monitors. For example, the Oltmans paper focused on the area “from Boulder to Ft. Collins and the area to the east.” Oltmans at 2. This area is north of Black Hawk and Evergreen. Second, the Black Hawk and Evergreen monitors are, or will be, south of Boulder County and thus further away from the major VOC emission sources in the DJ Basin in Weld County. Third, at least for Black Hawk, we are concerned the Black Hawk sits in a valley or depression. The Black Hawk monitor appears to be not be on a ridgetop and thus may not be adequately capturing the highest values.

Sincerely,

s/ Robert Ukeiley

Robert Ukeiley
Senior Attorney – Environmental Health
Center for Biological Diversity
1536 Wynkoop St., Ste. 421
Denver, CO 80202
rukeiley@biologicaldiversity.org
(720) 496-8568

**APCD Responses to Comment #1:**

1. The APCD agrees that high ozone levels can, and do occur in the foothills along the Colorado Front Range and that additional monitoring is desired. As pointed out, this has been seen during the 2014 FRAPPE study, and has also been seen by the APCD during a plains-to-divide ozone study during the summer of 2016. This APCD study, as well as other passive monitoring studies and meteorological evaluations in the past, has led to the establishment of the existing Black Hawk site and the proposal of the Evergreen site.

   For the lower foothills west of Boulder, there is no specific ozone monitoring in place at this time. However, there is nearby monitoring that can be utilized. First, data from the National Park Service "Rocky Mountain" ozone site, located just to the north of Boulder County are available hourly at https://www.nps.gov/subjects/air/current-data.htm?site=romo. Second, the National Oceanographic and Atmospheric Administration operates an ozone site at Niwot Ridge, to the north-northwest of Nederland. While these data are not available to the public in real-time, the site does provide a long-term view of ozone in the higher elevation area. Both of these sites are over 2700m in elevation.

   The APCD conducts targeted ozone studies every year, which are designed to evaluate ozone concentrations in areas where we have limited data, to determine areas where additional monitoring may be needed, and to provide information on more optimal monitoring locations. The 2016 study was one of these studies. The APCD feels that further foothills studies are need to identify optimal areas prior to simply installing a monitor based on locations from the 2014 FRAPPE study. We unfortunately do not have the resources to add long-term sites in every area. A northern Colorado study was under consideration for summer 2020, but was put on hold due to Coronavirus impacts and travel restrictions. Studies are being planned for summer 2021 in northern Colorado and foothills areas, which can include Boulder County.

2. The APCD would note that the Black Hawk monitor is not in a valley, but is on a ridge almost 200m higher than the town of Black Hawk.