COLORADO
Department of Public Health & Environment

Air Pollution Control Division

Technical Services Program

Quality Assurance Project Plan

Prepared by the Technical Services Program
Air Pollution Control Division
July 30th 2015

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1.0 FORWARD

The Environmental Protection Agency's (EPA) mission is to protect human health and to safeguard the natural environment — air, water, and land — upon which life depends. The EPA Quality Program provides a framework for ensuring that our products and services meet quality standards that are appropriate for their intended use. Quality Assurance Project Plans (QAPPs) are one component of the EPA Quality Program, and are required for all projects involving the collection, production, and use of environmental data. A QAPP is a formal document describing in comprehensive detail the necessary quality assurance (QA), quality control (QC), and other technical activities that will be implemented to ensure that the results of the work performed will satisfy the stated performance criteria. The QAPP provides a clear description of the activities of a project in the acquisition of environmental data or information from direct measurement activities, existing data, or generated by models.

The hierarchical relationship of EPA QA documents are as follows: ANSI/ASQ E4-2004 national consensus standard, together with the Information Quality Act of 2001 (IQG 2001), establish a basis for the Agency's Quality Policy; the Quality Procedure provides additional explanation about how to carry out the Policy; the *Quality Standard for Environmental Data Collection, Production, and Use by Non-EPA (External) Organizations*, CIO 2106-S-02 (EPA 2013b), the "External Standard," contains requirements for applying the Policy and Procedure to environmental data operations external to the Agency; *The Handbook for Developing Quality Assurance Project Plans*, CIO 2106-G-05 (EPA 2013c), offers guidelines, advice, and examples of the best way to develop QAPPs that will help users satisfy provisions of the Standards at the project level.

The previous revision of the Colorado Department of Public Health and Environment (CDPHE), Air Pollution Control Division (ACPD), Technical Services Program (TSP) QAPP was generated using the EPA QA regulations and guidance as described in EPA QA/R-5 *EPA Requirements for Quality Assurance Project Plans* and the accompanying document EPA QA/G-5 *Guidance for Quality Assurance Project Plans*. Both of these documents have been withdrawn by the EPA in favor of the new Standard CIO-2106-S-02.

The following document is the most current revision of the APCD QAPP for the ambient air monitoring program within Colorado's State and Local Air Monitoring Stations (SLAMS) program. This QAPP is organized in such a way as to document the "plan-do-check-act life cycle" of CDPHE APCD activities data of high quality and comparability. This document has been prepared by the CDPHE APCD TSP. Changes to the QAPP are expected to be made on a year-to-year basis as deemed necessary by the APCD or EPA. All revisions are to be approved by the EPA or by the Quality Assurance Manager of the CDPHE Environmental Programs or by an authorized representative as defined in the CDPHE environment programs Quality Management Plan (QMP) and the APCD QMP. The Quality Assurance Project Plan (QAPP) is an essential element in the APCD's ability to demonstrate the validity of the ambient air quality data collected by the agency. This QAPP provides specific details about all aspects of our data gathering activities.

Additional copies of this document may be obtained from:

Colorado Department of Public Health and Environment
Air Pollution Control Division
Technical Services Program
APCD-TS-B1
4300 Cherry Creek Drive South
Denver, CO 80246-1530
(303) 692-3100

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1.1 APPROVALS PAGE

The attached Quality Assurance Project Plan for Ambient Air Monitoring is hereby recommended by the quality assurance staff and program managers for approval and commits the Colorado Department of Public Health and Environment to the elements described within:

By: _____ Date: 7/30/2015

Gordon Pierce, Program Manager
Colorado Department of Public Health and Environment
Air Pollution Control Division – Technical Services Program

By: _____ Date: 7. 30. 2015

Pat McGraw, Particulate Monitoring Supervisor
Colorado Department of Public Health and Environment
Air Pollution Control Division – Technical Services Program

By: _____ Date: 7-30-15

Greg Harshfield, Gaseous and Meteorological Monitoring Supervisor
Colorado Department of Public Health and Environment
Air Pollution Control Division – Technical Services Program

As delegated under the Air Pollution Control Division's Quality Management Plan (EPA approved – October 2006), the attached Quality Assurance Project Plan for Ambient Air Monitoring is hereby approved by the Air Pollution Control Division's Quality Assurance Officer and commits the Colorado Department of Public Health and Environment to the elements described within:

By: _____ Date: 7/30/15

Cindy Wike, Quality Assurance Officer and Quality Assurance Unit Supervisor
Colorado Department of Public Health and Environment
Air Pollution Control Division – Technical Services Program

The attached Quality Assurance Project Plan for Ambient Air Monitoring is hereby endorsed by the Air Pollution Control Division's Director and commits the Colorado Department of Public Health and Environment to the elements descried within.

By: _____ Date : 30 July 2015

William Allison, Director
Colorado Department of Public Health and Environment
Air Pollution Control Division

USEPA, Region VIII:
Copies of the attached Quality Assurance Project Plan for Ambient Air Monitoring are to be distributed to the following persons at USEPS – Region VIII. Comments by EPA regarding oversights incurred during this revision of this QAPP are welcomed, and corrections will be incorporated in subsequent QAPP revisions.

Carl Daly – Director, Air and Radiation Program
Deirdre Rothery – Air Permitting, Monitoring and Modeling Unit
Richard Payton – State Air Monitoring Contact, Air and Radiation Program

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CDPHE Laboratory Services Division:

Appendix LSD1 LSD Quality Assurance Manual (QAM) (unsigned copy)
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Air Resource Specialists, Inc,:

App. ARS1 SOP for QUARTERLY MAINTENANCE TO AN AMBIENT AIR MONITORING STATION, 01/2012
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App. ARS14 SOP for CALIBRATION AND ROUTINE MAINTENANCE OF API MODEL 400 SERIES OZONE ANALYZERS, 04/2012
App. ARS15 SOP for CALIBRATION AND ROUTINE MAINTENANCE OF R.M. YOUNG MODEL 05305 WIND MONITOR-AQ WIND SPEED AND DIRECTION SENSOR SYSTEMS, 11/2012
App. ARS16 SOP for CALIBRATION AND ROUTINE MAINTENANCE OF R.M. YOUNG TEMPERATURE/DELTA TEMPERATURE SYSTEMS, 06/2012
App. ARS17 SOP for CALIBRATION OF ESC 8816 OR 8832 ANALOG INPUT CARD, 04/2012
App. ARS18 SOP for FIELD CALIBRATION AND ROUTINE MAINTENANCE OF KIPP & ZONEN SOLAR RADIATION SENSORS, 10/2012
App. ARS19 SOP for COLLECTION OF AMBIENT AIR QUALITY AND METEOROLOGICAL DATA AND SITE DOCUMENTATION, 10/2013
App. ARS20 SOP for AMBIENT AIR QUALITY AND METEOROLOGICAL MONITORING DATA VALIDATION

Inter-Mountain Labs:

Appendix IML1 IML QAPP for Laboratory and Data Management Support of the Determination of Fine Particulate Matter as $PM_{2.5}$ and Coarse Particulate Matter as $PM_{10-2.5}$ in the Atmosphere, 01/21/13

Other Associated Documents (not included as appendices):

Quality Assurance Project Plan for the National Air Toxics Trends Study (NATTS) in Grand Junction, by CDPHE/APCD/TSP, (Draft, final revision expected August 2015)

Quality Assurance Guidance Document: Quality Assurance Project Plan: $PM_{2.5}$ Chemical Speciation Sampling at Trends, NCore, Supplemental and Tribal Sites (An Update to the $PM_{2.5}$ Speciation Trends Network Field Sampling QAPP, December 2000), June 2012, can be found at:
http://www.epa.gov/ttnamti1/files/ambient/pm25/spec/CSN_QAPP_v120_05-2012.pdf

1.2 DISTRIBUTION LIST

Table 1.1 Distribution List

NAME	POSITION	DIVISION/BRANCH
Colorado Department of Public Health and Environment		
Will Allison	Division Director	Air Pollution Control Division
Gordon Pierce	Program Manager	APCD, Technical Services Program
Gregory Harshfield	Gaseous & Meteorological Monitoring Supervisor	APCD, TSP, Gaseous and Meteorological Monitoring Unit
Patrick McGraw	Particulate Monitoring Supervisor	APCD, TSP, Particulate Monitoring Unit
Cindy Wike	Quality Assurance Supervisor / QA Officer	APCD, TSP, Quality Assurance Unit
CDPHE: Environmental Quality Management Plan Coordinators		
Andrew Putnam	Environmental Information Manager	CDPHE Environmental Information Unit
Eric Brown	Environmental Data Specialist	CDPHE Environmental Information Unit
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY – REGION VIII		
Carl Daly		
Deirdre Rothery		
Richard Payton		

Additional copies of the QAPP are available upon request at the APCD main offices located at:
4300 Cherry Creek Drive South B1
Denver, CO 80246-1530

Acknowledgements:

Development of the APCD Quality Assurance Project Plan was a cooperative effort of a large group of Technical Services Program staff. Significant sections of the current document were written by Bonnie Wright, Pat McGraw, Gordon Pierce, Gregory Harshfield, Bradley Rink, Erick Mattson, Cindy Wike, Alicia Frazier, Vincent Stucker, Bill Kotasek, Phillip Stauffer, Nancy Chick, Ken Heald, Monet Ramirez, Clyde Sharp, Brett Harkwell, Ken Helcoski, Jeff Gawrych, John Olasin, Will Vicars, Frank Martelli, Mike Kannely, and Terry Furuli. Many other program staff contributed editorial reviews of the final document.

2.0 PROJECT MANAGEMENT (PLAN)

2.1 PROJECT ORGANIZATION AND SCHEDULE

2.1.1 ROLES AND RESPONSIBILITIES

Federal, state, tribal and local agencies all have important roles in developing and implementing satisfactory air monitoring programs. As part of the planning effort, EPA is responsible for developing National Ambient Air Quality Standards (NAAQS), defining the quality of the data necessary to make comparisons to the NAAQS, and identifying a minimum set of QC samples from which to judge data quality. The state and local organizations are responsible for taking this information and developing and implementing a quality system that will meet the data quality requirements. Then it is the responsibility of both EPA and the state and local organizations to assess the quality of the data and take corrective action when appropriate. The responsibilities of the APCD are provided in the following subsection:

2.1.1.1 Colorado Department of Public Health and Environment

40 CFR Part 58 defines a State Agency as "the air pollution control agency primarily responsible for the development and implementation of a State Implementation Plan (SIP) under the Clean Air Act (CAA)". Under Title III, General Provisions sections 302 and 319 of the CAA and 42 U.S. Codes 7602 and 7619 provide more detailed descriptions of an air pollution agency and air quality monitoring.

40 CFR Part 58 defines the Local Agency as "any local government agency, other than the state agency, which is charged with the responsibility for carrying out a portion of the plan (SIP)". A major responsibility of State and local agencies is the implementation of a satisfactory monitoring program, which would include the implementation of an appropriate Quality Assurance (QA) program. It is the responsibility of the APCD to implement QA programs in all phases of the environmental data operation (EDO), including the field, its own laboratories, and in any consulting and contractor laboratories which they may use to obtain data. An EDO is defined as work performed to obtain, use, or report information pertaining to environmental processes or conditions.

The APCD is separated into three (3) programs of approximate equal responsibility: the Stationary Sources Program, the Mobile Sources Program and the Technical Services Program. Figure 2.1 provides detailed information about the organizational structure of the Technical Services Program, which is the group solely responsible for the APCD ambient air quality monitoring data. Figure 2.2 shows the APCD organizational structure. Figure 2.3 provides the organizational structure of the CDPHE. Subsection 2.1.1.1.c provides a description of key QA personnel in the APCD and Technical Services Program and their QA-related responsibilities.

The APCD ambient air sampling network is operated and maintained by a staff of technicians and scientific professionals who serve as the first line of quality control. These operators are either part of the APCD Technical Services Program (TSP) or part of a local environmental agency. Technicians in TSP conduct monitoring site inspections, perform instrument control checks, and perform regular maintenance and repairs on monitors operated by the APCD. These regularly scheduled monitoring site visits provide the operational support, which is the first level of quality control in the APCD air monitoring program.

Quality control activities such as instrument calibrations, operational assessments, troubleshooting and maintenance are performed on the gaseous analyzers by the Gaseous and Meteorological Monitoring (GMM) Unit and on the particulate samplers by the Particulate Monitoring (PM) Unit. Assessment of the validity of the air quality data collected by the APCD monitoring network occurs at several levels in the Technical Services Program and is described further in Section C of this document.

Quality assurance activities such as technical system audits, accuracy audits, precision test reviews, investigation and resolution of operational problems through corrective action procedures, and submittal of precision and accuracy data to EPA are conducted by the Visibility Research and Quality Assurance Unit. Gravimetric laboratory work, as well as Lead, metals, and speciation analyses are subcontracted to various laboratories based on the type of work being performed and each laboratory's capabilities.

APCD management recognizes that a thoroughly trained staff is essential to the success of any air quality monitoring agency. Section 2.4 of the QAPP provides detailed information about the ongoing training activities conducted by the APCD.

Figure 2.1 Technical Services Program Organizational Chart

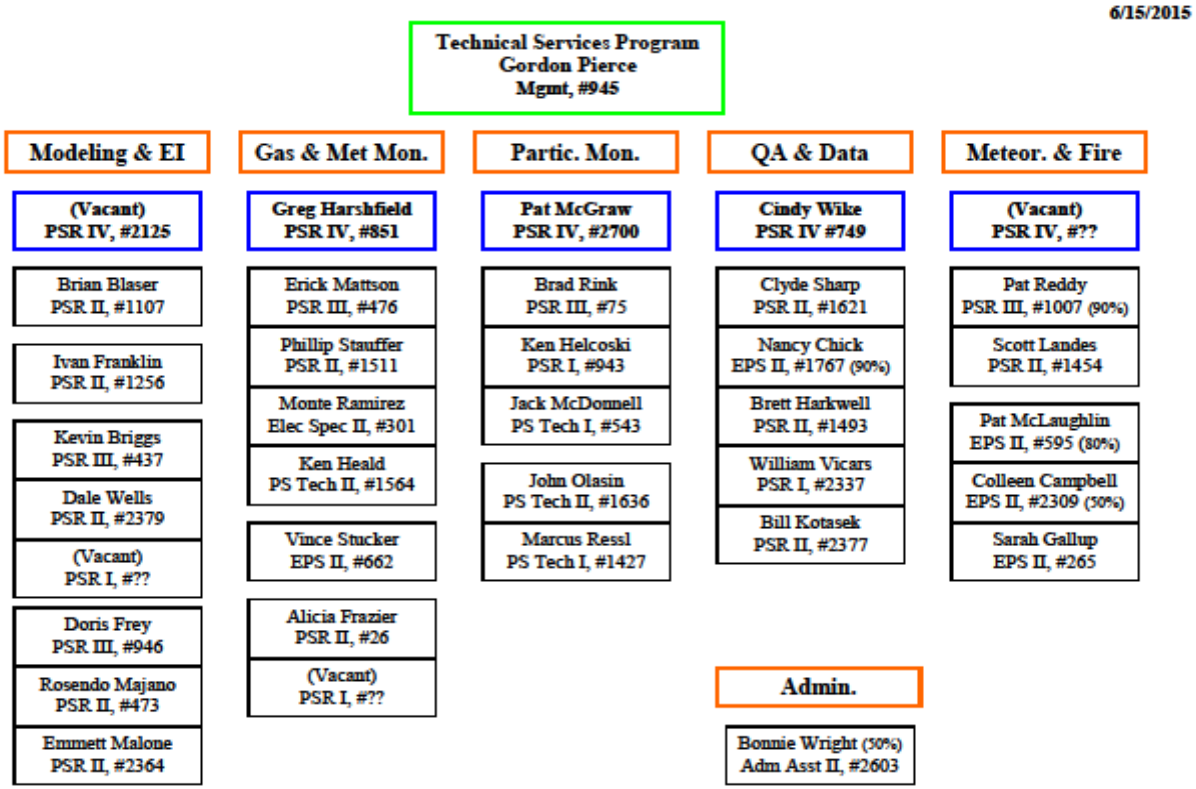


Figure 2.2 Air Pollution Control Division Organizational Chart

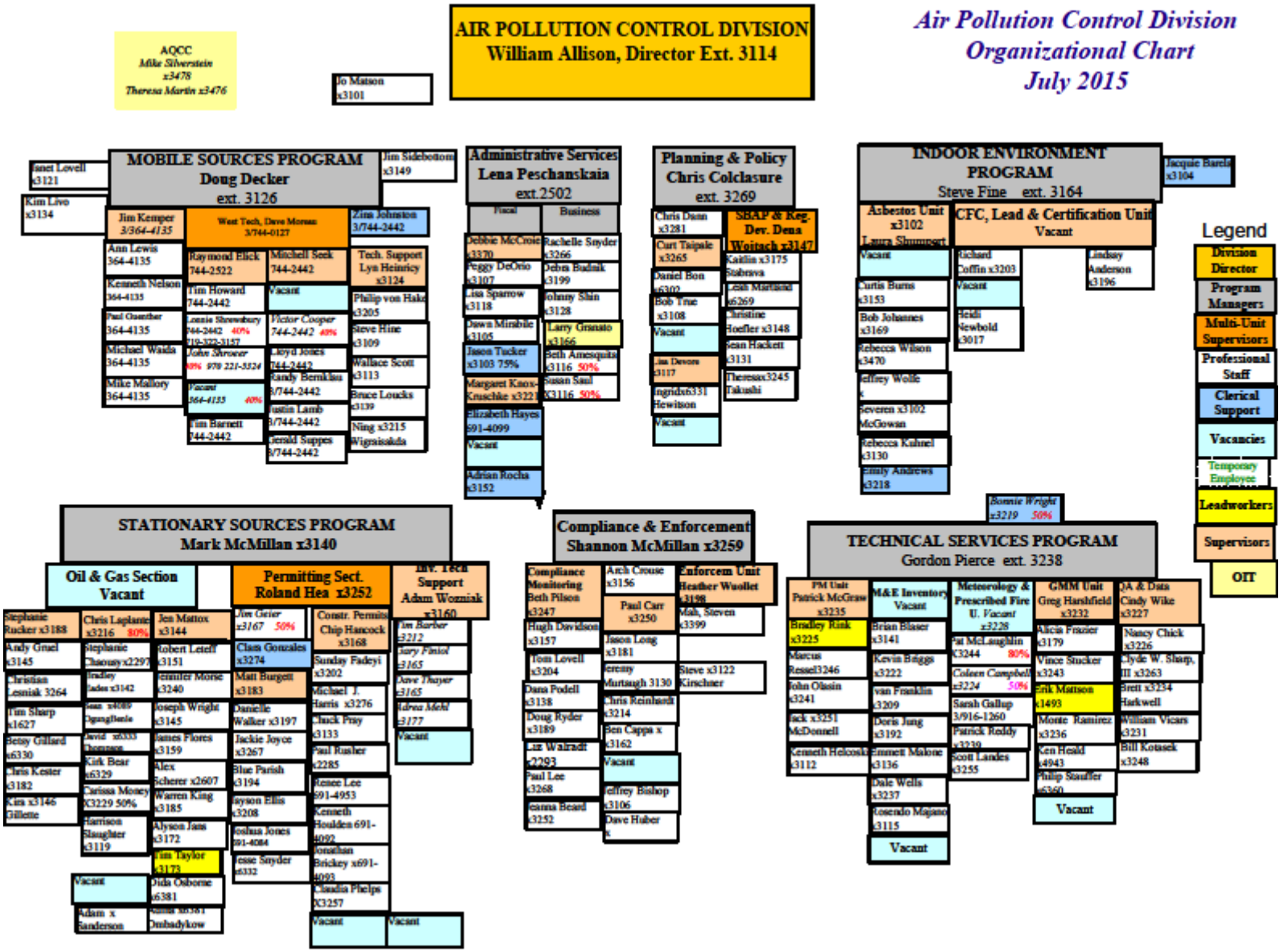
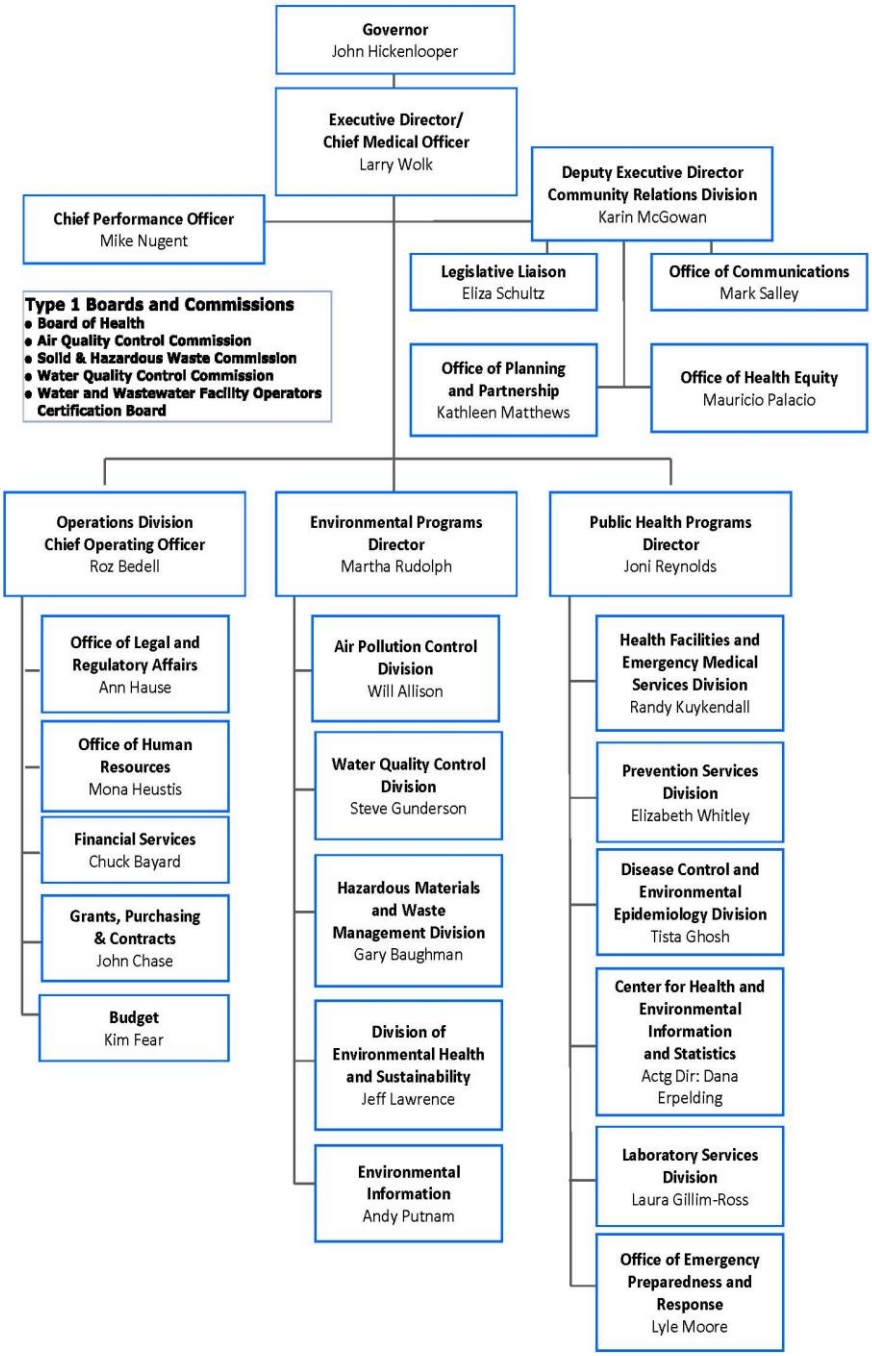


Figure 2.3 CDPHE Organizational Chart



2.1.1.1.a Air Pollution Control Division, Director's Office

Division Director – William C. Allison

The Director has overall responsibility for managing the Air Pollution Control Division according to Department policy and holds the direct responsibility for assuring data quality rests with management. Ultimately, the Director is responsible for establishing QA policy and for resolving QA issues identified through the QA program. Major QA related responsibilities of the Director include:

- Approve the budget and planning processes to ensure adequate financial and human resources are made available to accomplish departmental and division goals
- Ensures that the Department develops and maintains a current QAPP and ensures adherence to the document by staff,
- Maintains an active line of communication with the QA Officer, program managers and technical supervisors,
- Conducts management systems reviews.

In accordance with Department policy the Director delegates the responsibility of the QA program development and implementation to the Program Manager. The Program Manager has delegated the responsibility of the QA program development and implementation to the Quality Assurance Officer.

2.1.1.1.b Technical Services Program (TSP)

TSP Program Manager – Gordon Pierce

The Technical Services Program Manager's major QA related responsibilities include:

- Ensures the QMP, QAPPs, and SOPs are correctly developed and kept current through revisions,
- Ensures adherence to the QAPP by all staff involved in ambient monitoring,
- Budget and planning process development that ensures QA objectives are met,
- Ensures staff receive appropriate training,

Gaseous and Meteorological Monitoring Supervisor – Gregory Harshfield

The Gaseous and Meteorological Monitoring (GMM) Supervisor has the responsibility of assuring that the continuous monitoring network is maintained, that ambient air monitoring data are available on the Environmental Protection Agency's database, and that data are provided to other individuals or organizations, as needed. Specific QA responsibilities include:

- Ensures that the gaseous air monitoring network is maintained,
- Ensures that quarterly calibrations are performed on the gaseous monitoring network,
- Ensures that the meteorological network is maintained,
- Ensures that semi-annual calibrations are performed on the meteorological network,
- Ensures that calibration equipment standards are maintained,
- Coordinates all field activities related to the gaseous and meteorological monitoring networks,
- Coordinates modifications to the gaseous and meteorological monitoring networks,
- Implements and coordinates special monitoring studies with local agencies,
- Ensures that all gaseous and meteorological air monitoring data are uploaded to EPA's database,
- Ensures that the continuous monitoring data acquisition system is maintained,
- Ensures that the proper QC protocols are being performed
- Coordinates reviews of air monitoring data,
- Responds to data requests from internal and external sources,
- Provides technical support to other government agencies, industry, citizen groups, special interest groups, and the public,
- Provides oversight of the central polling data systems
- Interprets and implements Federal rules, and guidance related to gaseous, meteorological, amd toxics air quality monitoring,
- Performs scientific data analyses and reviews,

- Interprets monitoring results,
- Responds to data requests,
- Develops, tracks, plans and coordinates budget.

Particulate Monitoring Supervisor – Pat McGraw

The Particulate Monitoring Unit Coordinator has the main responsibility of assuring the sampling network is maintained, laboratory/field logistics are being coordinated properly and ensures sampler maintenance and site installation are being conducted as necessary. The Particulate Monitoring Unit Coordinator QA responsibilities include:

- Coordinates the overall implementation and modification of the particulate monitoring network,
- Coordinates the installation and maintenance of particulate monitoring sites,
- Ensures that the annual multi-point sampler flow rate, temperature and pressure calibrations are maintained,
- Ensures that the monthly sampler verifications are being performed,
- Supports the national FRM audit program,
- Serves as the primary liaison between the laboratory and the APCD,
- Ensures sampler calibrations upon accuracy audit failure report,
- Ensures that the filter/sample shipment logistics are being maintained,
- Implements and coordinates all field activities with field staff who work with site operators and other auditors,
- Maintains the particulate monitoring operating budget within the boundaries of the Section 103 grant,
- Lead trainer for $PM_{2.5}$ field operations,
- Develops the annual work-plan for the Particulate Monitoring Unit to ensure monitoring objectives are met,

2.1.1.1.c Quality Assurance Unit

Quality Assurance Officer and QA Unit Supervisor- Cindy Wike

The QA Officer acts as an internal auditor of program methods and performs field services as a part of the QA responsibilities. Major QA related responsibilities include:

- Supervises gaseous and meteorological monitor QA auditors/analysts,
- Supervises particulate monitor QA auditors/analysts,
- Develops annual work-plan for QA auditors to ensure QA program objectives are met.
- Provides annual certification of APCD data,
- Ensures that each project QAPP and all associated SOPs within the APCD are current with EPA requirements, guidance, and proper QA procedure,
- Reviews quarterly data and quality control prior to AQS report submittal,
- Performs QA accuracy audits on monitoring systems (meteorological, gaseous, particulate and special studies) as per 40CFR Part 58,
- Coordinates certification the equipment needed for field calibrations, audits, and bench studies,
- Responds to problematic findings for all audits conducted on APCD by external entities,
- Ensures CDPHE/APCD SOPs are being followed and that proper QC protocol is being performed,
- Develops special study monitoring and QA protocols,
- Prepares quarterly accuracy submission to AQS,
- Assigns duties on quarterly basis to QA team staff,
- Prepares Data Quality Assessment to be submitted as part of Annual Air Quality Data Report,
- Coordinates 5-year Network Assessment,
- Coordinates Annual Data Report,
- Coordinates Annual Network Review,
- Coordinates Exceptional Events to keep them on regulatory time-line,
- Maintains APCD QMP,
- Takes lead in coordination with EPA Region VIII and other agencies to have audits conducted on APCD,
- Provides coaching, mentoring, and career path planning to QA staff,
- Implements Corrective actions where necessary,
- Performs Technical Systems audits and laboratory audits on contracted work,
- Consults with external agencies to provide technical expertise,
- Coordinates TSP staff training,

- Serves on CDPHE Environmental Quality Management Council and National QA workgroups.

QA Unit, Auditor/Analysts – Nancy Chick, Clyde Sharp, Brett Harkwell, Will Vicars, Bill Kotasek

The QA SLAMS Auditor/Analyst acts as an internal auditor of program methods and performs field services as a part of the QA responsibilities. Major QA related responsibilities include:

- Ensures that each project QAPP within the APCD is current with EPA requirements, guidance, and proper QA procedure,
- Reviews quarterly data prior to AQS report submittal,
- Performs QA accuracy audits on all monitoring systems (meteorological, gaseous, particulate and special studies) as per 40CFR Part 58,
- Certifies regularly the equipment needed for field calibrations, audits, and bench studies,
- Maintains appropriate authoritative standards in accordance with National Institute of Standards and Technology (NIST) traceability requirements,
- Performs ESAT evaluations of final data reported from Federal Reference Method (FRM) Performance Evaluation Program (PEP) audits,
- Assures CDPHE/APCD SOPs are being followed and that proper QC protocol is being performed,
- Performs the National Performance Audit Program (NPAP) for high-volume Particulate sampler audits
- Reviews quarterly accuracy submissions to AQS prior to submission,
- Prepares Data Quality Assessments to be submitted as part of Annual Air Quality Data Reports.
- Prepares Annual Data Report,
- Prepares Annual Network Review,
- Prepares 5-year Network Assessment,
- Tracks Exceptional Event documentation,
- Tacks TSP training,
- Provides Quality Assurance review for industry submittals of data,
- Maintains QA data bases,
- Uploads data to AQS.

2.2 PROJECT BACKGROUND, OVERVIEW AND INTENDED USE OF DATA

In 1970 President Nixon created the Environmental Protection Agency (EPA) by Executive Order. The formation of the EPA marked a dramatic change in national policy regarding the control of air pollution. The EPA was assigned the daunting task of repairing the damage already done to the natural environment and establishing new criteria to guide Americans in making a cleaner environment a reality. A few weeks later the United States Congress passed the Clean Air Act Amendments (CAA) of 1970. The passage of the CAA of 1970 marked the beginning of modern efforts to control air pollution.

The CAA and its subsequent amendments provide the framework for protecting air quality. In order to protect air quality, active environmental data collection operations must be established and operated in a manner that ensures that the most applicable and highest quality data are collected. Ambient air quality monitoring programs monitor the following criteria pollutants: particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide (SO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), ozone (O_3), and Lead (Pb).

Measurements of air pollution levels are used to assess whether pollutant levels are harmful to public health and welfare, to determine temporal and spatial trends of air pollution levels, and to aid in the development of pollution control measures. These ambient air quality data are an essential input to decision-making on a number of environmental issues in Colorado. Many activities are performed to provide ambient air quality data of sufficient quality to meet the needs of the State of Colorado.

Specific goals of the Colorado Air Pollution Control Division's ambient air monitoring program include:

1. Protection of the health and welfare of all citizens in the State of Colorado from the adverse effects of air pollutants.

2. Identification of any areas in Colorado where violations of state and federal ambient air quality standards may occur.

3. Maintenance and operation of a reliable ambient air monitoring network that is operated in a manner consistent with all applicable federal regulations.

2.2.1 PROJECT TASK/ORGANIZATION

The purpose of the air monitoring program is to protect the health and welfare of the citizens of Colorado by establishing a database for comparison to the NAAQS. The monitoring for coarse particulate matter and gaseous pollutants began in Colorado during the 1960's. The monitoring of $PM_{2.5}$ began in Colorado, and across the nation, on January 1, 1999. The quality assurance project plan (QAPP) provides background information on the design, implementation, and maintenance of the monitoring network and guidance for ensuring that quality data is collected. Qualified data is compared to the NAAQS in order to establish an attainment status. In the event that an area of Colorado is designated as non-attainment, the APCD will develop a State Implementation Plan (SIP) in order to reduce ambient concentrations and gain attainment status with the NAAQS.

2.2.1.1 Measurements

The Air Pollution Control Division (APCD) operates a large network of both automated and manual air quality monitors. Automated analyzers are used to measure ambient concentrations of four gaseous pollutants: carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), and nitrogen oxides (NO_x). Manual samplers are used to monitor ambient levels of total suspended particulate (TSP) and lead (Pb). Both manual and automated sampling systems are used by the APCD to monitor ambient concentrations of inhalable particulate (PM_{10}) and respirable particulate ($PM_{2.5}$). Samplers and analyzers used to measure criteria pollutants at all SLAMS sites have either Federal Reference Method (FRM) or Federal Equivalence Method (FEM) designation. EPA has designated several samplers and analyzers from different vendors that meet all the stringent federal design guidelines for the federal method or equivalency. Colorado Ambient Air Standards and National Ambient Air Quality Standards (NAAQS) have been promulgated for each of these gaseous and particulate pollutants. Detailed information on the characteristics of the sites in Colorado where these pollutants are monitored can be found in the annual Colorado Air Quality Network Review, an annual report prepared by the APCD. The APCD also maintains a system of meteorological stations and visibility monitoring sites.

Extensive records are maintained in order to provide supporting information about the air monitoring activities conducted by the APCD. All air pollutant concentration data for which NAAQS have been established are reported to the Air Quality Subsystem (AQS) within 90 days of the end of each calendar quarter for manual methods and 60 days for automated methods. The APCD is also required to submit an annual State and Local Air Monitoring Systems (SLAMS) Data Certification Report to EPA regional and national headquarters. This report provides detailed information about pollutant levels for which NAAQS have been established. An annual Colorado Air Quality Data Report prepared by APCD staff also summarizes this information in order to make it available to the public, interested scientists, planners, and citizens in the community.

2.2.2 TECHNICAL QUALITY STANDARD CRITERIA

Standards for the compliance monitoring network include the National Ambient Air Quality Standards (NAAQS) and laboratory standards. These standards are used for comparison to establish an attainment status and to provide a primary standard to certify laboratory and field instrumentation, respectively.

2.2.2.1 NAAQS Standards

The Clean Air Act, which was last amended in 1990, requires EPA to set National Ambient Air Quality Standards (40 CFR part 50) for pollutants considered harmful to public health and the environment. The Clean Air Act identifies two types of national ambient air quality standards. ***Primary standards*** provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. ***Secondary standards*** provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

EPA has set National Ambient Air Quality Standards (NAAQS) for six principal pollutants, which are called "criteria" pollutants. They are listed below. Units of measure for the standards are parts per million (ppm) by volume, parts per billion (ppb) by volume, and micrograms per cubic meter of air ($\mu g/m^3$).

Table 2.1 National Ambient Air Quality Standards

Pollutant [final rule cite]		Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide [76 FR 54294, Aug 31, 2011]		primary	8-hour	9 ppm	Not to be exceeded more than once per year
			1-hour	35 ppm	
Lead [73 FR 66964, Nov 12, 2008]		primary and secondary	Rolling 3 month average	0.15 $\mu g/m^3$ (1)	Not to be exceeded
Nitrogen Dioxide [75 FR 6474, Feb 9, 2010] [61 FR 52852, Oct 8, 1996]		primary	1-hour	100 ppb	98th percentile, averaged over 3 years
		primary and secondary	Annual	53 ppb (2)	Annual Mean
Ozone [73 FR 16436, Mar 27, 2008]		primary and secondary	8-hour	0.075 ppm (3)	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
Particle Pollution Dec 14, 2012	$PM_{2.5}$	primary	Annual	12 $\mu g/m^3$	annual mean, averaged over 3 years
		secondary	Annual	15 $\mu g/m^3$	annual mean, averaged over 3 years
		primary and secondary	24-hour	35 $\mu g/m^3$	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24-hour	150 $\mu g/m^3$	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide [75 FR 35520, Jun 22, 2010] [38 FR 25678, Sept 14, 1973]		primary	1-hour	75 ppb (4)	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year

(1) Final rule signed October 15, 2008. The 1978 lead standard (1.5 $\mu g/m^3$ as a quarterly average) remains in effect until one year after an area is designated for the 2008 standard, except that in areas designated nonattainment for the 1978, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.

(2) The official level of the annual NO_2 standard is 0.053 ppm, equal to 53 ppb, which is shown here for the purpose of clearer comparison to the 1-hour standard.

(3) Final rule signed March 12, 2008. The 1997 ozone standard (0.08 ppm, annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years) and related implementation rules remain in place. In 1997, EPA revoked the 1-hour ozone standard (0.12 ppm, not to be exceeded more than once per year) in all areas, although some areas have continued obligations under that standard ("anti-backsliding"). The 1-hour ozone standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is less than or equal to 1.

(4) Final rule signed June 2, 2010. The 1971 annual and 24-hour SO_2 standards were revoked in that same rulemaking. However, these standards remain in effect until one year after an area is designated for the 2010 standard, except in areas designated nonattainment for the 1971 standards, where the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standard are approved.

2.2.2.2 Laboratory Standards

Laboratory standards are utilized to perform verifications or calibrations on field transfer standards. The APCD maintains a set of laboratory mass reference standards that are sent to a contract laboratory to be annually certified against National Institute of Standards and Technology (NIST) standards. The laboratory mass reference standards are used annually to perform audits of the gravimetric contract laboratories' microbalances. The APCD maintains two primary flow standards that are sent to a contract flow laboratory at least once every three years for a NIST-traceable certification. The APCD primary flow standards are used at least annually to certify the APCD flow transfer standards used in the field. Flow transfer standards (FTS) are used in the field for site operator flow verification, annual multi-point calibrations and quarterly multi-point flow rate audits. The APCD maintains a laboratory temperature standard that is verified annually by a zero point check and is sent once every three years to a contract laboratory for a NIST-traceable certification. Transfer field temperature standards are certified annually against the APCD laboratory standard. The APCD maintains a primary pressure standard that is sent once every three years to a contract laboratory for a NIST-traceable certification. Transfer pressure standards, such as barometers and manometers are certified annually against the APCD laboratory standard. Standards certification will compare the standards against the primary standards per SOPs.

2.2.3 SPECIAL PROJECT REQUIREMENTS

All air monitoring equipment complies with Federal Reference Methods (FRM) or Federal Equivalent Methods (FEM) criteria. Criteria for achieving a Federal Reference Method or a Federal Equivalent Method for CO, O_3 SO_2, NO_2 and PM_{10} are given in Volume 40 Part 53 of the CFR and Volume 40 Part 50 of the CFR. Criteria for achieving a Federal Reference Method or a Federal Equivalent Method for $PM_{2.5}$ sampling are given in Volume 40 Part 58 App. L of the CFR. Criteria for quality assurance and quality control standards are given in Volume 40 Part 58 App. L of the CFR and in the QA Guidance Document 2.12. More detailed information can be found on this topic in the method-specific Standard Operating Procedures (SOPs) located in the appendices of this CDPHE/APCD/TSP QAPP document.

Special weighing rooms are required for the gravimetric analysis of particulate matter filters. The APCD does not currently have the ability to support a gravimetric laboratory. A contract laboratory on behalf of the APCD performs all gravimetric filter analyses. Prior to performing any work on behalf the APCD, the contract laboratory must prove compliance with all pertinent federal regulations and demonstrate their ability to perform the volume of work desired by the APCD. The APCD also requires the contract laboratory to demonstrate continued compliance with the pertinent federal regulations by allowing annual audits of their laboratories by auditors from the APCD QA unit or particulate matter unit.

Special requirements are demanded of all site operators. These requirements are entirely based upon site operator's training and the site operator's continued application of that training in the field. Site operators that operate and maintain computer-controlled samplers and analyzers are expected to learn and maintain an in-depth knowledge of those samplers and analyzers for which they are responsible. Along with intensive onsite training, standard operating procedures have been developed to assist in the site operator's ability to perform their required tasks.

The APCD attempts to meet all requirements that have been well substantiated and are in accordance with quality assurance guidance documents developed by EPA.

2.2.4 ASSESSMENT TOOLS

The degree of quality assessment activity for a project depends on the project's complexity, duration, and objectives. The assessments performed will evaluate the project's performance through sampler audits, performance evaluations, management systems reviews, peer reviews, and site inspections. Table 2.2 provides information on the parties implementing the assessments and their frequency.

Table 2.2 Project Quality Assessment Schedule

Project Assessment	Assessment Agency	Frequency
Technical Systems Audit	EPA Region VIII	Every three years
Quality Systems Review	EPA Region VIII	Unknown, 1st evaluation in 2014
Network Assessment	APCD Technical Services Program	Every 5 years
Annual Network Plan	APCD Technical Services Program	Every year
Annual Air Quality Data Report	APCD Technical Services Program	Every year
Data Quality Assessment	APCD Technical Services Program	Every year
Site Evaluations	APCD Technical Services Program	Every two years
Performance Evaluations (Audits)	APCD Technical Services Program	Quarterly for particulate samplers and semi-annually for gaseous analyzers.
PEP PM low-vol audits	ESAT contractor	1/6 of sites annually
NPAP TTP gaseous audits	EPA Region VII	1/6 of analyzers annually
NPAP PM high-vol audits	EPA Region VIII and ACPD Technical Services	50% or more of samplers every three years
NPAP Pb audit strips	EPA OAQPS and contracted laboratories	Every Quarter

A more detailed description of these assessment tools can be found in Section 5.

2.2.5 WORK SCHEDULE

More detailed information on work schedules for each type of monitoring being performed by APCD can be found in the method specific Standard Operating Procedures (SOPs) located in the appendices of this CDPHE/APCD/TSP QAPP.

2.2.6 PROJECT RECORDS

The APCD will establish and maintain procedures for the timely preparation, review, approval, issue, use, control, revision and maintenance of documents and records. Table 2-3 represents the categories and types of records and documents that are applicable to document control. Information on key documents in each category is explained in more detail in Section A9.

Table 2.3 Project Records

Categories	Record Type
Management and Organization	State Implementation Plan, reporting agency information, organizational structure, personnel qualifications and training, training certification, quality management plan, document control plan, EPA directives, grant allocations, and support contract. Exceptional Event Reports.
Site Information	Network description, site characterization file, site maps, site pictures, network plans, and network modification requests.
Environmental Data Operations	Standard operating procedures (SOPs), QAPPs, field and laboratory notebooks, sample handling/custody records, and inspection/maintenance records.
Raw Data	Any original data (routine and QC data) including data entry forms.
Data Reporting	Air quality index report, annual SLAMS air quality information, data/summary reports, and presentations.
Data Management	Data algorithms, data management plans/flowcharts, and data management systems
Quality Assurance	Good laboratory practice, network reviews, control charts, data quality assessments, Quality Management Plan (QMP), Quality Assurance Project Plan (QAPP), SOPs, system audits, response/corrective action reports, and site audits.

2.3 DATA / PROJECT QUALITY OBJECTIVES AND MEASUREMENT PERFORMANCE CRITERIA

The purpose of establishing data quality objectives (DQOs) and measurement quality objectives (MQOs) is to provide a systematic procedure for defining the criteria that a data collection design should satisfy, including when to collect samples, where to collect samples, the tolerable level of decision error for the study, and how many samples to collect, balancing risk and cost in an acceptable manner. Table 2.4 below defines the relationship between the quality teams.

Table 2.4 Quality Objectives

DQOs or PQOs	Qualitative and quantitative quality objectives for project conclusions or decisions. The decision to call these Data Quality Objectives (DQOs) or Project Quality Objectives (PQOs) depends on the organization's preferences.
DQIs	These are the indicators of data quality attributes.
MQOs or MPCs	Acceptance thresholds or goals for the data, usually based on individual DQIs. The decision to call these Measurement Quality Objectives (MQOs) or Measurement Project Criteria (MPCs) depends on the organization's preferences.

2.3.1 DATA QUALITY INDICATORS

The following definitions listed below in Table 2.5 summarize the various APCD quality assurance objectives for ambient air quality data: completeness, accuracy, precision, and comparability.

Table 2.5 Quality Indicators

DQI	Definition	Examples of Determination
Precision	An evaluation of agreement among replicate measurements of the same property under similar conditions; also referred to as random error or measurement variability and usually expressed as standard deviation, variance, percent difference, or range, in either absolute or relative terms	Overall project precision is measured by collecting data from collocated field duplicate (or replicate) samples. Precision specific to the laboratory is measured by analyzing laboratory duplicate (or replicate) samples
Bias	The systematic or persistent distortion of a measurement process resulting in error in one direction	Measurement of materials with a known concentration (e.g., performance evaluation or reference materials), analysis of matrix spikes, or the use of laboratory control samples
Accuracy	A measure of the closeness of an individual measurement to a known or reference value; includes a combination of random error (precision) and systematic error (bias) components of both sampling and analytical operations	Replicate analysis of a reference material or sample to which a material of known concentration or amount of pollutant has been added; usually expressed either as percent recovery or as a percent bias
Representativeness	A qualitative measure of the degree to which data accurately and precisely represent a characteristic of a population parameter	Evaluation of whether a sample that is collected and then processed and sub-sampled by the laboratory is proportionately representative of some predefined population characteristic or property. As such, representativeness is an "objective-defined" parameter (e.g., total concentration versus dissolved concentration versus bio-available

DQI	Definition	Examples of Determination
		concentration)
Comparability	A qualitative term describing the degree of which different processes, methods, or data agree or can be represented as similar. It describes the confidence that two data sets can contribute to a common analysis and interpolation. Comparability criteria must be determined for each matrix, analytical group, concentration level, and analytes (if possible).	A comparison of the output of two sediment transport models via sensitivity analysis. Or comparison of the sample collection methods, analytical procedures, holding times, stability issues and QA protocols. One study with results of µg/L is not necessarily comparable to another with results in ppb. A similar argument exists between wet and dry weight comparisons
Completeness	An evaluation of the amount of data needed to be obtained from a measurement system; expressed as a percentage of the number of measurements that should have been collected or were planned to be collected	Evaluation of the number of measurements needed to make a determination of the project results and comparison of this to the number of samples planned to be collected
Sensitivity	The capability of a method or instrument to discriminate the parameter of interest at the level of interest. Terms sometimes used to describe sensitivity include Method Detection Limit (DML), Limit of Detection(LOD), and Limit of Quantitation (LOQ)	The measurement responses representing different levels or amounts of the variable of interest, MDL, study, and verification of LOD

Minimum EPA data acceptance criteria as reviewed by CFR are presented in Table 2.6.
40 CFR Part 58, Appendix A identifies a number of quality control samples that must be implemented for the SLAMS (and NCore) SPM and PSD networks. Any special purpose monitors that use FRMs or FEMs will be required to follow these requirements unless granted a waiver by the Regional Administrator (or delegate). Table 2.6 provides a summary of the QC checks for the criteria pollutants and the CFR reference where an explanation of each check is described. The reader should distinguish the requirements that are related to automated and manual methods since there are some differences.

Table 2.6 CFR Related Quality Control Samples

Method	CFR Reference	Coverage (annual)	Minimum frequency	MQOs*
Automated Methods				
One-Point QC: for SO_2, NO_2, O_3, CO	Section 3.2.1	Each analyzer	Once per 2 weeks	**O_3** Precision 7%, Bias ± 7%. **SO_2, NO_2, CO** Precision 10% , Bias ± 10%
Annual performance evaluation for SO_2, NO_2, O_3, CO	Section 3.2.2	Each analyzer	Once per year	See validation template in Appendix DD of this QAPP.
Flow rate verification PM_{10},$PM_{2.5}$, $PM_{10-2.5}$,	Section 3.2.3	Each sampler	Once every month	≤ 4% of standard and 5% of design value
Semi-annual flow rate audit PM_{10}, $PM_{2.5}$, $PM_{10-2.5}$,	Section 3.2.4	Each sampler	Once every 6 months	≤ 4% of standard and 5% of design value
Collocated sampling $PM_{2.5}$, $PM_{10-2.5}$,	Section 3.2.5	15% within PQAO	Every twelve days	$PM_{2.5}$, 10% precision $PM_{10-2.5}$, 15% precision TSP, 10% precision
Performance evaluation program $PM_{2.5}$,$PM_{10-2.5}$	Section 3.2.7	1. 5 valid audits for primary QA orgs, with ≤ 5 sites 2. 8 valid audits for primary QA orgs, with > 5 sites 3. All samplers in 6 years	over all 4 quarters	$PM_{2.5}$, ± 10% bias $PM_{10-2.5}$, ±15% bias
Manual Methods				
Collocated sampling PM_{10}, $PM_{10-2.5}$, $PM_{2.5}$ Pb-TSP, Pb-P_{10}	3.3.1 and 3.3.5	15% within PQAO	Every 12 days PSD every 6 days	PM_{10}, TSP, $PM_{2.5}$, 10% precision $PM_{10-2.5}$, 15% precision
Flow rate verification PM_{10}(low-vol), $PM_{10-2.5}$, $PM_{2.5}$, Pb-PM_{10}	3.3.2	Each sampler	Once every month	≤ 4% of standard and 5% of design value
Flow rate verification PM_{10} (high-vol), Pb-TSP	3.3.2	Each sampler	Once every quarter	Precision 10% , Bias ± 10%
Semi-annual flow rate audit PM_{10} (low-vol), $PM_{10-2.5}$, $PM_{2.5}$,	3.3.3	Each sampler, all locations	Once every 6 months	≤ 4% of standard and 5% of design value
Semi-annual flow rate audit PM_{10} (high-vol), Pb-TSP	3.3.3	Each sampler, all locations	Once every 6 months	Varies by instrument type see validation templates
Pb Analysis Audits Pb-TSP, Pb-PM_{10}	3.3.4	1. Each sampler 2. Analytical (lead strips)	1. Include with TSP 2. Each quarter	1. Same as for TSP. 2. ± 10% bias
Performance evaluation program $PM_{2.5}$, $PM_{10-2.5}$	3.3.7 and 3.3.8	1. 5 valid audits for primary QA orgs, with ≤ 5 sites 2. 8 valid audits for primary QA orgs, with ≥ 5 sites 3. All samplers in 6 years	Over all 4 quarters	$PM_{2.5}$, ± 10% bias $PM_{10-2.5}$, ±15% bias

* Some of the MQOs are found in CFR and others in Appendix D of the QA Handbook.

2.3.2 CRITERIA FOR MEASUREMENT DATA

The Measurement Quality Objectives used by the APCD have predominantly been adopted from the 2013 version of the QA Handbook for Air Pollution Measurements Volume II (QA Handbook) Appendix D and slightly modified to fit the APCD network needs. The *Measurement Objectives and Validation Templates* for criteria Pollutants can be found in Appendix MQO of this QAPP. The information found in this Appendix comes from a compilation of references, including, but not limited to: 40CFR Parts 50-53 and 58, the National $PM_{2.5}$ QA Mass Validation Criteria Workgroup, and various EPA policies, procedures, standards, guidance's, and technical assistance documents. Any changes to APCD's MQOs that are recommended by EPA Region VIII, but not required by CFR, will be considered. Please note that the 40CFR Part 50, Appendix L, Section 8.0 does not fully describe the control criteria for temperature and relative humidity for $PM_{2.5}$ laboratory conditions. Therefore, it is the intent of the APCD to use the calculated standard deviation of these parameters as a comparison to the acceptance criteria for control defined by the QA Mass Validation Criteria Workgroup. Additional descriptions of Measurement Quality Objectives for PM_{10}, TSP and $PM_{2.5}$ can be found in Appendices PM1, PM2, PM3, PM4, and in Appendix MQO. Additional information of laboratory MQOs can be found in Appendices MQO, IML1, LSD1, LSD2, LSD3, LSD4, LSD5 and LSD6. More information of Measurement Quality Objectives for CO, NO_2, SO_2, and O_3 can be found in Appendices GM1, GM2, GM3, GM4, GM5, GM6, GM7 and Appendix MQO.

2.3.3 MEASUREMENT QUALITY OBJECTIVES AND VALIDATION TEMPLATES

Adopted with a few slight modifications from the QA Handbook for Air Pollution Measurements, Volume II, Appendix D, revised May 2013. Where modifications from the QA Handbook occur, a "*" symbol will be included to designate the change (*: followed by a description of why the change was made will be in the Information/Action column).

In June 1998, a workgroup was formed to develop a procedure that could be used by State and locals that would provide for a consistent validation of $PM_{2.5}$ mass concentrations across the US. The workgroup included personnel from the monitoring organizations, EPA Regional Offices, and OAQPS who are involved with assuring the quality of $PM_{2.5}$ mass and was headed by a State and local representative. The workgroup developed three tables of criteria where each table has a different degree of implication about the quality of the data. The criteria included on the tables are from 40 CFR Part 50 Appendices L and N, 40 CFR Part 58 Appendix A, Method 2.12, and a few criteria that were neither in CFR nor Method 2.12 but which the workgroup felt should be included. Upon completion and use of the table, it was decided that a "validation template" should be developed for all the criteria pollutants.

One of the tables has the criteria that the workgroup felt *must* be met to ensure the quality of the data. An example criterion for $PM_{2.5}$ is that the average flow rate for the sampling period must be maintained to within 5% of 16.67 liters per minute. The second table has the criteria that indicate that there *might* be a problem with the quality of the data and further investigation is warranted before making a determination about the validity of the sample or samples. An example criterion is that the field filter blanks should not change weight by more than 30 micrograms between weighings. The third table has criteria that indicate a potentially systematic problem with the environmental data collection activity. Such systematic problems may impact the ability to make decisions with the data. An example criterion is that at least 75% of the scheduled samples for each quarter should be successfully collected and validated.

To determine the appropriate table for each criterion, the members of the workgroup considered how significantly the criterion impacted the resulting concentration. This was based on experience from workgroup members, experience from non-workgroup members, and feasibility of implementing the criterion.

Criteria that were deemed critical to maintaining the integrity of a sample or group of samples were placed on the first table. Observations that do not meet each and every criterion on the **Critical Criteria Table** should be invalidated unless there are compelling reason and justification for not doing so. The sample or group of samples for which one or more of these criteria are not met is invalid until proven otherwise. The cause of not operating in the acceptable range for each of the violated criteria must be investigated and minimized to reduce the likelihood that additional samples will be invalidated.

Criteria that are important for maintaining and evaluating the quality of the data collection system are included on the second table, the **Operational Evaluations Table**. Violation of a criterion or a number of criteria may be cause for invalidation. The decision maker should consider other quality control information that may or may not indicate the data are acceptable for the parameter being controlled. Therefore, the sample or group of samples for which one or more of these criteria are not met is suspect unless other quality control information demonstrates otherwise. The reason for not meeting the criteria MUST be investigated, mitigated or justified.

Finally, those criteria which are important for the correct interpretation of the data but do not usually impact the validity of a sample or group of samples are included on the third table, the **Systematic Issues Table**. For example, the data quality objectives are included in this table. If the data quality objectives are not met, this does not invalidate any of the samples but it may impact the error rate associated with the attainment/non-attainment decision.

Please note the designation Operational or Systematic Criteria do not imply that these quality control checks need not be performed. If an operational or systematic quality control check that is required by regulation is not performed that can be a basis for invalidation of all associated data.

Following are the tables for all the criteria pollutants. For each criterion, the tables include: (1) the requirement (2) the frequency with which compliance is to be evaluated, (3) acceptance criteria, and (4) information where the requirement can be found or additional guidance on the requirement.

The validation templates have been developed based on the current state of knowledge. The templates should evolve as new information is discovered about the impact of the various criteria on the error in the resulting mass estimate or concentration. Due to the potential misuse of invalid data, data that are invalidated will not be uploaded to AQS but should be retained on the monitoring organizations local database. This data will be invaluable to the evolution of the validation template.

2.3.3.1 Use of Bold Italics Font to Identify CFR Requirements.

The criteria listed in the validation templates are one of the following: requirements that can be found in the Code of Federal Regulations, guidance found in a variety of guidance documents, or recommendations by the QA Workgroup or EPA. Any time a CFR requirement is identified in the MQO tables in the QA Handbook under Requirement, Frequency or Acceptance Criteria column, it will be identified by ***bold and italics*** font. The Information/Action column will provide the appropriate references for CFR or guidance documents.

2.3.3.2 Hyperlink References

Where requirements or guidance documents are found on the web, a hyperlink is created which will lead the user to the closest URL address. Any links to CFR are directed to the electronic CFR document (e-CFR) which is the most up-to-date. E-CFR will not get you to an individual section. For example e-CFR will get the user to 40 CFR part 50 App L but not to section 5.5.2, which you will have to page down to find. Not every reference is hyperlinked but every reference that shows up on an individual page is linked at least once.

2.3.3.3 PM_{10} Note of Caution

The validation templates for PM_{10} get complicated because PM_{10} is required to be reported at standard temperature and pressure (STP) for comparison to the NAAQS (and follow 40 CFR Part 50 App J) and at local conditions if using it to monitor for $PM_{10-2.5}$ (and follow 40 CFR Part 50 App O). Moreover, PM_{10} can be measured with filter-based sampling techniques as well as with automated methods. The validation templates developed for PM_{10} try to accommodate these differences, but monitoring organizations are cautioned to review the operations manual for the monitors/samplers they use and augment the validation template with QC information specific to their EPA reference or equivalent method designation and instrument. http://www.epa.gov/ttn/amtic/files/ambient/criteria/reference-equivalent-methods-list.pdf

2.3.3.4 Location of MQO Tables

For validation Tables please see Appendix MQO in this QAPP. The tables have gotten too large to embed into the main body of the QAPP, so they have been separated out into their own Appendix

2.4 SPECIAL TRAINING REQUIREMENTS AND CERTIFICATION

Adequate education and training are integral to any monitoring program that strives for reliable and comparable data. It is recommended that monitoring organizations maintain some requirements for air personnel qualifications (combination of education and experience). Training is aimed at increasing the effectiveness of employees and their organization. As part

of a quality assurance program, EPA QA/G- 10, *Guidance for Developing a Training Program for Quality Systems* suggests the development of operational procedures for training. These procedures should include information on:

- Personnel Qualifications – general and position specific
- Training Requirements – by position
- Training Frequency

Appropriate training should be available to employees supporting the Ambient Air Quality Monitoring Program, commensurate with their duties. Such training may consist of classroom lectures, workshops, web-based courses, teleconferences, vendor provided, and on-the-job training.

Along with suggested training, there are some EPA programs that require mandatory training and/or certifications. These programs include, but are not limited to, the National Performance Audit Program (NPAP), Performance Evaluation Program (PEP), Interagency Monitoring of Protected Visual Environments (IMPROVE), and $PM_{2.5}$ Speciation Trends Network Audit Program. All personnel performing audits in these projects or programs are required to possess mandatory training or a current certification issued by the EPA Office responsible for the monitoring program.

2.4.1 PERSONNEL QUALIFICATIONS

The State of Colorado has a civil service type personnel system which is detailed in the "State Personnel Rules and Procedures" and Colorado Statute C.R.S. 24-50. Job qualifications are established through the hiring process and determined by program and unit supervisors.

Professional staff is expected to have either a formal or technical education, training, and experience with the program/project goals. An understanding of atmospheric chemistry, statistics, field-sampling techniques, meteorology and quality control are developmental objectives for staff. Specifically with regards to approval authority for QMPs, QAPPs and SOPs, staff will be encouraged to have completed a QA training class.

Technical staff is expected to have a technical education, and/or training and experience with the program/project goals. Technical staff typically holds in-depth knowledge in a trade or technical program and bring on-the-job experience to programs within the Technical Services Program. Staff will be encouraged to have training in computer software, computer hardware and training from equipment manufactures.

2.4.2 TRAINING REQUIREMENTS

When establishing personnel needs for a specific project, it is the Unit Leader's responsibility to review the personnel skills and expertise required to implement a project. Personnel assigned to ambient air monitoring activities are expected to have the educational, work experience, responsibility, personal attributes and training requirements for their positions. Also, the Unit Leader must ensure that such personnel resources are available before a project will be approved and implemented. There are six methods that the Unit Leaders have available to prompt training amongst staff. These are:

- Required Reading
- Mentoring or Coaching
- Individual Performance Goals (IPGs)
- Professional Conferences
- Training Classes Internal to CDPHE
- Training Classes External to CDPHE

2.4.2.1 Required Reading

A primary training requirement for all staff prior to the implementation of this QAPP is the thorough understanding of sections and Appendices in this QAPP as it pertains to the person's job description. Generally, it is expected that all professional level staff members have read the entire QAPP and have an in-depth knowledge of sections and appendices (SOP's) that pertain to their job duties. It is expected that all technical level staff have read all pertinent sections and Appendices relating to the methods/equipment they are working with before operating or maintaining any of the instruments.

The following sources are used to supplement in-house training provided by the Air Pollution Control Division:

- Code of Federal Regulations, Title 40, Sections 50-53, 58.
- "Ambient Monitoring Guidelines for the Prevention of Significant Deterioration", May 1987, EPA-450/4-87-007.
- Quality Assurance Handbook for Air Pollution Measurement Systems, Vol. I-IV, as revised, EPA/RTP.
- Reference and Equivalent Ambient Air Monitoring Methods and Guidance, as revised, EPA/RTP.

2.4.2.2 Mentoring or Coaching

Mentoring or on-the-job training is one of the most efficient training methods utilized by the APCD, because it is planned, organized, and conducted at the employee's worksite. Mentoring will generally be the primary method used for broadening employee skills and increasing productivity. It is particularly appropriate for developing proficiency skills unique to an employee's job, especially jobs that are relatively methodical and require locally owned equipment and facilities. Until proficient with all expected job duties, new staff is mentored by senior staff or by other staff that are experts in associated areas. Mentoring serves as a cornerstone for the training of new staff and with staff that are being cross-trained.

2.4.2.3 Individual Performance Goals (IPGs)

Individual Performance Goals are written expectations submitted by the employee to management that describes tasks or learning opportunities that are typically outside or in addition to the employee's job description. Staff is encouraged to pursue professional development and project specific training through individual performance goals stated within an individual's annual job performance plan. IPGs provide the management framework for employees to further ones knowledge and/or pursue job related interests. Once set in place, and approved by management, it is the responsibility of the employee to see the plan through to fruition. Management provides constant feedback and coaching to guarantee the successful completion of an employee's IPGs.

2.4.2.4 Professional Conferences

It is expected of all professional staff that they remain current and knowledgeable within their field. Conferences are one of the best ways to stay current with new products, recent research and the latest federal regulations within the field of air pollution. The department allows for the attendance of conferences as long as it directly pertains to the employees job tasks.

2.4.2.5 Training Classes Internal to CDPHE

The Division of Human Resources has a variety of training opportunities for Colorado State employees through the Professional Development Center, Risk Management and the Colorado State Employee Assistance Program (C-SEAP), C-SEAPs overall mission is to provide learning opportunities to help state employees grow professionally and personally and excel in their work environment. With extensive state employment experience, the C-SEAP professionals cater their coursework to the state employee and gear course material and scheduling to the state workforce.

Further information regarding C-SEAP training can be found at https://www.colorado.gov/pacific/dhr/training

2.4.2.6 Training Classes External to CDPHE

Employees are encouraged to further their education and pursue training outside the state workforce. These training opportunities must pertain to the employee's job tasks, and a written demonstration of applicability must be given in order to receive financial assistance from the department. This can include classes from equipment manufacturers, universities, community colleges and government agencies.

Example training groups and classes that are recommended to staff members:

Over the years, a number of courses have been developed for personnel involved with ambient air monitoring and quality assurance aspects. Formal QA/QC training is offered through the following organizations:

- Air Pollution Training Institute (APTI) http://www.apti-learn.net/
- Air & Waste Management Association (AWMA) http://www.awma.org/
- American Society for Quality (ASQ) http://www.asq.org/
- EPA Quality Staff http://www.epa.gov/quality/train.html
- EPA Regional Offices http://www2.epa.gov/aboutepa/visiting-regional-office
- EPA Ambient Monitoring Technology Information Center (AMTIC) Technology Transfer Network (http://www.epa.gov/ttn/amtic/)

In addition, OAQPS uses contractors and academic institutions to develop and provide training for data collection activities that support regulatory efforts throughout EPA and monitoring organizations. In addition, instrument and data management manufacturers provide training on the equipment they sell. Sometimes this training can be added to the equipment purchase cost.

Training Frequency

No matter how qualified and competent an employee is, there will always be a need for training. Whenever the department introduces a new product or service, implements a new analytical measurement or software application, modifies its structure or goals, or seeks to make improvements in overall operations, training is critical. The demand for training is always present and its frequency is set by the implementation of new equipment, methods and federal regulations. It is the responsibility of management to design a training program that ensures the employee can perform all required tasks.

2.4.3 CERTIFICATION AND DOCUMENTATION

Documentation of training should be kept for each individual employee. The following items should be incorporated into this training file:

A list of job related reading material that has been digested by each employee such as: (QMP, QAPP, SOPs, Policies, Procedures, Standards, Regulations, Guidance, Operating Manuals, technical documents, etc.)

For on-the-job training, a task sheet should be kept and initialed by both the instructor and the trainee for each job task they have been trained on such as: operating equipment, maintenance procedures, troubleshooting techniques, calibrating an analyzer, auditing an analyzer, certifying equipment, learning to use a new standard, etc.

Copies of transcripts or continuing education credits for coursework applicable to the job should be added to these files.

Copies of certification of training that is sponsored by a federal agency or professional organization should be added to the file. Certified programs are highly encouraged and valued because the training typically applies directly to tasks within an employee's job description. The certification establishes a level of competence that is recognized by federal agencies that have program oversight responsibilities. External training certification is not available for all aspects of work within the air pollution program and its availability has been proven to be more an exception, rather than a regular occurrence. Recently, APCD staff has received various certificates of training through courses and workshops that have been sponsored by EPA-OAQPS, AWMA, and WESTAR.

Original documentation of formal training, such as Certificates of Completion, Certificates of Certification, transcripts, documentation of continuing education credits and academic transcripts are maintained by individual employees.

2.5 DOCUMENTATION AND RECORDS REQUIREMENTS

2.5.1 PURPOSE / BACKGROUND

The information and records that must be included in the data report package and that specify the desired reporting format for hard copy and electronic forms are described in this section. Other records and documents applicable to the project have been included.

The purpose of establishing procedures for documentation and records of data collected is to provide a uniform and consistent method within the APCD and to submit an appropriate report to Region VIII. This section defines which records are critical to the project and what information needs to be included in reports as well as the data reporting format and the document control procedures to be used. Specification of the proper reporting format, compatible with data validation, will facilitate clear, direct communication of the investigation and its conclusions.

2.5.2 DATA REPORTING PACKAGES

The APCD publishes the *Colorado Air Quality Annual Data Report* that summarizes all ambient air quality monitoring data collected by the Technical Services Program and its sub-contractors. The *Data Report* addresses changes in ambient air quality measured by APCD monitors. The report will include a summary of all air monitoring data in a format that meets all EPA requirements. The following subsections will describe the Field Operations Records (sample collection records, chain-of-custody records, QC sample records, general field procedures and corrective action reports), Laboratory Records and Data Handling Records to be included in the APCD annual *Data Report*.

2.5.2.1 Field Operations Records

The information contained in these records documents the overall field operations and generally consists of the following:

Certificates of Analyses Records: Will be maintained in a filing cabinet in the back laboratory for all primary standards, field standards, protocol gases and reference materials.

Field Data Sheet/Chain-of-Custody Records: There are four elements of the APCD sample chain-of-custody procedure. These elements include (1) data collection, (2) sample handling and storage, (3) analysis and data processing, and (4) reporting and record keeping. Detailed information about the data collection and sample handling components of this process is provided in each of the Standard Operating Procedures (SOP). The analysis, data processing, reporting, and record keeping components are detailed in the SOPs relating to Laboratory Procedures and QAPP section on Data Acquisition and Validation. A brief overview of this sample custody and record keeping process is presented below.

A field operator of the Particulate Matter Monitoring Group is responsible for ensuring each sample is collected properly and a sample data form is filled out. Sample data forms have been created by APCD. For particulate methods, sample data forms will originate from the laboratory issuing the pre-weighed filters. Thus, the sample data forms will act as a field data sheet and a chain-of- custody (FDS/COC). One form will accompany a batch of filters from the point of origin to post- weight analysis and will be archived at either the gravimetric laboratory or at the APCD. The field operator is responsible for properly filling out a sample data slip, changing filters, and mailing exposed filters directly to the gravimetric laboratory. Data to be included on the FDS/COC (where applicable) are date of set up and sample recovery, site ID number and name, sampler type and ID number, filter number, cassette number, sample date and run time, manometer flow readings, preliminary and subsequent sampler conditions, shipping conditions, operator name and lab technician name. APCD stores all filters and data slips as prescribed by 40 CFR Part 50.

Field operators in the GMM Unit and the continuous particulate operators are responsible for ensuring agreement between the backup data acquisition system, the primary data logger reporting system, and the data that has been collected through the polling system, before reporting this data to AQS. Each data logger is programmed with a unique site identification number that is associated with each data value. The Technical Services Program maintains all copies of calibration records, control charts, maintenance logs, and strips charts.

QC Sample Records: Quality Control (QC) sample records are maintained for both field and laboratory activities. In field applications, each sampler is tracked according to the results of sampler verification procedures, calibration results, audit results, field and trip blank results, sample integrity results and collocated precision results. This will allow for tracking sampler and operator performance and will work towards establishing a maintenance schedule. QC records also provide feedback on how well the filters are being prepared, if the filters received have a stable mass, if there is any potential contamination of filters occurring via deposition to the lab blank, and the repeatability of the microbalance. Other QC sample records come from the time of sample preparation and include temperature and relative humidity readings within the weighing room.

General Field Procedures: Field procedures have been developed and are included in the Field Standard Operating Procedures found in the appendices of this QAPP. A copy of each SOP will also be located at each station where applicable sampling is occurring. The field SOP outlines the necessary steps required to be carried out by the field operators, calibration staff, and QA staff for proper sampler operations, maintenance, verification, quality control protocols, filter loading, sample recovery, storage, shipping, auditing, and documentation.

Corrective Action Reports: The Quality Assurance Unit, Unit Supervisors, and Unit Work Leads can generate corrective action reports. The need for a corrective action report will be determined on a sample-by-sample or site-by-site basis when a MQO is not met. Corrective actions will validate data if applicable, otherwise, data will be considered invalid and will be flagged as suspect or not reported to AQS. Reports will be given to the QA Auditor/Analyst and Officer. A description of corrective actions is included in Section C.

Lab Records: Lab records generated by the Laboratory Technician. The records include (where applicable) the sample ID, environmental criteria, equilibration period, QC checks, field and lab blanks, max shipping temperature, and analysis results.

Particulate Samplers: The gravimetric laboratories use customized data management systems. Data generated at the gravimetric laboratories are acquired through inputs into computer databases and data loggers. Data is collected from the peripheral databases and data loggers and stored in a centralized database. The data management system has been developed for QA/QC purposes and for data tracking, summary, and report generation needs. Data is received by the APCD from the gravimetric laboratory in spreadsheet or database format. Gravimetric data is uploaded into its appropriate APCD database for evaluation. The programming within the database module allows for calculating, summarizing, reporting, and flagging data that are outside of the DQOs. A more detailed description can be found in the PM_{10} and $PM_{2.5}$ data processing SOPs located in the appendices of this document.

Continuous Analyzers: Data loggers at remote sites collect data from the continuous analyzers continuously. A host central computer located at the APCD polls all the remote data loggers hourly via a modem and downloads their data. Programming within the central host system processes the data and prepares it for uploading to the AQS system.

A copy of all calculations involved in the determination of gaseous or particulate concentrations is maintained in a permanent electronic record within the Colorado Department of Public Health and Environment in a Microsoft Access program.

Actual resultant data for gaseous, particulate and meteorological data are maintained on the Air Quality Subsystem (AQS) database.

Performance Evaluation records: Will be maintained by the Quality Assurance Unit in both an electronic database, and in a hard copy format.

2.5.3 REPORTING PACKAGE DOCUMENT CONTROL

The format of all data reporting packages must be consistent with the requirements and procedures used for data validation and data assessment described in Sections 3, 4 and 5 of the QAPP. All individual records that represent actions taken to achieve the objective of the data operation and the performance of specific QA functions are potential components of the final data-reporting package. All raw data required for the calculation of a PM concentration, the submission to the AQS database, and QA/QC data are collected electronically or on data forms that are included in the

field and analytical methods sections. All hardcopy information will be filled out in indelible ink. Corrections will be made by inserting one line through the incorrect entry, initialing the correction, and placing the correct entry alongside the incorrect entry, if this can be accomplished legibly, or by providing the information on a new line.

The report will contain the following information:

- Site names;
- County and AQS site codes;
- AQS monitoring method codes;
- Summary Data

2.5.4 REPORTING PACKAGE ARCHIVE AND RETRIEVAL

The APCD prepares monthly data tabulations to include all validated continuous and manual data. These tabulations are stored on a centralized computer file and copied to a hard copy output that is available for public viewing. Annually, a data summary report is prepared consistent with the requirements of 40 CFR Part 51.285 titled "Public Notification." Additionally, reports of precision and accuracy tests are completed consistent with requirements of 40 CFR Part 58, Appendix A "Reporting Requirements." In addition, daily reporting of pollutant levels is conducted consistent with the requirements for "Index Reporting" as described in 40 CFR Part 58 Appendix G.

Data reporting packages will be maintained according to 40 CFR Part 31.42. All documentation and sample filters will be stored and readily available to APCD personnel for three (3) years. $PM_{2.5}$ filters need to be stored in a refrigerated storage area. Thereafter, documentation will be archived and stored in State files, and filters will be held in an unrefrigerated archive for two (2) additional years and discarded at the end of the total five (5) year time frame.

3.0 Data Acquisition (DO)

3.1 DATA COLLECTION PROCEDURE, EXPERIMENTAL DESIGN, AND SAMPLING TASKS

There are three major air monitoring networks that are maintained by the APCD and are operated under the guidance of this Quality Assurance Project Plan. These are as follows:

SLAMS – State or Local Air Monitoring Stations
The SLAMS network make up the ambient air quality monitoring sites that are primarily needed to perform NAAQS comparisons, but may serve other data purposes. The SLAMS network excludes the Special Purpose Monitoring Network but includes the NCore, and all other state and local monitors that are not designated as SPM stations. NAMS is a subset of SLAMS.

NCore - National Core Multi-pollutant Monitoring Stations
NCore multi-pollutant stations are intended to track long-term trends for accountability of emission control programs and health assessments that contribute to ongoing review of the NAAQS; support development of emissions control strategies through air quality model evaluation and other observational methods; support scientific studies ranging across technological, health, and atmospheric process disciplines, and support ecosystem assessments. These sites are required to measure O_3, CO, SO_2, total reactive nitrogen (NO_y), $PM_{2.5}$ (manual and continuous), $PM_{2.5}$ speciation, $PM_{10\text{-}2.5}$, $PM_{10\text{-}2.5}$ speciation and meteorological variables (wind speed, wind direction, temperature, relative humidity). Note: *The DMAS NCore site was shut down during 2012 because the land where it was located was sold to another owner. The NCore site reopened at the new La Casa location in 2013. Due to failure of the implementation of the $PM_{10\text{-}2.5}$ NAAQS and the lack of available trace level and $PM_{10\text{-}2.5}$ guidance made available by the EPA, there may still be some areas at the NCore network that could use further improvement*. (NCORE TAD link)

SPM - Special Purpose Monitoring Stations
A special purpose monitor means a monitor included in an agency's monitoring network that the agency has designated as a special purpose monitor station in its monitoring network plan and in the Air Quality System, and which the agency does not count when showing compliance with the minimum requirements of the SLAMS and NCore networks. Definition of an SPM can be found at 40 CFR Part 58.20.

NATTS - National Air Toxic Trends Stations
The National Air Toxics Trends Station (NATTS) Network was developed to fulfill the need for long-term HAP monitoring data of consistent quality. Among the principle objectives are assessing trends and emission reduction program effectiveness, assessing and verifying air quality models (e.g., exposure assessments, emission control strategy development, etc.), and as direct input to source-receptor models. The current network configuration includes 27 sites (20 urban, 7 rural) across the United States. There are typically over 100 pollutants monitored at each NATTS (though only 19 of those are required; included are VOCs, carbonyls, PM_{10} metals, and PAHs. (NATTS Work Plan link) (NATTS TAD link)

Near-Road Monitoring
On February 9, 2010, the U.S. Environmental Protection Agency (EPA) promulgated new minimum monitoring requirements for the nitrogen dioxide (NO_2) monitoring network in support of a newly revised 1-hour NO_2 National Ambient Air Quality Standards (NAAQS) and the retained annual NAAQS. In the new monitoring requirements, state and local air monitoring agencies are required to install near-road NO_2 monitoring stations at locations where peak hourly NO_2 concentrations are expected to occur within the near-road environment in larger urban areas.
State and local air agencies are required to consider traffic volumes, fleet mix, roadway design, traffic congestion patterns, local terrain or topography, and meteorology in determining where a required near-road NO_2 monitor should be placed. In addition, there are other factors that affect the selection and implementation of a near-road monitoring station, including satisfying siting criteria, favorable site logistics (e.g., gaining access to property and safety), and consideration of population exposure. (Near-road TAD link)

The APCD employs special purpose monitoring for both criteria and non-criteria pollutants. All special purpose monitoring of criteria is done to the same specifications as required for the SLAMS network. This includes meeting the SLAMS siting criteria, quality control criteria and quality assurance criteria.

Special purpose short-term monitoring for non-criteria monitoring is conducted from time to time in Colorado. Most of this monitoring relates to hazardous air pollutants (or "air toxics") or ozone precursors. For this type of monitoring, whole air samples, adsorbent cartridges or filters may be employed. The U.S. Environmental Protection Agency has developed a series of "TO" (for toxic organic) and "IO" (for inorganic) methods that are followed for this special purpose monitoring. Both field and analytical techniques are covered in the methods. These methods are available at http://www.epa.gov/ttn/amtic/airtox.html for the "TO" methods and http://www.epa.gov/ttn/amtic/inorg.html for the "IO" methods.

Specific references for these documents are:

Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air – Second Edition, EPA/625/R-96/010b. January 1999. U.S. Environmental Protection Agency. Washington, DC.

Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air, EPA/625/R-96/010a. June 1999. U.S. Environmental Protection Agency. Washington, DC.

Additional networks maintained by the APCD but operating under the guidance of separate EPA Quality Assurance Project Plans are as follows:

1. Chemical Speciation Network(CSN) which has some Speciation Trends Network (STN) sites
2. Ozone Precursor Network

The purpose of this section is to describe all the relevant components of the experimental design; define the key parameters to be estimated; indicate the number and type of samples expected; and describes where, when, and how samples are to be taken. This element provides the main opportunity for QAPP reviewers to ensure that the "right" samples will be taken. The network design components comply with the following appendices of 40 CFR Part 58:

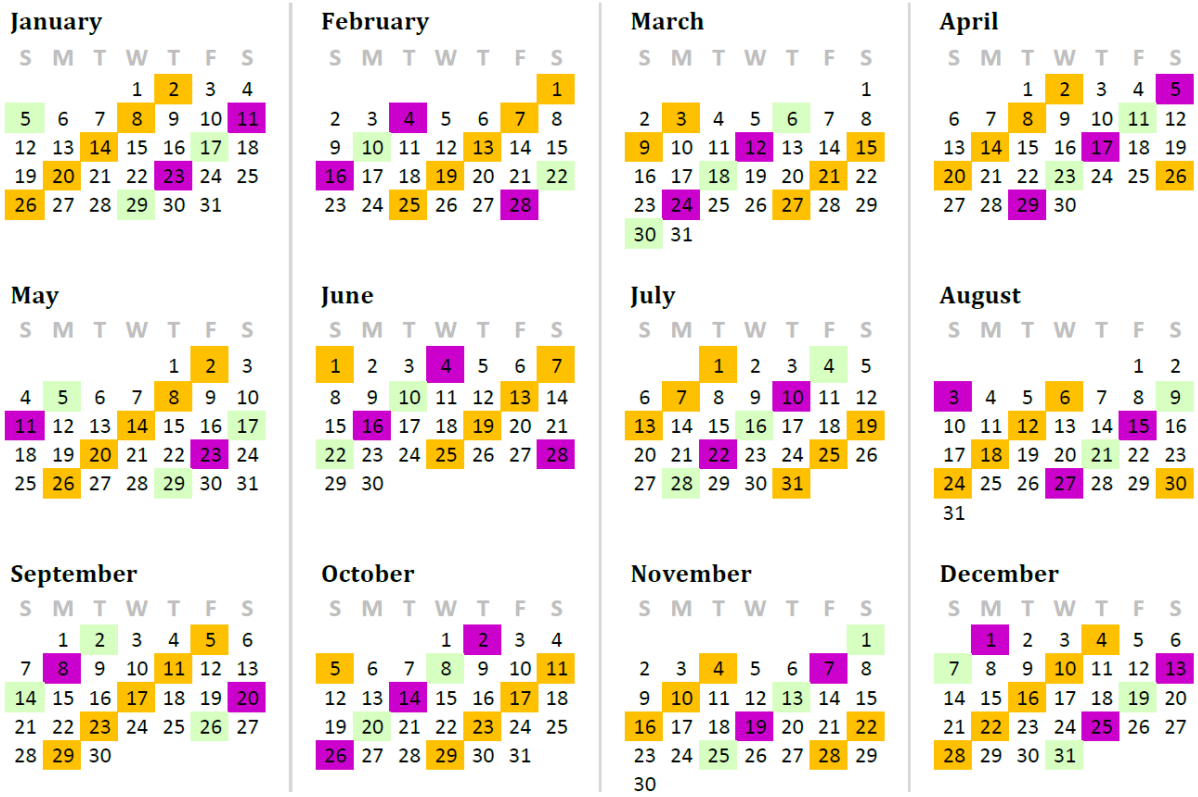
- 40 CFR Part 58, Appendix A – Quality Assurance Requirements for State and Local Air Monitoring Stations (SLAMS) and National Core multi-pollutant stations (NCore)
- 40 CFR Part 58, Appendix D – Network Design for State and Local Air Monitoring Stations (SLAMS) and National Core multi-pollutant stations (NCore).
- 40 CFR Part 58, Appendix E – Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring

3.1.1 SCHEDULED PROJECT ACTIVITIES

The annual Colorado Network Plan is developed to meet the criteria as set forth in 40 CFR Part 58.20. It is designed to present a brief summary of all ambient air monitoring sites, analyzers and samplers operated by the APCD, as well as planned changes to these sites, analyzers and samplers. Each section includes tables showing when sites began operation and descriptions of each site, including the reason each site was established and how each site is classified.

As population in Colorado continues to grow and urban areas change, the APCD will continue to review the monitoring network and implement changes as needed. In the next few years, some areas are likely to need additional monitoring as populations exceed certain monitoring threshold levels. Other areas may receive Special Purpose Monitors (SPMs) based on local community concerns. SPM sites will continue to be operated as needed with review of the data every two years to see if continued monitoring is warranted. Areas determined to be at-risk based on growth levels and transportation issues are likely candidates for additional SPM monitoring.

Table 3.1 Monitoring Schedules



Note: http://www.epa.gov/ttnamti1/files/ambient/pm25/calendar_2014.pdf

Current federal regulations specify the frequency of sampling for criteria pollutants to meet minimum State Implementation Plan (SIP) surveillance requirements. Gaseous, meteorological, visibility, and many particulate analyzers are operated continuously. Manual particulate samplers can be operated every six days, every three days, or daily depending on anticipated particulate concentrations and network goals. The specific sampling days scheduled (assuming the minimum requirement of every six days) is based on the National Sampling Schedule (See Table 3.1) For a more detailed explanation of sampling, maintenance, and QC schedules, please refer to the method-specific Standard Operating Procedures (SOPs) located in the appendices of the CDPHE/APCD/TSP QAPP document.

3.1.2 RATIONALE FOR THE DESIGN

The rationale for the network design is to provide areas of optimum exposure and an excellent representativeness of population exposure to all criteria pollutants. Concepts are explicit or implicit in the standards and their implementation. These relate to how the criteria pollutant concentrations vary over a monitored area, how measurements correspond to population levels, and how nearby and distant sources affect measurement locations. Spatial uniformity is the extent to which particle concentrations vary over a specified area. It is expressed as a spatial coefficient of variation of measured concentrations from several monitors in an area and as the deviation of measurements taken by a single monitor from the spatial average of all monitors. Community-oriented (core) monitoring sites are beyond the zone of influence of a single source, and should represent the neighborhood- to urban- scale zones. The principal purpose of core monitoring sites is to approximate the short-term and long-term exposures of large numbers of people where they live, work, and play. Background sites are intended to quantify regionally representative concentrations for sites located away from populated areas and other significant emission sources. Transport sites are intended to measure pollution contributions from upwind source areas, or mixtures of source areas, that move into a planning area.

Most monitors being utilized within the network can be classified as primary or collocated. Primary monitors are used to measure compliance with national standards. The purpose of collocated monitors is to estimate the precision and bias of the various monitors, respectively. These levels of bias and precision are determined through the DQO/MQO process so

that decision makers can make decisions regarding the attainment and/or non-attainment status of the NAAQS with sufficient confidence.

Additional monitors being used are considered to be special purpose monitors (SPM). This allows APCD to monitor in areas of public concern or as part of a scientific study. These SPM monitors are not used for comparison to the NAAQS, unless they are located at a single sampling site for more than two calendar years

3.1.2.1 Primary Samplers and Analyzers

The primary purpose of the ambient air-monitoring program operated by APCD is to measure compliance with National Ambient Air Quality Standards (NAAQS) and to address the impact of population increases and local community concerns through Special Purpose Monitoring. The NAAQS are detailed in 40 CFR Part 50 and are summarized in Table 2.1. To be in compliance with the primary and secondary NAAQS, the following conditions must be met:

1. The three year average of the 99th percentile of the one hour daily maximum concentrations for sulfur dioxide may not exceed 75ppb. This is the primary standard for sulfur dioxide.
2. The second highest 3-hour average for sulfur dioxide is not to exceed 0.50ppm in a calendar year. This is a secondary standard.
3. The 24-hour primary and secondary PM_{10} standards are met when the expected number of days per calendar year with a 24-hour concentration above 150 $\mu g/m^3$ is less than or equal to one.
4. The 24-hour primary and secondary $PM_{2.5}$ standards are met when the 3-year average of the 98th percentile values at each monitoring site is less than or equal to 35 $\mu g/m^3$. This comparison shall be based on three consecutive years of ambient air quality data with at least 75% completeness of data. Data completeness is discussed in further detail in Appendix MQO.
5. The primary annual $PM_{2.5}$ standard is met when the 3-year average of the averaged annual mean is less than or equal to 12.0 $\mu g/m^3$. This is calculated by obtaining calendar quarterly means to get annual means at each monitor, and averaging 3 years of annual means to obtain the 3-year average.
6. The secondary annual $PM_{2.5}$ standard is met when the 3-year average of the averaged annual mean is less than or equal to 15.0 $\mu g/m^3$ This is calculated by obtaining calendar quarterly means to get annual means at each monitor, and averaging 3 years of annual means to obtain the 3-year average.
7. The 8-hour average concentration for carbon monoxide is not to exceed 9ppm more than once in a calendar year. This is a primary standard.
8. The 1 hour average concentration for carbon monoxide is not to exceed 35ppm more than once in a calendar year. This is a primary standard.
9. The three year average ozone standards are met at an ambient monitoring site when the average of the annual 4th highest daily maximum 8-hour average ozone concentration is less than or equal to 0.075ppm. An ozone monitoring day is considered valid if at least 18 of the 24 possible 8-hour averages are available for the day. Additionally, for the three year period 8 hour average concentrations must be available for at least 90% of the days during designated ozone season.
10. The annual arithmetic mean concentration for nitrogen dioxide is not to exceed 0.053ppm in a calendar year. This is a primary and a secondary standard.
11. The 1-hour primary NO_2 standard is met when the 3-year average of the 98th percentile value is less than or equal to 100ppb.
12. The rolling three month average of Lead concentrations is not to exceed 0.15$\mu g/m^3$. This is the primary standard.

3.1.2.2 Collocated Monitors

The purpose of collocated monitors and the NPEP performance evaluations are to estimate the precision, bias and accuracy of the various samplers or analyzers. The MQOs developed in Appendix MQO detail the allowable differences. Attaining these documented levels of precision, bias and accuracy must be met so that decision-makers can make evaluations about attainment and/or non-attainment of the NAAQS with sufficient confidence.

To estimate the level of bias and precision being achieved in the field, some of the sites will operate collocated samplers. If a sampler is operating within the required bias and precision levels, then the decision-maker can proceed knowing that the decisions will be supported by unambiguous data. If however, a sampler exceeds either the bias limits or the precision limits or both, then the decision-maker cannot use the data to make decisions at the desired level of confidence and

corrective action must be implemented to ensure that future data collected by the sampler does meet the bias and precision limits. Thus the key characteristics being measured with the QA samplers are bias and precision.

To estimate the level of accuracy being achieved in the field, sites will be audited with standardized equipment and methods that meet EPA criteria. Internal audits are performed by quality assurance staff to evaluate equipment accuracy and compliance with departmental MQOs. Equipment utilized in the performance of internal audits and equipment used in the calibration of analyzers and samplers are typically verified against a common laboratory standard. Because of this, true independence is not obtained and official accuracy values are not obtained by internal audits. To obtain true independence, NPEP audits are performed. NPAP equipment is certified against standards that are maintained by EPA and are considered to be independent from standards maintained by the state.

3.1.3 DESIGN ASSUMPTIONS

Chapter 1 of EPA *Data Quality Assessment: Statistical Methods for Practitioners* QA/G-9S and *Data Quality Assessment: A Reviewer's Guide* QA/G-9R provides an overview of sampling plans and the assumptions needed for their implementation. EPA *Guidance on Choosing a Sampling Design for Environmental Data Collection* QA/G-5S provides more detailed guidance on the construction of sampling plans to meet the requirements generated by the DQO Process.

The sampling design is based on the assumption that following the rules and guidance provided in the CFR and the Guidance for Network Design and Optimum Site Exposure for $PM_{2.5}$ and PM_{10} will result in data that can be used to measure compliance with the national standards. The APCD assumes that the levels of $PM_{2.5}$ concentrations are lower than PM_{10} concentrations. This information has generally been used in order to site supplemental samplers within a zone of PM_{10} influence in the Denver metropolitan area and to identify the location of regional background and transport sites. The only issue at the APCD's discretion is the monitor siting and the particulate sampling frequency. The basis for current site locations within the network and any future siting or sample frequency changes is described in the next section, 3.1.4.

3.1.4 PROCEDURE FOR LOCATING AND SELECTING ENVIRONMENTAL SAMPLING SITES

The need for comparability in ambient air quality data from sites throughout Colorado and the country require that the monitoring sites operated by the APCD adhere to a consistent set of station siting criteria. Air monitoring networks must be designed to both adequately represent air quality over a broad spatial area and also to monitor maximum concentrations of pollutants to which the population may be exposed. It is essential that as far as is practical, these monitoring locations be removed from potential interferences that would cause monitored pollutant levels to be unrepresentative of ambient conditions.

These EPA siting criteria are specified in the *Quality Assurance Handbook for Air Pollution Systems Volume II: Part I: Section 6* and in federal regulation 40 CFR Part 58, Appendices D and E, which discuss monitoring network design and probe and monitoring path siting criteria for ambient air quality monitoring. All APCD monitoring stations are reviewed by EPA Region VIII staff for adherence to these siting guidelines. Some special situations may prevent the APCD from following every aspect of the siting guidelines at a particular monitoring station. EPA Region VIII staff may then grant a waiver from some of these siting criteria.

The procedures for siting APCD samplers and analyzers are based on judgmental sampling, as is the case for most ambient air monitoring networks. Judgmental sampling uses data from existing monitoring networks, knowledge of source emission and population distribution, and inferences from analyses of meteorology to select optimal sampler locations.

The Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Part I, Section 6 and Section 7 describe in greater detail the materials covered in this section. Much of the content in this section comes directly from the QA handbook.

The APCD produces an annual Monitoring Network Plan, which details the rationale for each monitoring location, as well as any site deficiencies and corrective actions.

The development of a monitoring network of sites for a specific pollutant requires:

1. Understanding the monitoring objective(s).
2. Identifying the spatial scale most appropriate for the monitoring objective(s).
3. Identifying the general locations where the monitoring site(s) should be placed in order to collect a representative pollutant measurement.
4. Identifying specific monitoring sites.

This section describes the general concepts for establishing the State and Local Air Monitoring Stations (SLAMS), National Core (NCore), and open path monitoring. Additional details can be found in 40 CFR Part 58. Air quality samples are generally collected for one or more of the following purposes:

1. To provide air pollution data to the general public in a timely manner;
2. To support compliance with and/or progress made towards meeting ambient air quality standards;
3. To activate emergency control procedures that will prevent or alleviate air pollution episodes;
4. To observe pollution trends throughout the region, including non-urban areas;
5. To provide a database for research evaluation of urban, land-use, and transportation planning, development and evaluation of abatement strategies; and development and validation of diffusion models.
6. To support air pollution research studies.

3.1.4.1 Timely Air Quality Public Reporting - AIRNow

The U.S. EPA, NOAA, NPS, tribal, state, and local agencies developed the AIRNow website to provide the public with easy access to national air quality information. The Web site offers daily Air Quality Index (AQI):

Conditions - Nationwide and regional real-time ozone and $PM_{2.5}$ air quality maps covering 46 US States and parts of Canada. These maps are updated daily every hour. A click of a mouse brings up the U.S. map and a second click can bring up the AQI details of a region, state or local area within a state.

Forecasts - Nationwide daily air quality forecasts provided by monitoring organizations for over 300 major cities and areas in the U.S.

Federal requirements state that Metropolitan Statistical Areas (MSAs) with a population of more than 350,000 are required to report the AQI daily to the general public. The U.S. Office of Management and Budget defines MSAs according to the 2010 census. However, many other tribal, state and local monitoring organizations participate in AIRNow.

There are no specific network requirements or guidelines for reporting to AIRNow. Sites used for reporting to AIRNow are sites that have been set up for the other monitoring objectives discussed above. The air quality data used in these maps and to generate forecasts are collected using either federal reference or equivalent monitoring techniques or techniques approved by the monitoring organizations. Since the information needed to make maps must be as "real-time" as possible, the data are displayed as soon as practical after the end of each hour. Although some preliminary data quality assessments are performed, the data as such are not fully verified and validated through the quality assurance procedures monitoring organizations use to officially submit and certify data on the EPA AQS. Therefore, data are used on the AIRNow Web site only for the purpose of reporting the AQI. Information on the AIRNow web site is not used to formulate or support regulation, guidance or any other Agency decision or position.

3.1.4.2 Compliance Monitoring

The information required for selecting the number of samplers and the sampler locations include isopleths maps, population density maps, traffic count data, and source locations. The following are suggested guidelines:

- the priority area is the zone of highest pollution concentration within the region; one or more stations are to be located in this area,
- close attention should be given to densely populated areas within the region, especially when they are in the vicinity of a heavy pollution source,
- the quality of air entering the region is to be assessed by stations situated on the periphery of the region; meteorological factors (e.g., frequencies of wind directions) are of primary importance in locating these stations,

- sampling should be undertaken in areas of projected growth to determine the effects of future development on human health and the environment,
- a major objective of surveillance is evaluation of progress made in attaining the desired air quality; for this purpose, sampling stations should be strategically situated to facilitate evaluation of the implemented control tactics,
- some information of air quality should be available to represent all portions of the regions.

Some stations will be capable of fulfilling more than one of the functions indicated (for example, a station located in a densely populated area can indicate population exposures and can also document the changes in pollutant concentrations resulting from mitigation strategies used in the area).

3.1.4.3 Monitoring Objectives

The design of the SLAMS network must achieve one of six basic monitoring objectives, as described in 40 CFR Part 58, Appendix D. These objectives are:

1. Determine the highest concentrations expected to occur in the area covered by the network.
2. Measure typical concentrations in areas of high population density.
3. Determine the impact of significant sources or source categories on air quality.
4. Determine general background concentration levels.
5. Determine the extent of regional pollutant transport among populated areas; and in support of secondary standards.
6. Measure air pollution impacts on visibility, vegetation damage, or other welfare-based impacts.

3.1.4.4 Spatial Scales

Sampling equipment requirements are generally divided into three categories, consistent with the desired averaging times:

1. **Continuous** - Pollutant concentrations determined with automated methods and recorded or displayed continuously.
2. **Integrated** - Pollutant concentrations determined with manual or automated methods from integrated hourly or daily samples on a fixed schedule.
3. **Static -** Pollutant estimates or effects determined from long-term (weekly or monthly) exposure to qualitative measurement devices or materials.

Air monitoring sites that use automated equipment to continually sample and analyze pollutant levels may be classified as primary. Primary monitoring stations are generally located in areas where pollutant concentrations are expected to be among the highest and in areas with the highest population densities; thus, they are often used in health effects research networks. These stations are also designed as part of the air pollution episode warning system.

The goal in siting stations is to correctly match the spatial scale represented by the sample of monitored air with the spatial scale most appropriate for the monitoring objective of the station. The representative measurement scales of greatest interest are shown below:

Micro	Concentrations in air volumes associated with area dimensions ranging from several meters up to about 100 meters.
Middle	Concentrations typical of areas up to several city blocks in size with dimensions ranging from about 100 meters to 0.5 kilometer.
Neighborhood	Concentrations within some extended area of the city that has relatively uniform land use with dimensions in the 0.5 to 4.0 kilometers range.
Urban	Overall, citywide conditions with dimensions on the order of 4 to 50 kilometers. This scale would usually require more than one site for definition.
Regional	Usually a rural area of reasonably homogeneous geography and extends from tens to hundreds of kilometers.
National/Global	Concentrations characterizing the nation and the globe as a whole.

Table 3.2 illustrates the relationships among the four basic monitoring objectives and the scales of representativeness that are generally most appropriate for that objective. Table 3.3 provides more detailed spatial characteristics for each pollutant while Table 3.4 provides a summary for SLAMS and NCore sites.

Table 3.2 Relationship among Monitoring Objectives and Scales of Representativeness

Highest concentration	Micro, middle, neighborhood, sometimes urban/regional or secondarily formed
Population	Neighborhood, urban
Source impact	Micro, middle, neighborhood
General/background & Regional Transport	Urban/regional
Welfare-related	Urban/regional

Table 3.3 Characteristics of Spatial Scales Related to Each Pollutant

Pollutant	Spatial Scale	Characteristics
PM_{10}	Micro	Areas such as downtown street canyons and traffic corridors; generally not extending more than 15 meters from the roadway but could continue the length of the roadway. Sites should be located near inhabited buildings or locations where the general public can be expected to be exposed to the concentration measured.
	Middle	Measurements of this type would be appropriate for the evaluation of possible short-term public health effects of particulate matter pollution. This scale also includes the characteristic concentrations for other areas with dimensions of a few hundred meters such as the parking lot and feeder streets associated with shopping centers, stadiums, and office buildings. In the case of PM_{10}, unpaved or seldom swept parking lots associated with these sources could be an important source in addition to the vehicular emissions themselves.
	Neighborhood	Measurements in this category would represent conditions throughout some reasonably homogeneous urban sub-region with dimensions of a few kilometers. This category also includes industrial and commercial neighborhoods, as well as residential.
	Urban	This class of measurement would be made to characterize the particulate matter concentration over an entire metropolitan or rural area. Such measurements would be useful for assessing trends in area-wide air quality, and hence, the effectiveness of large scale air pollution control strategies.
	Regional	These measurements would characterize conditions over areas with dimensions of as much as hundreds of kilometers. Using representative conditions for an area implies some degree of homogeneity in that area. For this reason, regional scale measurements would be most applicable to sparsely populated areas with reasonably uniform ground cover. Data characteristics of this scale would provide information about larger scale processes of particulate matter emissions, losses and transport.
$PM_{2.5}$	Micro	Areas such as downtown street canyons and traffic corridors where the general public can be expected to be exposed to maximum concentrations from mobile sources. In some circumstances, the microscale is appropriate for particulate stations; core SLAMS on the microscale should however, be limited to urban sites that are representative of long term human exposure and of many such microenvironments in the area.
	Middle	Measurements of this type would be appropriate for the evaluation of possible short-term exposure public health effects of particulate matter pollution. This scale also included the characteristic concentrations for other areas with dimensions of a few hundred meters such as the parking lot and feeder streets associated with shopping centers, stadium, and office buildings.
	Neighborhood	Measurements in this category would represent conditions throughout some reasonably homogeneous urban sub-region with dimensions of a few kilometers and of generally more regular shape than middle scale. Much of the $PM_{2.5}$ exposures are expected to be associated with this scale of measurement. This category also includes industrial and commercial neighborhoods, as well as residential.
	Urban	This class of measurement would be made to characterize the particulate matter concentration over an entire metropolitan or rural area. Such measurements would be useful for assessing trends in area-wide air quality, and hence, the effectiveness of large scale air pollution control strategies.
	Regional	These measurements would characterize conditions over areas with dimensions of as much as hundreds of kilometers. Using representative conditions for an area implies some degree of homogeneity in that area. For this reason, regional scale measurements would be most applicable to sparsely populated areas with reasonably uniform ground cover. Data characteristics of this scale would provide information about larger scale processes of particulate matter emissions, losses and transport.

Table 3.3 Continued

Pollutant	Spatial Scale	Characteristics
SO_2	Middle	Assessing the effects of control strategies to reduce urban concentrations (especially for the 8-hour and 24-hour averaging times) and monitoring air pollution episodes.
	Neighborhood	This scale applies in areas where the SO_2 concentration gradient is relatively flat (mainly suburban areas surrounding the urban center) or in large sections of small cities and towns. May be associated with baseline concentrations in areas of projected growth.
	Urban	Data from this scale could be used for the assessment of air quality trends and the effect of control strategies on urban scale air quality.
	Regional	Provide information on background air quality and interregional pollutant transport.
CO	Micro	Measurements on this scale would represent distributions within street canyons, over sidewalks, and near major roadways.
	Middle	This category covers dimensions from 100 meters to 0.5 kilometer. In certain cases, it may apply to regions that have a total length of several kilometers. If an attempt is made to characterize street-side conditions throughout the downtown area or along an extended stretch of freeway, the dimensions may be tens of meters by kilometers. Also included are the parking lots and feeder streets associated with indirect sources (shopping centers, stadia, and office buildings) which attract significant numbers of pollutant emitters.
	Neighborhood	Homogeneous urban sub-regions, with dimensions of a few kilometers.
O_3	Middle	Represents conditions close to sources of NO_x such as roads where it would be expected that suppression of O_3 concentrations would occur.
	Neighborhood	Represents conditions throughout some reasonably homogeneous urban sub-region, with dimensions of a few kilometers. Useful for developing, testing, and revising concepts and models that describe urban/regional concentration patterns.
	Urban	Used to estimate concentrations over large portions of an urban area with dimensions of several kilometers to 50 or more kilometers. Such measurements will be used for determining trends, and designing area-wide control strategies. The urban scale stations would also be used to measure high concentrations downwind of the area having the highest precursor emissions.
	Regional	Used to typify concentrations over large portions of a metropolitan area and even larger areas with dimensions of as much as hundreds of kilometers. Such measurements will be useful for assessing the ozone that is transported into an urban area.
NO_x	Middle	Dimensions from about 100 meters to 0.5 kilometer. These measurements would characterize the public exposure to NO_x in populated areas.
	Neighborhood	Same as for O_3.
	Urban	Same as for O_3.

Table 3.3 Continued

Pollutant	Spatial Scale	Characteristics
Pb	Micro	Would typify areas such as downtown street canyons and traffic corridors where the general public would be exposed to maximum concentrations from mobile sources. Because of the very steep ambient Pb gradients resulting from Pb emissions from mobile sources, the dimensions of the Micro scale for Pb generally would not extend beyond 15 meters from the roadway.
	Middle	Represents Pb air quality levels in areas up to several city blocks in size with dimensions on the order of approximately 100 meters to 500 meters. However, the dimensions for middle scale roadway type stations would probably be on the order of 50-150 meters because of the exponential decrease in lead concentration with increasing distances from roadways. The middle scale may for example, include schools and playgrounds in center city areas that are close to major roadways.
	Neighborhood	Would characterize air quality conditions throughout some relatively uniform land use areas with dimensions in the 0.5 to 4.0 kilometer range. Stations of this scale would provide monitoring data in areas representing conditions where children live and play.
	Urban	Would be used to present ambient Pb concentrations over an entire metropolitan area with dimensions in the 4 to 50 kilometer range.

Table 3.4 Summary of Spatial Scales for SLAMS, NCore, PAMS, and Open Path (OP) Sites

Spatial Scale	SLAMS Sites[1]							$PM_{10-2.5}$	NCore	CSN	NATTs	PAMS	OP
	SO_2	CO	O_3	NO_2	Pb	PM_{10}	$PM_{2.5}$						
Micro	*	*		*	*	*	*	*					
Middle	*	*		*	*	*	*	*					*
Neighbor-hood	*	*	*	*	*	*	*	*	*	*	*	*	*
Urban	*		*	*			*		*	*	*	*	*
Regional			*				*		*		*		*

[1] SLAMS Site scales based on the current listing in 40 CFR Part 58, Appendix D and do not include NCore spatial scale objective.

3.1.4.5 Monitoring Boundaries

The NAAQS refer to several boundaries that are defined below. These definitions are derived from the U.S. Office of Management and Budget (OMB).

Core-based Statistical Area (CBSA): is defined by the OMB as a statistical geographic entity consisting of the county or counties associated with at least one urbanized area/urban cluster of at least 10,000 population, plus adjacent counties having a high degree of social and economic integration.

Metropolitan Statistical Area (MSA): a category of CBSA with a population greater than 50,000.

Micropolitan Statistical Area: a category of CBSA with a population between 10,000 and 50,000.

Combined Statistical Area (CSA): is defined by the OMB as a geographical area consisting of two or more adjacent CBSAs with employment interchange of at least 15 percent. Combination is automatic if the employment interchange is 25 percent and determined by local opinion if more than 15 but less than 25 percent.

Monitoring Planning Area (MPA): means a contiguous geographic area with established, well defined boundaries, such as a CBSA, county or State, having a common area that is used for planning monitoring locations for $PM_{2.5}$. An MPA may cross State boundaries, such as the Philadelphia PA–NJ MSA, and be further subdivided into community monitoring zones. MPAs are generally oriented toward CBSAs or CSAs with populations greater than 200,000, but for convenience, those portions of a State that are not associated with CBSAs can be considered as a single MPA.

Community Monitoring Zone (CMZ): means an optional averaging area with established, well defined boundaries, such as county or census block, within an MPA that has relatively uniform concentrations of annual $PM_{2.5}$ as defined by 40 CFR Part 50, Appendix N.

3.1.4.6 Monitoring Site Location

Location of the monitoring site is initially dependent on the monitoring objective. For example, once it is known that there is a requirement to monitor for peak ambient CO at a microscale site, it reduces the monitoring site location to specific areas. Hence, the first task when evaluating a possible site location is to determine the scale for which a candidate location can qualify by considering the following:

1. location and emissions strengths of nearby sources, especially major source
2. prevailing wind direction in the area
3. nearby uniformity of land use
4. nearby population density

To select locations according to these criteria, it is necessary to have detailed information on the location of emission sources, geographical variability of ambient pollutant concentrations, meteorological conditions and population density. Therefore, selection of the number, locations and types of sampling stations is a complex process. The variability of

sources and their intensities of emissions, terrains, meteorological conditions and demographic features require that each network be developed individually. Thus, selection of the network will be based upon the best available evidence and on the experience of the decision team.

Economics: The amount of resources required for the entire data collection activity, including instrumentation, installation, maintenance, data retrieval, data analysis, quality assurance and data interpretation.

Security: Experience has shown that in some cases, a particular site may not be appropriate for the establishment of an ambient monitoring station simply due to problems with the security of the equipment in a certain area. If the problems cannot be remedied via the use of standard security measures such as lighting, fences, etc., then attempts should be made to locate the site as near to the identified sector as possible while maintaining adequate security.

Logistics: Logistics is the process of dealing with the procurement, maintenance, and transportation of material and personnel for a monitoring operation. This process requires the full knowledge of all aspects of the data collection operation including:

Planning
Staffing
Reconnaissance
Procurement of goods and services
Training
Communications
Scheduling
Inventory
Safety
Power requirements/availability
Land/building owner permission

Atmospheric considerations: Atmospheric considerations may include spatial and temporal variability of the pollutants and their transport. Effects of buildings, terrain, and heat sources or sinks on the air trajectories can produce local anomalies of excessive pollutant concentrations. Meteorology must be considered in determining not only the geographical location of a monitoring site but also such factors as height, direction, and extension of sampling probes. The following meteorological factors can greatly influence the dispersal of pollutants:

Wind speed affects the travel time from the pollutant source to the receptor and the dilution of polluted air in the downwind direction. The concentrations of air pollutants are inversely proportional to the wind speed.

Wind direction influences the general movements of pollutants in the atmosphere. Review of available data can indicate mean wind direction in the vicinity of the major sources of emissions.

Wind variability refers to the random motions in both horizontal and vertical velocity components of the wind. These random motions can be considered atmospheric turbulence, which is either mechanical (caused by structures and changes in terrain) or thermal (caused by heating and cooling of land masses or bodies of water). If the scale of turbulent motion is larger than the size of the pollutant plume, the turbulence will move the entire plume and cause looping and fanning; if smaller, it will cause the plume to diffuse and spread out.

If regularities exist with the meteorological phenomena, data may need to be interpreted with regards to these atmospheric conditions. Other meteorological conditions to consider are atmospheric stability and lapse rate.

More detailed guidance for meteorological considerations is available in the *Guidelines for Evaluation of Air Quality Data*. Relevant weather information such as stability-wind roses is usually available from local National Weather Service stations.

Meteorological conditions, particularly those that can affect light transmission, should also be considered in selecting the location for open path analyzers (e.g., the influence of relative humidity on the creation of fog, the percentage of heavy snow, and the possible formation of haze, etc.). The percent fog, percent snow fall, percent haze, and hourly visibility (from nearest airport) may impact data completeness.

Topography: Both the transport and the diffusion of air pollutants are complicated by topographical features. Minor topographical features may exert small influences; major features, such as deep river valleys or mountain ranges may affect large areas. Before final site selection, the topography of the area should be reviewed to ensure that the purpose of monitoring at that site will not be adversely affected. Table 3.5 summarizes important topographical features, their effects on air flow, and some examples of influences on monitoring site selection. Land use and topographical characterization of specific areas can be determined from U.S. Geological Survey (USGS) maps as well as from land use maps.

Table 3.5 Relationships of Topography, Air Flow, and Monitoring Site Selection

Topographical feature	Influence on air flow	Influence on monitoring site selection
Slope/Valley	Downward air currents at night and on cold days; up slope winds on clear days when valley heating occurs. Slope winds and valley channeled winds; tendency toward down-slope and down-valley winds; tendency toward inversions.	Slopes and valleys are special sites for air monitors because pollutants generally are well dispersed, concentration levels not representative of other geographic areas, possible placement of monitor to determine concentration levels in a population or industrial center in valley.
Water	Sea or lake breezes inland or parallel to shoreline during the day or in cold weather; land breezes at night.	Monitors on shorelines generally for background readings or for obtaining pollution data on water traffic.
Hill	Sharp ridges causing turbulence; air flow around obstructions during stable conditions, but over obstructions during unstable conditions.	Depends on source orientation; upwind source emissions generally mix down the slope, and siting at foot of hill not generally advantageous; downwind source emissions generally down washed near the source; monitoring close to a source generally desirable if population centers adjacent or if monitoring protects workers.
Natural or manmade obstruction	Eddy effects.	Placement near obstructions not generally representative in readings.

Pollutant Considerations: A sampling site or an array of sites for one pollutant may be appropriate for another pollutant species because of the configuration of sources, the local meteorology, or the terrain. Pollutants undergo changes in their compositions between their emission and their receptor; therefore, the impact of that change on the measuring system should be considered. Atmospheric chemical reactions such as the production of O_3 in the presence of NO_x and hydrocarbons (HCs) and the time delay between the emission of NO_x and HCs and the detection peak of O_3 values may require either a sampling network for the precursors of O_3 and/or a different network for the actual O_3 measurement.

None of the factors mentioned above stand alone. Each is dependent, in part, on the others. However, the objective of the sampling program must be clearly defined before the selection process can be initiated, and the initial definition of priorities may have to be reevaluated after consideration of the remaining factors and before the final site selection. While the interactions of the factors are complex, the site selection problems can be resolved. Experience in the operation of air quality measurement systems, estimates of air quality, field and theoretical studies of air diffusion, and considerations of atmospheric chemistry and air pollution effects make up the required expertise needed to select the optimum sampling site for obtaining data representative of the monitoring objectives.

3.1.4.7 SLAMS/NCore Monitor Placement

Final placement of the monitor at a selected site depends on physical obstructions and activities in the immediate area, accessibility/availability of utilities and other support facilities in correlation with the defined purpose of the specific monitor and its design. Because obstructions such as trees and fences can significantly alter the air flow, monitors should be placed away from obstructions. It is important for air flow around the monitor to be representative of the general air flow in the area to prevent sampling bias. Detailed information on urban physiography (e.g., buildings, street dimensions) can be determined through visual observations, aerial photography and surveys. Such information can be important in determining the exact locations of pollutant sources in and around the prospective monitoring site areas.

Network designers should avoid sampling locations that are unduly influenced by down wash or ground dust (e.g., a rooftop air inlet near a stack or a ground-level inlet near an unpaved road); in these cases, the sample intake should either be elevated above the level of the maximum ground turbulence effect or placed at a reasonable distance from the source of ground dust.

Depending on the defined monitoring objective, the monitors are placed according to exposure to pollution.
Due to the various physical and meteorological constraints discussed above, tradeoffs will be made to locate a site in order to optimize representativeness of sample collection. The consideration should include categorization of sites relative to their local placements. Suggested categories relating to sample site placement for measuring a corresponding pollution impact are identified in Table 3.6.

Table 3.6 Relationships of Topography, Air Flow, and Monitoring Site Selection

Station Category	**Characterization**
A (ground level)	Heavy pollutant concentrations, high potential for pollutant buildup. A site 3 to 5 m (10-16 ft) from major traffic artery and that has local terrain features restricting ventilation. A sampler probe that is 3 to 6 m (10-20 ft) above ground.
B (ground level)	Heavy pollutant concentrations, minimal potential for a pollutant buildup. A site 3 to 15 m (15-50 ft) from a major traffic artery, with good natural ventilation. A sampler probe that is 3 to 6 m (10-20 ft) above ground.
C (ground level)	Moderate pollutant concentrations. A site 15 to 60 m (5-200 ft) from a major traffic artery. A sampler probe that is 3 to 6 m (10-20 ft) above ground.
D (ground level)	Low pollutant concentrations. A site > 60m (> 200 ft) from a traffic artery. A sampler probe that is 3 to 6 m (10-20 ft) above ground.
E (air mass)	Sampler probe that is between 6 and 45 m (20-150 ft) above ground. Two subclasses: (1) good exposure from all sides (e.g., on top of building) or (2) directionally biased exposure (e.g., probe extended from window).
F (source-oriented)	A sampler that is adjacent to a point source. Monitoring that yields data directly related to the emission source.

3.1.4.8 Minimum Network Requirements

Tables 3-7 identifies the numbers of core SLAMs goals for the $PM_{2.5}$ Network.

Table 3.7 $PM_{2.5}$ Core SLAMS Sites Related to MSA

MSA Population	Min Required No. of Core Sites[1]
>1 Million	3
>2 Million	4
>4 Million	6
>6 Million	8
>8 Million	10

[1] Core SLAMS at PAMS are in addition to this number

3.1.4.9 Sensor Exposure Criteria

Ideally, in most ambient air quality monitoring applications, the inlet probe will be at or near breathing height, typically about three meters above ground level. The inlet must also be sited away from nearby obstructions, which would interfere with free transport of polluted air to the station monitoring equipment. Table 3.8 is from 40 CFR 58 Appendix E, gives general sensor exposure criteria. Table 3.9 defines required separation distances between roads and monitoring probes.

3.1.4.9.a Sulfur Dioxide (SO_2) Analyzers

The SO_2 intake probe must be 2 to 15 m above the ground. The probe must be at least one meter away, both vertically and horizontally, from any supporting structure. The probe must be at least 1 m away from any small local obstruction, such as a pipe, pole, etc., and at least 1 m from any other analyzer probe intakes. The probe must be at least 20 m from any trees or shrubs extending higher than the sampler intake. The distance shall be measured from the drip-line or outside edge of the crown, not the trunk. If the tree or shrub acts as an obstruction, the distance from the drip-line to the probe shall not be less than 10m. For monitors to be operated at the same site for several years, it is best to allow some additional space for vegetation growth. Because of their ability to alter normal wind flows and provide surfaces for SO_2 deposition or absorption, trees and shrubs shall not be located between a source and the analyzer. In a situation where trees or shrubs could be considered an obstruction (this is particularly true of large coniferous trees), the distance between the tree or shrubs and the sampler shall be either at least 10 m or twice the height the tree protrudes above the sampler intake, whichever is greater. The distance between the probe and any large obstruction higher than the probe must be more than twice the height that the obstruction extends above the probe. There must be no minor sources of SO_2 (coal or oil fired stoves or furnaces) within 100 m of the probe intake.

The analyzer must have an unrestricted airflow in at least a 270^o arc around the analyzer. The arc must include the predominant wind directions and any major sources in the area. An exception is made for probes located on the sides of buildings for measuring street canyon pollution in urban areas. In these cases, the probe must have an unrestricted airflow of 180^o. For an explanation of these and other siting criteria, please see 40 CFR Part 58, Appendix E.

3.1.4.9.b Carbon Monoxide (CO) Analyzers

If the site is a city street canyon and the desired measurement scale is micro scale, the probe intake must be located 3 m ±0.5 m above the ground. Other measurement scales require the probe to be 2 to 15 m above the ground. In both cases the probe inlet must be at least one meter horizontally or vertically away from any supporting structures. The probe intake shall be at least 2 m from any small local obstruction such as a pipe or pole, and at least 2 m from any other analyzer probe intake. The major concern with trees and shrubs is their ability to alter normal wind flow patterns. Thus for middle and neighborhood scale stations, trees and shrubs shall not be located between the major sources of CO, usually vehicles on a

heavily traveled road, and the analyzer. In addition, the analyzer shall be located at least 20 m from all trees. The distance must be measured from the drip-line or outside edge of the crown, not the truck. For monitors to be located at the same site for several years, additional space must be provided when siting monitors adjacent to trees or shrubs to accommodate vegetation growth. In situations where trees or shrubs could be considered an obstruction (this particularly true of large coniferous trees), the distance between the trees or shrubs shall be either at least 10 meters or twice the height the tree protrudes above the sampler intake, whichever is greater. The distance between the probe and any large obstruction higher than the probe must be more than twice the height that the obstruction extends above the ground. For a micro scale station, no trees or shrubs should be located between the probe inlet and the road.

The analyzer must have an unrestricted airflow in at least a 270^{o} arc around the analyzer. The arc must include the predominant wind directions and any major sources in the area. An exception is made for probes located on the sides of buildings for measuring street canyon pollution in urban areas. In these cases, the probe must have an unrestricted airflow of 180^{o}. For street traffic micro scale monitoring, the probe must be 2 to 10 m from the roadway and at least 10 m from an intersection. A mid-block location is preferred. For neighborhood or larger scales, use the data in Table 3.9 to calculate the required separation distance from the nearest traffic lane.

Sites set up to monitor CO from wood-fired residential heating should be classed as neighborhood and sited accordingly. For an explanation of these and other siting criteria, please see 40 CFR Part 58, Appendix E.

3.1.4.9.c Ozone (O_3) Analyzers

The probe intake is to be located from 2 to 15 m above the ground. The probe is to be more than 1 meter horizontally or vertically away from any supporting structures. The probe intake shall be at least 2 m from any small local obstructions such as a pipe, pole, etc., and at least 2 m from any other analyzer probe intake. It shall be at least 20 m away from any trees or shrubs. Because of their ability to alter normal wind flow patterns and provide surfaces for absorption or reactions (the scavenging effect of vegetation is greater for ozone than for other criteria pollutants), trees and shrubs shall be located between a nearby source and the analyzer. Analyzers monitoring O_3 transport over a long distance, such as from an urban city core area, shall be sited so that no trees are within 20 m of the analyzer inlet on the predominant summer daytime wind direction. The distance shall be measured form the drip-line of outside edge of the crow, not the trunk. For monitors to be operated at the same site for several years, it is best to allow some additional space for vegetation growth. In situations where trees or shrubs could be considered an obstruction (this is particularly true for large coniferous trees), the distance between the trees or shrubs and the sampler shall be either at least 10 m or twice the height the tree protrudes above the sampler intake, whichever is greater. The distance between the probe and any large obstruction higher than the probe must be more than twice the height that the obstruction extends above the probe.

The analyzer must have an unrestricted airflow in at least a 270^{o} arc around the analyzer. The arc must include the predominant wind directions and any major sources in the area. An exception is made for probes located on the sides of buildings for measuring street canyon pollution in urban areas. In these cases, the probe must have an unrestricted airflow of 180^{o}. The probe must be separated from the traffic lane according to the information in Table 3.9.

No sinks (plants that remove O_3 from the atmosphere, especially legumes such as peas, alfalfa, clover and beans) should be within the micro scale (100m) of the monitor. For an explanation of these and other siting criteria, please see 40 CFR Part 58, Appendix E.

3.1.4.9.d Nitrogen Oxides (NO_x) Analyzers

The siting criteria for NO_x analyzers are identical to the criteria for ozone analyzers.

3.1.4.9.e Meteorological Sensors

The siting criteria for meteorological sensors vary greatly from parameter to parameter. Because of the variation, the siting criteria are discussed below on a parameter-by-parameter basis.

Instruments shall be mounted on booms at the top of, or projecting horizontally from, the tower. The booms shall be securely fastened to the tower and shall be strong enough so that they will not sway or vibrate in strong winds. Wind instruments shall be mounted on a boom so that the sensors are twice the maximum diameter or diagonal of the tower away for the tower. The boom or cross arm shall project true north and south and shall be used for orienting the wind direction sensors. Wind sensors shall be mounted on booms or cross arms so that a sensor's wake does not impact adjacent sensors.

Usually, this means mounting the sensors a minimum of 2 meters apart. If the wind sensors are to be mounted on top of a tower, they shall be mounted at a height and distance from the tower so that the diagonal distance between the sensor and tower is equal to twice the maximum diameter of diagonal of the tower.

Temperature sensors that are to be mounted on a boom shall be mounted with a length that is greater than the diameter of the tower and the height at which the boom is mounted. The temperature sensors should always be mounted on the south side of the tower. Temperature sensors that are mechanically aspirated shall have a downward-facing shielding.

Towers
The sensors should be securely mounted on a mast (tower or pole) that will not twist, rotate or sway. A tower shall be of an open grid-type construction and be rigid enough to maintain all mounted instruments in proper alignment and orientation in high winds.

When instruments are located on a cross arm projecting out from the tower, the cross arms shall be securely fastened to the tower and shall be strong enough so that the sensors do not sway or vibrate in high winds. The sensors shall be securely fastened to the cross arm at a distance of two tower diameters or widths, measured from the edge of the tower to the sensor, to avoid any influence of tower-induced turbulence on the sensor. The cross arm shall be installed so that it is horizontally level and the sensors shall be installed so that they are vertical. The cross arm shall be mounted and aligned so that the wind direction sensor is correctly aligned. The correct alignment varies on a sensor–by-sensor basis. Consult the appropriate section of manufacturer's operator's manual for the correct alignment.

Wind Velocity and Direction Sensors
If the wind sensors are to measure surface level winds, the sensors should be located on a 10 m tower in open terrain. Open terrain is defined as an area where the distance between the tower's base and any obstruction is at least ten times the height of an obstruction above the instrument. This applies to manmade (buildings) and natural (tree or hills) obstructions. All distances are to be measured from the edge of the obstruction nearest the tower. Trees and shrubs shall be measured from the outside edge of the crown or drip-line, and not the trunk.

If sensors (and tower) are to be located in areas of uneven terrain or terrain containing obstacles, refer to Table 3-10 for the limits for terrain variations and obstacle height near the tower.

Temperature and Humidity Sensors

Temperature and humidity sensors shall be mounted over an open plot of short grass or natural earth (not concrete or asphalt) at least 9 m in diameter. A height of 1.25 to 2 m above the ground surface is the standard height for mounting temperature and humidity sensors, but tower mounting, as is the case in most air pollution/meteorological monitoring application, is also acceptable. Wherever the sensors are mounted, the height of the sensor should be measured and recorded.

The sensors shall be no closer to obstructions than a distance of four times the height differential between the height of the sensor and the height of the obstruction. This applies to both manmade and natural obstructions.

The distance shall be measured from the edge of the crown or drip-line of the vegetation, not the trunk. The sensors shall be positioned at a minimum of 30 m from large paved areas (streets, parking lots, etc.), steep slopes, ridges, hollows, or bodies of standing water. Temperature probes shall be located so that they are not influenced by heat leakage from the shelter containing the electronics and recorders for the meteorological equipment.

3.1.4.9.f Visibility Analyzers

The siting criteria for visibility monitors must allow for the considerable differences among the monitors themselves (e.g., integrating nephelometer vs. transmissometer). The siting criteria listed below are the general siting criteria. When a specific monitor is to be installed, APCD staff shall be contacted to review the proposed site, instrument specifications, and monitoring objectives to insure that the monitoring objectives will be met.

When siting a visibility monitor that uses a probe, the probe should be located from 2 to 15 m above the ground. The probe is to be more than 1 m vertically and horizontally away from any supporting structure, and at least 2 m from any nearby small obstruction (poles, pipes, cables, etc., or other sampler or probe intakes). The distance between the probe and any obstacle that protrudes above the probe must be more than twice the height that the obstruction extends above the probe.

The probe should be located a minimum of 220 m from any shrubs or trees. This distance shall be measured form the drip-line or edge of the crown and not the trunk. If the monitors are to be retained at the site for multiple years, additional space must be provided when siting monitors adjacent to trees or shrubs to accommodate vegetation growth. In situations where trees or shrubs could be considered an obstruction (this is particularly true of coniferous tree), the distance between the trees or shrubs and the probe shall be either at least 20 m or twice the height that the trees or shrubs protrude above the probe intake, whichever is greater.

The analyzer must have an unrestricted airflow in at least a 270^{o} arc around the analyzer. The arc must include the predominant wind directions and any major sources in the area. An exception is made for probes located on the sides of buildings for measuring street canyon pollution in urban areas. In these cases, the probe must have an unrestricted airflow of 180^{o}.

Visibility monitors requiring clear lines of sight (transmissometers) should have several targets (mountains or other permanent landmarks) visible from the same vantage point and at varying distances (2 to50 km) from the site. This requires an open field of view in at least one direction. There should be no micro scale sources of any pollutant within 100 m of the monitor and no sources of any visible pollutant within 100 m (one either side) of a centerline running from the monitor to the target.

3.1.4.9.g PM_{10} Monitors

When monitoring PM_{10}, it is important to select a site or sites where the collected particulate mass is representative of the monitored area. Optimum placement of the sampling inlet for PM_{10} is at breathing height level. However, practical factors such as prevention of vandalism, security, and safety precautions must also be considered. Given these considerations, the monitor inlets for micro scale PM_{10} monitors must be between 2 and 7 m above the ground. For middle or larger spatial scales the inlet must be 2 to 15 m above the ground.

If the monitor is located on a roof or other structure, there must be 2 m separation for walls, parapets, penthouses, etc. No furnace or incineration flues should be nearby. Collocated monitors must be at least 2 m, but not greater than 4 m away from each other.

Monitors should be located at least 20 m from the drip-line of the nearest trees, but must be 10 m from the drip-line when it acts as an obstruction. The monitor must be located away from obstacles such as buildings, so that the distance between the obstacle and the monitor is at least two times the height that the obstacle protrudes above the monitor.

There must be unrestricted airflow in an arc of at least 270^{o} around the monitor. The predominant wind direction for the season with the greatest pollutant concentration potential must be included in the 270^{o} unrestricted arc. If the monitor is to measure concentrations from a road or point source, there must be no obstruction between the road or point source and the monitor, even when other spacing from obstruction criteria is met.

There are many factors to be considered in establishing a particulate sampling location. These include accessibility under all weather conditions, availability of adequate electricity, and the security of the monitoring personnel and equipment. The monitor must be situated where the operator can reach it safely despite adverse weather conditions. If the monitor is located on a rooftop, care should be taken so that the operator's personal safety is not jeopardized by a slippery roof surface. Consideration should also be given to the fact that routine operational procedures such as calibration, maintenance, and filter installation and recovery involve transporting supplies and equipment to and from the monitoring site.

The lack of a suitable power source can often result in the loss of many samples because of power interruptions or fluctuations. To ensure that adequate power is available, consult the manufacture's instruction manual for the sampler's minimum amperage requirements.

The security of the sampler depends mostly on the location. Rooftop sites with locked access and ground level sites with fences are common. In all cases, the security of the operating personnel as well as the sampler should be considered.

3.1.4.9.h $PM_{2.5}$ Monitors

When monitoring $PM_{2.5}$, it is important to select a site or sites where the collected particulate mass is representative of the monitored area. Optimum placement of the sampling inlet for $PM_{2.5}$ is at breathing height level. However, practical factors such as prevention of vandalism, security, and safety precautions must also be considered. Given these considerations, the monitor's inlet for micro scale $PM_{2.5}$ monitors must be between 2 and 7 m above the ground. For middle or larger spatial scales the inlet must be 2 to 15 m above the ground.

If the monitor is located on a roof or other structure, there must be 2 m separation for walls, parapets, penthouses, etc. No furnace or incineration flues should be nearby. Collocated monitors must be at least 2 m, but not greater than 4 m away from each other.

Monitors should be located at least 20 m from the drip-line of the nearest trees, but must be 10 m from the drip-line when it acts as an obstruction. The monitor must be located away from obstacles such as buildings, so that the distance between the obstacle and the monitor is at least two-times the height that the obstacle protrudes above the monitor.

There must be unrestricted airflow in an arc of at least 270^o around the monitor. The predominant wind direction for the season with the greatest pollutant concentration potential must be included in the 270^o unrestricted arc. If the monitor is to measure concentrations from a road or point source, there must be no obstruction between the road or point source and the monitor, even when other spacing from obstruction criteria is met.

There are many factors to be considered in establishing a particulate sampling location. These include accessibility under all weather conditions, availability of adequate electricity, and the security of the monitoring personnel and equipment. The monitor must be situated where the operator can reach it safely despite adverse weather conditions. If the monitor is located on a rooftop, care should be taken so that the operator's personal safety is not jeopardized by a slippery roof surface. Consideration should also be given to the fact that routine operational procedures such as calibration, maintenance, and filter installation and recovery involve transporting supplies and equipment to and from the monitoring site.

The lack of a suitable power source can often result in the loss of many samples because of power interruptions or fluctuations. To ensure that adequate power is available, consult the manufacture's instruction manual for the sampler's minimum amperage requirements.

The security of the sampler depends mostly on the location. Rooftop sites with locked access and ground level sites with fences are common. In all cases, the security of the operating personnel as well as the sampler should be considered.

Table 3.8 Summary of Probe and Monitoring Path Siting Criteria

Table E-4 of Appendix E to Part 58					
Pollutant	Scale (maximum monitoring path length, meters	Height from ground to probe, inlet or 80% of monitoring path[1]	Horizontal and vertical distance from supporting structures[2] to probe, inlet or 90% of monitoring path[1] (meters)	Distance from trees to probe, inlet or 90% of monitoring path[1] (meters)	Distance from roadways to probe, inlet or monitoring path[1] (meters)
SO_2[3,4,5,6]	(300m) Middle (1 km) Neighborhood, Urban and Regional	2-15	>1	>10	N/A
CO[4,5,7]	(300m) Micro, Middle (1 km) Neighborhood	3±½: 2-15	>1	>10	2-10; see Table 3-9
NO_2, O_3[3,4,5]	(300m) Middle (1 km) Neighborhood, Urban and Regional	2-15	>1	>10	see Table 3-9
O_3 precursors (PAMS)[3,4,5]	(1 km) Neighborhood and Urban	2-15	>1	>10	see Table 3-9
PM, Pb[3,4,5,6,8]	Mirco: Middle, Neighborhood, Urban, Regional	2-7 Micro 2-7 Middle ($PM_{10-2.5}$) 2-15 (all other scales	>2 (all scales, horizontal distance only)	>10 (all scales)	2-10 (micro); see Table 3-9

N/A – Not applicable

[1] Monitoring path for open path analyzers is applicable only to middle or neighborhood scale CO monitoring and all applicable scales for monitoring SO_2, O_3, O_3 precursors and NO_2.

[2] When probe is located on a rooftop, this separation distance is in reference to walls, parapets, or penthouses located on roof.

[3] Should be > 20 meters from the drip-line of tree(s) and must be 10 meters from the drip-line when the tree(s) act as an obstruction.

[4] Distance from sampler, probe, or monitoring path. Sites not meeting this criterion may be classified as middle scale.

[5] Must have unrestricted airflow 270 degrees around the probe or sampler; 180 degrees if the probe is on the side of a building.

[6] The probe, sampler, or monitoring path should be away from minor sources, such as furnace or incineration flues. The separation distance is dependent on the height of the minor source's emission point, the type of fuel or waste burned, and the quality of the fuel. This criterion is designed to avoid undue influences form minor sources.

[7] For microscale CO monitoring sites, the probe must be >10 meters from a street intersection and preferably at a mid-block location.

[8] Collocated monitors must be within 4 meters of each other and at least 2 meters apart for flow rates greater than 200 liters/min or at least 1 meter apart for samplers having flow rates less than 200 liters/min to preclude airflow interference.

Table 3.9 Minimum Separation Distance Between Roadways and Sampling Probes or Monitoring Paths at Neighborhood and Urban Scales for O_3, Oxides of Nitrogen (NO, NO_2, NO_x, NO_y) and CO

Roadway average daily traffic vehicles per day	O_3 and Oxides of N Neighborhood & Urban [1](meters)	O_3 and Oxides of N Neighborhood. & Urban [1& 2](meters)	CO Neighborhood (meters)
≤ 1,000	10	10	
10,000	10	20	
≤ 10,000			10
15,000	20	30	25
20,000	30	40	45
30,000			80
40,000	50	60	115
50,000			135
≥ 60,000			150
70,000	100	100	
≥110,000	250	250	

[1]Distance from the edge of the nearest traffic lane. The distance for intermediate traffic counts should be interpolated from the table values based on the actual traffic count.
[2] Applicable for ozone monitors whose placement has not already been approved as of December 18, 2006.

Table 3.10 Limits on Terrain and Obstacles Near Towers

Distance from Tower (m)	Slope, No Greater Than (%)	Max Obstruction or Vegetation Height (m)
0 -15	± 2	0.3
15 - 30	± 3	0.5 – 1.0 (most vegetation < 0.3)
30 – 100	± 7	3.0
100 - 300	± 11	10 x Height *
* Tower must be more than 10x height away from obstruction or vegetation		

3.1.4.10 Actual Network

The APCD produces an annual Monitoring Network Review report, which details the rationale for each monitoring location, as well as any site deficiencies and corrective actions.

Figures 3.1 through 3.4 are maps showing current (as of January 2014) locations of samplers and analyzers throughout the APCD ambient air monitoring network.

Figure 3.1 Particulate Monitors in the Denver Metro Area

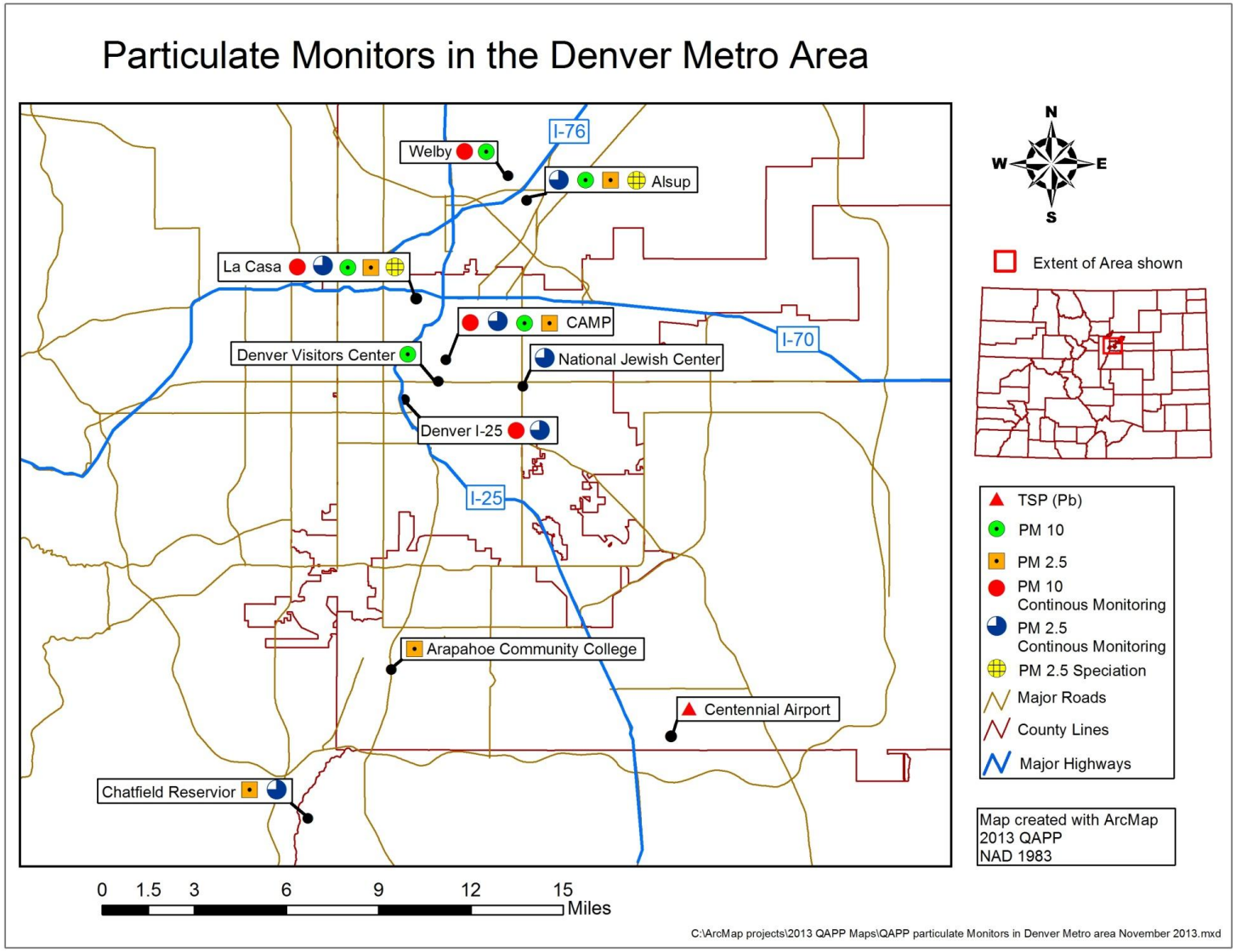


Figure 3.2 Particulate Monitors in Colorado

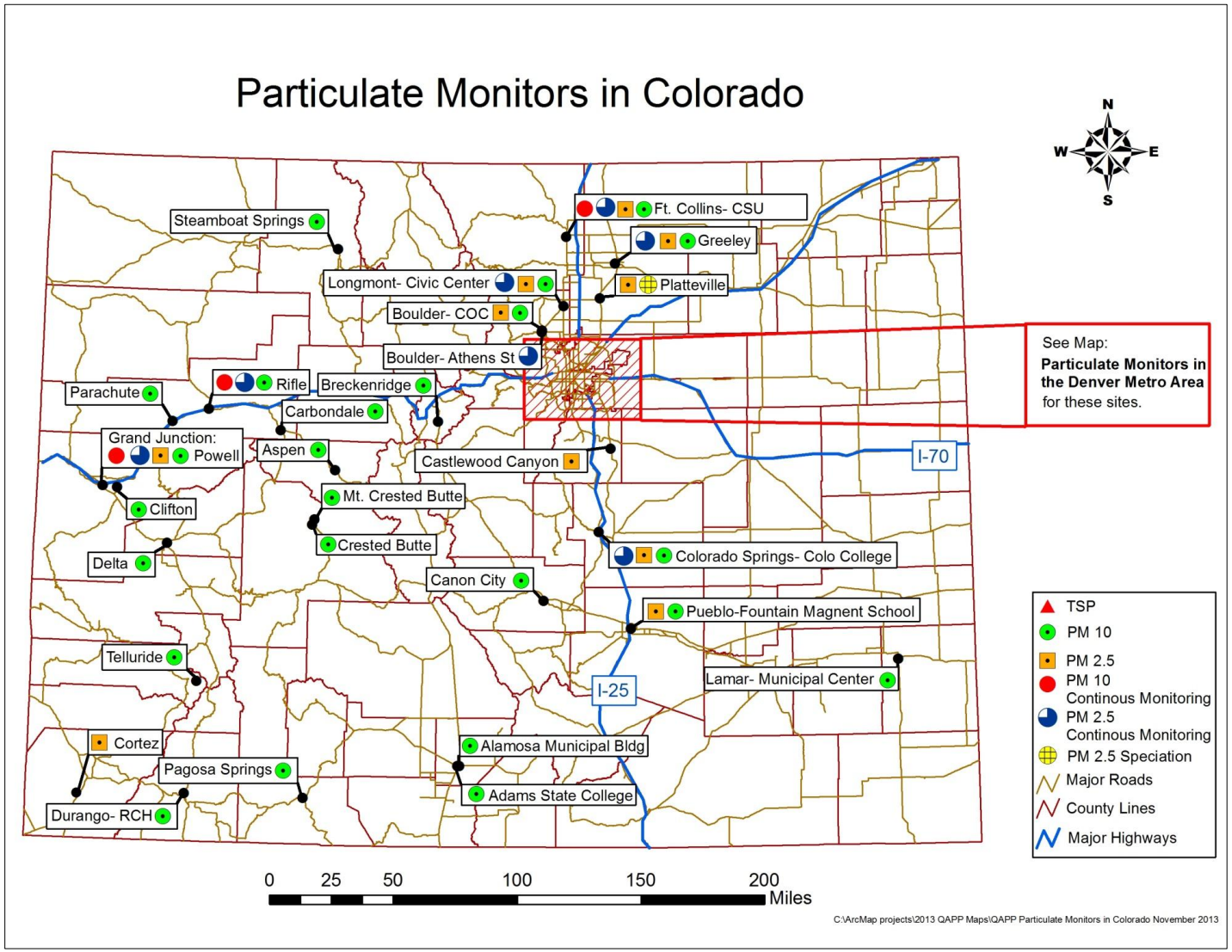


Figure 3.3 Continuous Monitors in the Denver Metro Area

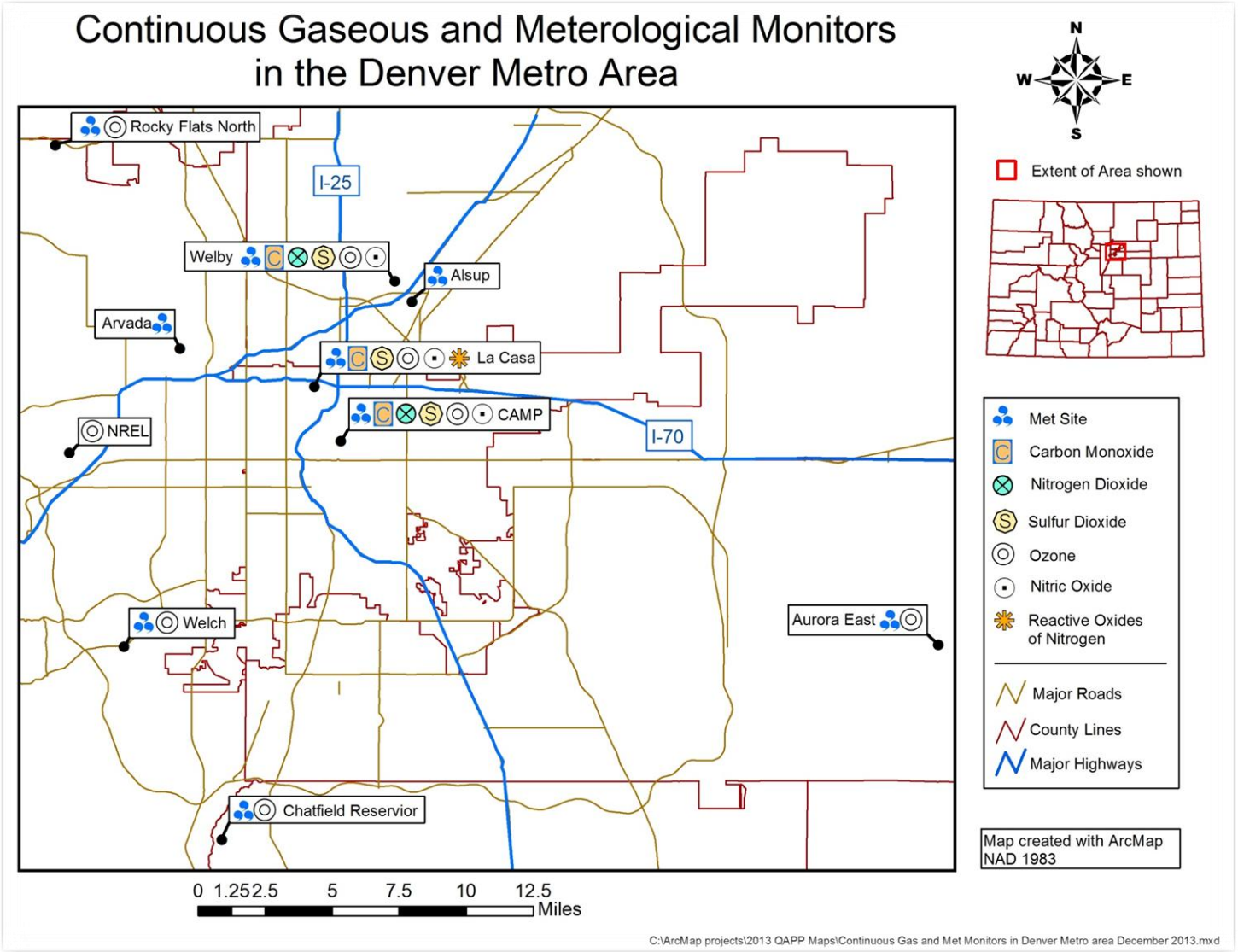
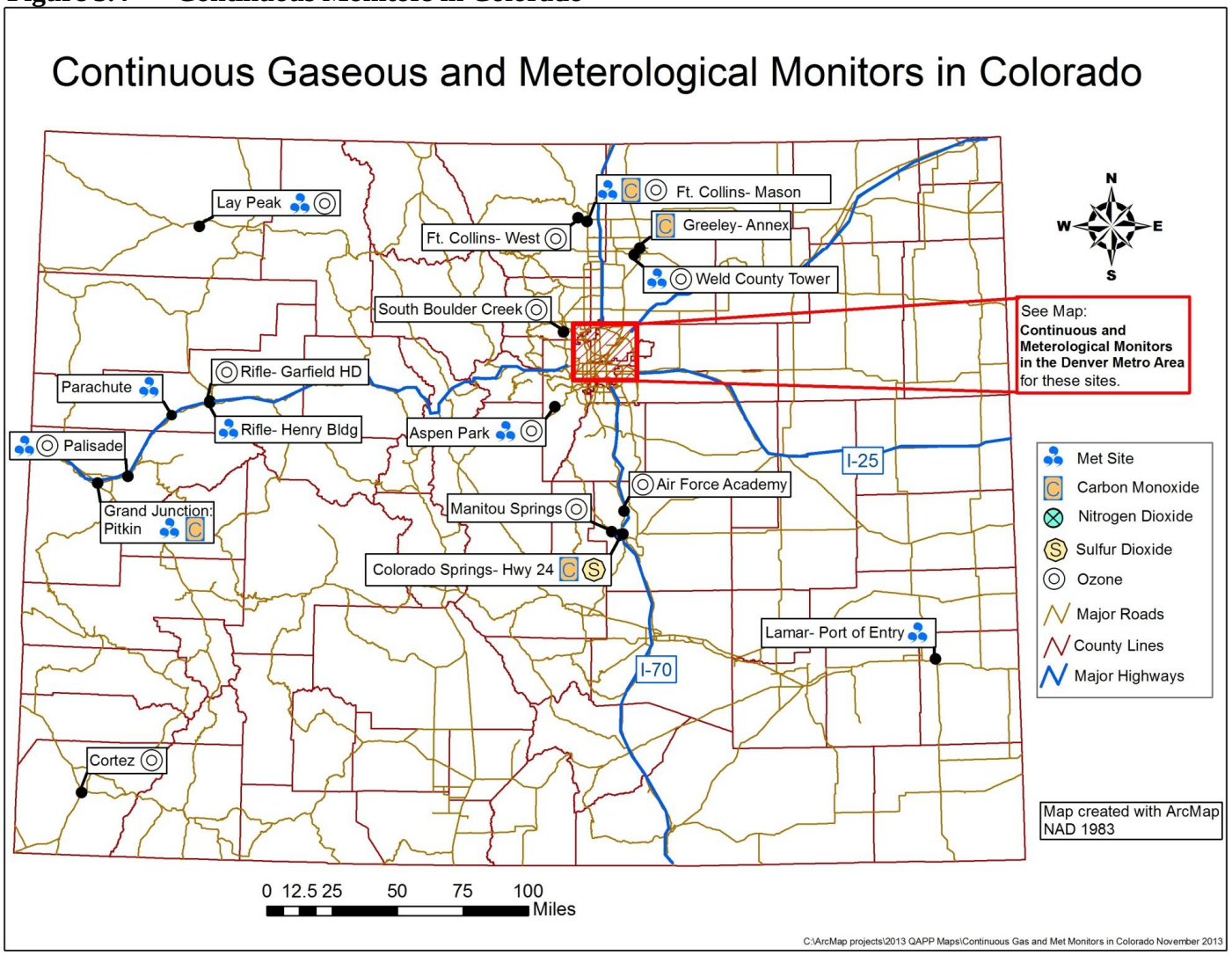


Figure 3.4 Continuous Monitors in Colorado



3.1.5 CLASSIFICATION OF CRITICAL AND NON-CRITICAL MEASUREMENTS

All measurements for NAAQS comparison are classified as critical (i.e., required to achieve project objectives or limits on decision errors, Step 6 of the DQO Process). Critical measurements are necessary for determining compliance with the NAAQS standards and will undergo closer scrutiny during the data gathering and review processes and will have first claim on limited budget resources. Most of these criteria are described in 40 CFR Part 50, 40 CFR Part 58 and Method 2.12. A non-critical measurement is one used for informational purposes only or to provide background information. Expanded critical and operational criteria are included in the MQO table which is derived from the document. The MQO tables for all criteria can be found in Appendix DD of this QAPP and are based on the MQO tables presented in Appendix D of the QA Handbook for Air Pollution Measurement Systems, Volume II, revised May 2013. The tables are divided into critical, operational and systematic criteria. Critical criteria must be met to insure the quality of the data. Operational criteria indicate there might be a problem with the quality of the data. Systematic issues indicate a potentially systematic problem with the environmental data collection activity.

For nonstandard sampling methods, sample matrices, or other unusual situations, appropriate method validation study information may be needed to confirm the performance of the method for the particular matrix. The purpose of this validation information is to assess the potential impact on the representativeness of the data generated.

3.1.6 VALIDATION OF NON-STANDARD MEASUREMENTS

CDPHE/APCD is deploying only FRMs/FEMs for NAAQS monitoring and will be operating them according to the QA Handbook for Air Pollution Measurement Systems, Volume II, revised May 2013, and EPA Guidance Document 2.12. There will not be any non-standard measurements from either the primary or QA samplers measuring critical pollutants. APCD sends its filters to a certified laboratory for weighing so there will not be any non-standard measurements from the analysis of the filters. SOPs for any non-standard methods used by APCD are included in the appendices to this document, but the data collected by these methods are not used for NAAQS comparison, only for special study purposes.

3.2 SAMPLING PROCEDURES AND REQUIREMENTS

The ambient air criteria pollutants are required by Federal law to be measured and reported on a nationwide basis. Regulations governing its measurement are set forth in 40 CFR Part 50. Specific performance characteristics of the samplers and analyzers are tested in accordance with the procedures in 40 CFR Part 53, Subpart E. Sampling methods that meet all requirements in both Parts 50 and 53 are designated as FRMs for use in SLAMS and Prevention of Significant Deterioration (PSD) monitoring networks. Filter based measurements are considered to be non-destructive, and the $PM_{2.5}$ sample can be subjected to subsequent physical or chemical analyses.

Environmental samples should reflect the target population and parameters of interest. As with all other considerations involving environmental measurements, sampling methods should be chosen with respect to the intended application of the data. Just as methods of analysis vary in accordance with project needs, sampling methods can also vary according to these requirements. Different sampling methods have different operational characteristics, such as cost, difficulty, and necessary equipment. In addition, the sampling method can affect the representativeness, comparability, bias, and precision of the final analytical result.

This section provides an overview of the sampling procedures and support equipment that is used in the APCD ambient air quality-monitoring network. The purpose of this section is to describe the requirements and qualitative assessments that are included in the program network. More detailed information about these topics is presented in the SOPs found in the appendices of this document.

Carbon Monoxide (Non dispersive Infrared Photometry)

The TECO 48 analyzers operate on the principle that carbon monoxide (CO) absorbs infrared radiation at a wavelength of 4.6 microns. Because infrared absorption is a non-linear measurement technique, it is necessary to transform the basic analyzer signal into a linear output. The TECO analyzers currently in use by the APCD use an internally stored calibration curve to accurately linearize the instrument output over any range.

The sample is drawn into the Model 48*i* through the *sample* bulkhead. The sample flows through the optical bench.Radiation from an infrared source is chopped and then passed through a gas filter alternating between CO and N_2. The radiation then passes through a narrow band-pass interference filter and enters the optical bench where absorption by the sample gas occurs. The infrared radiation then exits the optical bench and falls on an infrared detector.

The CO gas filter acts to produce a reference beam which cannot be further attenuated by CO in the sample cell. The N_2 side of the filter wheel is transparent to the infrared radiation and therefore produces a measurement beam which can be absorbed by CO in the cell. The chopped detector signal is modulated by the alternation between the two gas filters with amplitude related to the concentration of CO in the sample cell. Other gases do not cause modulation of the detector signal since they absorb the reference and measure beams equally. Thus, the GFC system responds specifically to CO.

Sulfur Dioxide (Fluorescence Analyzer)

The TAPI 100 series UV Fluorescence SO_2 Analyzers that APCD currently uses are microprocessor controlled analyzers that determine the concentration of sulfur dioxide (SO_2) in a sample gas drawn through the instrument. It requires that the sample and calibration gases be supplied at ambient atmospheric pressure in order to establish a constant gas flow through the sample chamber where the sample gas is exposed to ultraviolet light; this exposure causes the SO_2 molecules to change to an excited state (SO_2*). As these SO_2* molecules decay into SO_2 they fluoresce. The instrument measures the amount of fluorescence to determine the amount of SO_2 present in the sample gas.

Calibration of the instrument is performed in software and usually does not require physical adjustments to the instrument. During calibration, the microprocessor measures the sensor output signal when gases with known amounts of SO_2 at various concentrations are supplied and stores these measurements in memory. The microprocessor uses these calibration values along with other performance parameters, such as the PMT dark offset, the UV lamp ratio, the amount of stray light present and measurements of the temperature and pressure of the sample gas to compute the final SO_2 concentration.

This concentration value and the original information from which it was calculated are stored in the unit's internal data acquisition system and reported to the user through a vacuum fluorescent display or as electronic data via several communication ports.

This concentration value and the original information from which it was calculated are stored in the unit's internal data acquisition system and reported to the user through a vacuum fluorescent display or several communication ports

The physical principle upon which the analyzer's measurement method is based is the fluorescence that occurs when sulfur dioxide (SO_2) is excited by ultraviolet light with wavelengths in the range of 190 nm-230 nm. This reaction is a two-step process.

The first stage (equation 1) occurs when SO_2 molecules are struck by photons of the appropriate ultraviolet wavelength. In the case of the T100, a band pass filter between the source of the UV light and the affected gas limits the wavelength of the light to approximately 214 nm. The SO_2 molecules absorbs some of energy from the UV light causing one of the electrons of each of the affected molecules to move to a higher energy orbital state.

$$SO_2 + h\nu_{214nm} \xrightarrow{Ia} SO_2^* \qquad (SO_2 \text{ equation 1})$$

The amount SO_2 converted to excited SO_2* in the sample chamber is dependent on the average intensity of the UV light (***Ia)*** and not its peak intensity because the intensity of UV light is not constant in every part of the sample chamber. Some of the photons are absorbed by the SO_2 as the light travels through the sample gas.

The equation for defining the average intensity of the UV light (***Ia***) is:

$$Ia = I_o\{1-exp[-ax(SO_2)]\} \qquad (SO_2 \text{ equation 2})$$

Where:
I_0 = Intensity of the excitation UV light.
a = The absorption coefficient of SO_2 (a constant).
SO_2 = Concentration of SO_2 in the sample chamber.
x = The distance between the UV source and the SO_2 molecule(s) being affected (path length).

The second stage of this reaction occurs after the SO_2 reaches its excited state (SO_2*). Because the system will seek the lowest available stable energy state, the SO_2* molecule quickly returns to its ground state (equation 2) by giving off the excess energy in the form of a photon (*hv*). The wavelength of this fluoresced light is also in the ultraviolet band but at a longer (lower energy) wavelength centered at 330nm.

$$SO_2^* \rightarrow SO_2 + hv_{330nm} \qquad (SO_2 \text{ equation 3})$$

The amount of detectable UV given off by the decay of the SO_2* is affected by the rate at which this reaction occurs (*k*).

$$F = k(SO_2^*) \qquad (SO_2 \text{ equation 4})$$

Where:
F = the amount of fluorescent light given off.
k = The rate at which the SO_2* decays into SO_2.
SO_2^* = Amount of excited SO_2 in the sample chamber.

Therefore:

$$k(SO_2^*) \xrightarrow{F} SO_2 = hv_{330nm} \qquad (SO_2 \text{ equation 5})$$

Finally, the function (***k)*** is affected by the temperature of the gas. The warmer the gas, the faster the individual molecules decay back into their ground state and the more photons of UV light are given off per unit of time. In summary, given that the absorption rate of SO_2 (***a***) is constant, the amount of fluorescence (***F***) is a result of:

- The amount of exited SO_2* created which is affected by the variable factors from (equation 2) above: concentration of SO_2; intensity of UV light (I_0); path length of the UV light(x) and;

- The amount of fluorescent light created which is affected by the variable factors from (equation 5): the amount of SO_2* present and the rate of decay (***k***) which changes based on the temperature of the gas.

When the intensity of the light (I_0) is known; path length of excited light is short (***x***); the temperature of the gas is known and compensated for so that the rate of SO_2*decay is constant (***k***), and; no interfering conditions are present (such as interfering gases or stray light); the amount of fluorescent light emitted (***F***) is directly related to the concentration of the SO_2 in the Sample Chamber.
The newer TAPI Model 100 UV Fluorescence SO_2 Analyzers are specifically designed to create these circumstances.

- The light path is very short (***x***).
- A reference detector measures the intensity of the available excitation UV light and is used to remove effects of lamp drift (***I_0***).
- The temperature of the sample gas is measured and controlled via heaters attached to the sample chamber so that the rate of decay (***k***) is constant.
- A special hydrocarbon scrubber removes the most common interfering gases from the sample gas.
- And finally, the design of the sample chamber reduces the effects of stray light via its optical geometry and spectral filtering.

The net result is that any variation in UV fluorescence can be directly attributed to changes in the concentration of SO_2 in the sample gas.

.*Nitrogen Oxides (Chemiluminescence)*
The TAPI 200 series Nitrogen Oxide Analyzers that APCD currently use are microprocessor controlled instruments that determine the concentration of nitric oxide (NO), total nitrogen oxides (NO_x, the sum of NO and NO_2) and nitrogen dioxide (NO_2) in a sample gas drawn through the instrument.

- It requires that sample and calibration gases be supplied at ambient atmospheric pressure in order to establish a constant gas flow through the reaction cell where the sample gas is exposed to ozone (O_3), initiating a chemical reaction that gives off light (*hν*).
- The instrument measures the amount of chemiluminescence to determine the amount of NO in the sample gas.
- A catalytic-reactive converter reduces NO_2 in the sample gas to NO, which is measured together with the NO originally present in the sample. This measurement is reported as NO_x. NO_2 is calculated as the difference between the NO_x measurement and an NO measurement obtained without catalytic conversion of NO_2.

Calibration of the instrument is performed in software and usually does not require physical adjustments to the instrument. During calibration, the microprocessor measures the sensor output signal when gases with known amounts of NO or NO_2 are supplied and stores these results in memory. The microprocessor uses these calibration values, along with the signal from the sample gas and data for the current temperature and pressure of the gas, to calculate a final NO_x concentration.

The concentration values and the original information from which it was calculated are stored in the unit's internal data acquisition system and are reported to the user through a vacuum fluorescence display or several output ports.

The TAPI 200 analyzer measures the amount of NO present in a gas by detecting chemiluminescence, which occurs when nitrogen oxide (NO) is exposed to ozone (O_3). This reaction is a two-step process:

- In the first step, one molecule of NO and one molecule of O_3 collide and chemically react to produce one molecule of oxygen (O_2) and one molecule of nitrogen dioxide (NO_2). Some of the NO_2 molecules created by this reaction retain excess energy from the collision and exist in an excited state, where one of the electrons of the NO_2 molecule resides in a higher energy state than normal (denoted by an asterisk in the following equation).

$$NO + O_3 \rightarrow NO_2^* + O_2 \qquad (NO_x \text{ equation 1})$$

- The second step occurs because the laws of thermodynamics require that systems seek the lowest stable energy state available; therefore, the excited NO_2 molecule quickly returns to its ground state, releasing the excess energy. This release takes the form of a quantum of light (*h*ν). The distribution of wavelengths for these quanta range between 600 and 3000 nm, with a peak at about 1200 nm.

$$NO_2^* \rightarrow NO_2 + h\nu_{1200nm} \qquad (NO_x \text{ equation 2})$$

All things being constant (temperature, pressure, amount of ozone present, etc.), the relationship between the amount of NO present in the reaction cell and the amount of light emitted from the reaction is very linear. If more NO is present, more IR light is produced. By measuring the amount of IR light produced with a sensor sensitive in the near-infrared spectrum, the amount of NO present can be determined.

In addition, sometimes the excited NO_2 collides with other gaseous molecules in the reaction cell chamber, or even the molecules of the reaction cell walls, and transfers its excess energy to this collision partner (represented by *M* in the equation 3 below) without emitting any light at all. In fact, by far the largest portion of the excited NO_2 returns to the ground state this way, leaving only a few percent yield of usable chemiluminescence.

$$NO_2^* + M \rightarrow NO_2 + M \qquad (NO_x \text{ equation 3})$$

The probability of a collision between the NO_2* molecule and a collision partner, *M*, increases proportionally with the reaction cell pressure. This non-radiating collision with the NO_2* molecules is usually referred to as *third body quenching*, and is an unwanted process further described in the Manufacturer's Operating Manual.

Even under the best conditions, only about 20% of the NO_2 that is formed by the reaction described in equation 1 is in the excited state. In order to maximize chemiluminescence, the reaction cell is maintained at reduced pressure (thereby reducing the amount of available collision partners) and is supplied with a large, constant excess of ozone (about 3000-5000 ppm) from the internal ozone generator.

The TAPI 200 analyzers use a special kind of vacuum tube, called a photo-multiplier tube (PMT), to detect the amount of light created by the NO and O_3 reaction in the reaction cell.

Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by an applied high voltage and multiplied through a sequence of similar acceleration steps (dynodes) until a useable current signal is generated (see Operator's Manual for more details). The more light present (in this case photons given off by the chemiluminescent reaction described above), the more current is produced. Therefore the more NO present in the reaction cell, the more current is produced by the PMT.

The current produced by the PMT is converted to a voltage, amplified by the preamplifier board, and then communicated to the TAPI 200's CPU via the A→ D converter circuitry on the analyzer.

A high pass optical filter, only transparent to wavelengths of light above 645nm, placed between the reaction cell and the PMT (see figure in Operator's Manual for more information), in conjunction with the response characteristics of the PMT, creates a very narrow window of wavelengths of light to which the TAPI 200E will respond.

The narrowness of this band of sensitivity allows the M200E to ignore extraneous light and radiation that might interfere with the TAPI 200E's measurement. For instance, some oxides of sulfur can also be chemiluminescent emitters when in contact with O_3 but give off light at much shorter wavelengths (usually around 260nm to 480nm).

The only gas that is actually measured by the TAPI 200E/200EU/T200 is NO. NO_2, and therefore NO_x (which is defined here as the sum of NO and NO_2 in the sample gas), contained in the gas is not detected because NO_2 does not react with O_3 to create chemiluminescence.

In order to measure the concentration of NO_2, and therefore the concentration of NO_x, the M200E periodically switches the sample gas stream so that the pump pulls it through a special converter cartridge filled with molybdenum (Mo, "moly") chips that are heated to a temperature of 315°C.

The heated molybdenum reacts with NO_2 in the sample gas and produces a NO gas and a variety of molybdenum.

$$xNO_2 + yMo \rightarrow xNO + M_yO_z \text{ (at } 315^oC\text{)} \qquad (NO_x \text{ equation 4})$$

Once the NO_2 in the sample gas has been converted to NO, it is routed to the reaction cell where it undergoes the chemiluminescence reaction described in equation 1 and equation 2.

By converting the NO_2 in the sample gas into NO, the analyzer can measure the total NO_xcontent of the sample gas (i.e., the NO present + the converted NO_2 present). By switching the sample gas stream in and out of the "moly" converter every 6 - 10 seconds, the M200E analyzer is able to quasi-continuously measure both NO and total NO_x content.Finally, the NO_2 concentration is not directly measured but calculated by subtracting the known NO content of the sample gas from the known NO_x content.

The Model T200UP uses a UV-based photolytic converter to provide "true" trace level measurements of NO_2. The patented technology allows for speciation of NO_2. As the sample gas passes through the converter chamber it is exposed to blue light at specific wavelengths (350-420 nm) from an array of ultraviolet light-emitting diodes (LEDs). This selectively converts the NO_2 to NO with negligible radiant heating or interference from other gases. The T200 operation manual section, Principles of Operation, details the Chemiluminescent measurement as well as other components.

The T200U-NO_y system allows the point of sampling to be located in close proximity to the Converter. This configuration provides minimal time delay between the sample inlet and the remotely mounted (~10 meters above ground) external Converter. Minimizing the transit time between the sample inlet and Converter enables the conversion of labile components of NO_y. The equation for the conversion is:

$$3\,NO_y + Mo \xrightarrow{325^oC} 3\,NO + MoO_3 \qquad (NO_y \text{ equation 5})$$

Ozone (Ultraviolet Photometry)
The TAPI 400 ozone analyzer is a microprocessor-controlled analyzer that determines the concentration of Ozone (O_3) in a sample gas drawn through the instrument. It requires that sample and calibration gases be supplied at ambient atmospheric pressure in order to establish a stable gas flow through the absorption tube where the gas' ability to absorb ultraviolet (UV) radiation of a certain wavelength (in this case 254 nm) is measured.

The basic principle by which the TAPI 400 Ozone Analyzer works is called Beer's Law (also referred to as the Beer-Lambert equation). It defineshow light of a specific wavelength is absorbed by a particular gas molecule over a certain distance at a given temperature and pressure. The mathematical relationship between these three parameters for gases at standard temperature and pressure (STP) is:

$$I = I_o e^{-\alpha LC} \quad \text{at STP} \qquad (O_3 \text{ equation 1})$$

Where:
I_o is the intensity of the light if there was no absorption.
I is the intensity with absorption.
L is the absorption path, or the distance the light travels as it is being absorbed.
C is the concentration of the absorbing gas. In the case of the Model T400/400E/400A, Ozone (O_3).
α is the absorption coefficient that tells how well O_3 absorbs light at the specific wavelength of interest.

To solve this equation for **C**, the concentration of the absorbing Gas (in this case O_3), the application of a little algebra is required to rearrange the equation as follows:

$$C = \ln(I_o/I) \times (1/\alpha L) \quad \text{at STP} \qquad (O_3 \text{ equation 2})$$

Unfortunately, both ambient temperature and pressure influence the density of the sample gas and therefore the number of ozone molecules present in the absorption tube, thus changing the amount of light absorbed.

In order to account for this effect the following addition is made to the equation:

$$C = \ln(I_o/I) \times (1/\alpha L) \times (T/273K) \times (29.92\ inHg/P) \quad (O_3\ equation\ 3)$$

Where:
T = sample temperature in Kelvin
P = sample pressure in inches of mercury

Finally, to convert the result into parts per billion (PPB), the following change is made:

$$C = \ln(I_o/I) \times (10^{-9}/\alpha L) \times (T/273K) \times (29.92\ inHg/P) \quad (O_3\ equation\ 4)$$

In a nutshell the TAPI 400series Ozone Analyzers:

- Measure each of the above variables: sample temperature; sample pressure; the intensity of the UV light beam with and without O_3 present,
- Insert known values for the length of the absorption path and the absorption coefficient, and
- Calculate the concentration of O_3 present in the sample gas.

Particulate Matter (Intermittent operation)
This methodology utilizes filters that have been precisely weighed prior to of sampling that are placed in a carefully controlled volumetric flow for a specified period of time. By using flow rate and sample duration, a calculation can be performed to determine the volume of ambient air that has passed through the clean filter. By precisely measuring the total mass of the filter after sampling, and subtracting the mass of the filter before sampling, the mass applied to the filter during the sampling period when the flow was present can be determined. Dividing the total mass applied during sampling by the volume of air filtered yields a particulate concentration averaged over the time the flow occurred.

These intermittent operating filter monitors require that the filters be changed between each sampling period, which usually occurs once every six days, but can be scheduled more frequently. The filters are precisely weighed in a lab prior to field installation. They are once again precisely weighed, at the same humidity level and temperature as at the initial weighing, after the filtering operation. The resulting difference yields the mass trapped during filtering.

Trapped particulate matter can be separated into finer grades of matter than was originally mandated under federal total suspended particulates (TSP) regulations using an inertial separator on the inlet stream. These inertial separators selectively pass particulate matter classified as either PM_{10} or $PM_{2.5}$. Information required for installing and maintaining these types of particulate monitors is available in Appendix PM1 for High Volume PM_{10} and TSP samplers and in Appendix PM2 for FRM $PM_{2.5}$ samplers.

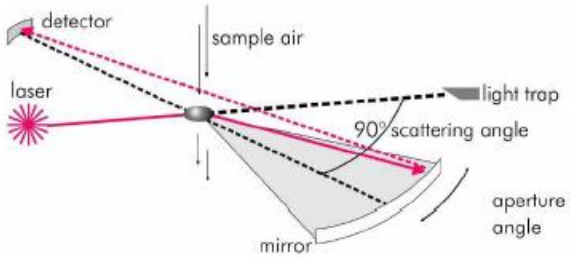
Particulate Matter (Continuous Operation, TEOM)
A Tapered Element Oscillating Microbalance (TEOM) is composed of sensing and control units. At the heart of the sensing unit is the tapered element oscillating micro-balance, which is a patented inertial mass measurement technique for making real time direct measurement of particle mass collected on a filter. This measuring equipment can determine the fine changes in mass that accumulate on the filter as a constant stream of air passes through it. The combination of the rate at which mass is accumulated on the filter and a near real-time measurement (10 minutes), coupled with the air's known volumetric flow rate, yields an accurate method of determining the concentration of particulates in the air. The equipment can calculate the 30-minute, 1-hour, 8-hour, and 24-hour averages, as well as the total mass accumulation on the filter from the raw data. Utilizing hydrophobic filter material and collecting the sample at above ambient temperatures (40 or 50°C) minimizes humidity effects. The control unit employs an industrial microprocessor system, flow control hardware, transformers and power supplies, and a gauge to determine filter lifetime.

Initially, the air stream is filtered through an inertial separator. An inertial separator is specifically designed to eliminate particles with aerodynamic diameters either greater than 10 micrometers, or greater than 2.5 micrometers, depending upon the desired data to be collected. This equipment draws in 16.7 L/min (1.0 m^3/hour) of air. After the air stream exits the inertial separator the stream is split into a 3-L/min sample that is sent to the mass transducer and a 13.7 L/min exhaust stream. The mass transducer assembly filters the sample air stream using a Teflon®-coated borosilicate glass filter. The system measures the accumulated mass every two seconds. Information required for installing and maintaining the TEOM particulate monitor is available in Appendix PM3 and PM4 of this QAPP, various Rupprecht & Patashnick TEOM Sampler Operations Manuals and TECO 1405 Sampler Operations Manuals.

Particulate Matter (Continuous Operation, GRIMM)
The sample air is being drawn through a stainless steel downtube (di=3 mm) into the measuring chamber. The particles in the sample air are being classified into size and counted inside the measuring chamber through scattering light measurement.

The sample flow is being pulled through the measurement cell. Every particle scatters light which is detected by secondary optics under an opening angle and a scattering angle. The scattered light is sent via a mirror to a detector where the light intensity is measured. The particle size is proportional to the intensity of the reflected light beam. The count rate is determined from the particle count and the volumetric flow rate. Having known particle diameters and an assumed density(s) the particle mass can be calculated from the particle count, the method assumes the particles are spherical. The light intensity can be influenced by the particle shape and its refractive index. However, this influence is very small at typical atmospheric concentrations.

Figure 3.5 Measurement Schematic for GRIMM



The measuring principle is explained in Figure 3.5. The scattering light intensities have been determined with test aerosols of known size and density. The intensities are then provided with an empirically established correction factor for the determination of the mass concentration.

A semi-conductive laser serves as light source. In order to minimize the influence of the refractive indices, the 90° arc of scattered light is being lead with an opening angle of 30° via a mirror onto a receiver diode. The electric signal of the diode will be classified after a size-dependent amplification into 31 different size bins. Thus the determination of the particle size distribution is possible.

From the measured particle size distribution the fractions will be calculated and summed up. The calculation factors are based on the sum frequency distribution of EN12341 (PM_{10}) and EN14907 ($PM_{2.5}$), which are adjusted under consideration of the segregation behavior of the sample inlet of the test device and the particle density through correlation to the gravimetrical measurement. For calibration of the channel thresholds a mother device with defined latex particles is being used which calibrates all devices previous to shipment and also at the annual calibration. More information about the GRIMM samplers can be found in Appendices PM5.

Particulate Matter (Continuous Operation, aethalometer)
The aethalometer provides a real time measurement of light absorption by particles. The aethalometer measures the attenuation of light transmitted through a quartz-fiber filter and a supporting stainless steel mesh during the continuous collection of an aerosol sample on the filter. The rate of accumulation of BC is proportional to both the BC concentration in the ambient air and to the sample air flow rate. An internal mass

flow meter monitors the sample flow rate. The sample air flows through a 0.5 cm^2 area of the quartz-fiber filter tape. The instrument measures the transmitted light intensities through both the sensing portion of the filter (mentioned above) and an unexposed or 'reference' portion of the filter. The reference measurement is made to correct for fluctuations in the intensity of the light source. The signal (sensing) and reference measurements are made by a high intensity light emitting diode (LED) lamp at a wavelength of 880 nm and a pair of matched photodiodes. Measurements of the reference and sensing detector outputs are also made with the LED off to determine the zero offset (dark response) correction for the signals. All optical signals from the diodes are converted to voltages and digitized. A ratio is taken of the zero offset corrected signal and reference voltages. This ratio is converted to an optical attenuation value that is proportional to the increment of aerosol black carbon collected on the filter during each measurement cycle. More information on the aethalometer can be found in Appendix PM8.

Particulate Matter (for regional haze measurements):
An integrating **nephelometer** measures the scattering coefficient of light (bscat) caused by aerosols and gases in a steady stream of ambient air. The light scattered from an internally mounted, variable rate flashing light source is wavelength limited by an optical filter to 475 nm. The photodiode detector measures light scattered (at deflection angles between 5° and 175°) by aerosols and gases in the tube's ambient air plus light reflected from the inside surfaces of the instrument optical chamber. The inside reflective component is constant and corrected for by performing zero and span calibrations. Directly across the optical tube a second photodiode detector measures the output level of light from the lamp. This compensates for any changes in lamp brightness due to power supply changes, lamp aging, and dust on optical surfaces. Information required for installing and maintaining a nephelometer is available in Appendix R of this QAPP.

A **transmissometer** is an instrument for measuring the extinction coefficient of the atmosphere and for the determination of visual range. It operates by sending a narrow, collimated beam of energy (usually a laser) through the propagation medium. A narrow field of view receiver at the designated measurement distance determines how much energy is arriving at the detector, and determines the path transmission and/or extinction coefficient. Atmospheric extinction is a wavelength dependent phenomenon, but the most common wavelength in use for transmissometers is 550 nm, which is in the middle of the visible waveband, and allows a good approximation of visual range.

More information about operations of transmissometers and nephelometers can be found in Appendices GM9 and GM10.

3.2.1 SAMPLE COLLECTION AND PREPARATION

Without exception, all sampling methods used by the APCD to monitor NAAQS criteria pollutants are designated by the EPA as reference or equivalent methods. Definitions of reference and equivalent methods are given in 40 CFR Part 50. Monitoring methodology (and any noted exceptions) are specified in 40 CFR Part 58 Appendix C except for Particulate Matter, which is specified in 40 CFR Part 50 Appendix J and 40 CFR Part 50 Appendix L. Information about the monitoring instrumentation currently in use by the APCD, and where applicable, their reference or equivalence designation, is presented in Table 3.11. Each model sampler shall be installed with adherence to procedures, guidance, and requirements detailed in 40 CFR Parts 50, 53, and 58, the QA Handbook, the sampler manufacturers operation manuals, CDPHE/APCD/TSP SOPs (found in the appendices to this document), and this CDPHE/APCD/TSP QAPP.

The preparation for utilizing the sampling method as part of the network design includes site selection, deployment, installation, and calibration of the monitors. Monitor operation will include the verification of ambient conditions, review of computer downloaded records upon recovery and installation, additional verification of flow rates, regular accuracy and precision checks, filter storage, sample shipping under controlled conditions and sample tracking where applicable.

The continuous gaseous and particulate monitors within the network report either hourly or 5 minute average values to the EPA's AQS database.

The FRM for particulate monitoring designate how measurements of the mass concentration over a 24-hour period are to be performed for the purposes of determining compliance with the primary and secondary national ambient air quality standards for particulate matter, as specified in 40 CFR Part 50. The measurement process is considered to be non-destructive and the particulate sample obtained can be subjected to subsequent physical or chemical analyses.

Sample set-up of the FRM or equivalent particulate samplers takes place any day after the previous sample has been recovered. At collocated sites the second monitor is set up to run at a sample frequency of 1 in 6 days; however, sample set-up takes place on the same day as the primary sampler. Detailed sample set-up procedures are available in the Standard Operating Procedures found in the appendices of this document.

The table below shows the current parameter and method codes being used for reporting data to AQS, as well as FRM or FEM designation codes for specific equipment the APCD uses.

Table 3.11 APCD Monitors and EPA Designation Numbers

	Monitor	Designation Number	Method Code
Carbon Monoxide (CO) (42101)	Thermo Electron or Thermo Environmental Instruments 48, 48C, 48i, 48iTLE	RFCA-0981-054	054 554 Trace
Ozone (O_3) (44201)	Teledyne - Advanced Pollution Instr. 400, 400A, 400E, T400	EQOA-0992-087	087
Ozone (O_3) (44201)	Thermo Electron or Thermo Environmental Instruments 49, 49C, 49i	EQOA-0880-047	047
Nitrogen Oxides (NO_x & NO_y) (42612, NO_y-NO) (42600, NO_y) (42601, NO) (42602, NO_2) (42603 NO_x)	Teledyne-Advanced Pollution Inst. 200A, 200AU, 200E, 200EU, T200, T200U	RFNA-1194-099	099 NO_x 599 NO_y
(42601, NO) (42602, NO_2) (42603 NO_x)	Teledyne-Advanced Pollution Inst. Photolytic 200EUP, T200UP	EQNA-0512-200	600
(42602, NO_2	TAPI CAPS T500U	EQNA-0414-212	212
Sulfur Dioxide (SO_2) (42401)	Teledyne-Advanced Pollution Inst. 100A, 100 AS, 100E, 100EU, T100, T100U	EQSA-0495-100	100 600 Trace
Total Suspended Particulate (TSP) (11101)	GMW	NA	091
Inhalable Particulate (PM_{10})	SA Model 1200	RFPS-1287-063	063
(81102) all PM_{10}	Thermo Scientific TEOM® 1400AB, 1405	EQPM-1090-079	079
	R & P Partisol® -FRM 2000	RFPS-1298-126	126
	R & P Partisol®	RFPS-1298-127	127

	Monitor	Designation Number	Method Code
	-Plus 2025 Seq.		
Inhalable Particulate ($PM_{2.5}$) (88101)	R & P Partisol® -Plus 2025 PM-2.5 [FEM] Seq.	EQPM-0202-145	145
(88101)	R & P Partisol® -FRM 2000 PM-2.5 [FEM]	EQPM-0202-143	143
(88501)	R & P TEOM® 1400, 1400a	NA	715, 30°C 716, other temp
(88500)	Thermo Scientific TEOM® 1400a with Series 8500C FDMS	EQPM-0609-181	761
(88500, $PM_{2.5}$) (86502, PM_{10})	Thermo Scientific TEOM® 1405-DF Dichot with FDMS	EQPM-0609-182	790
(88101)	Grimm Model EDM 180 $PM_{2.5}$ Monitor	EQPM-0311-195	195
	Aethalometer		
	Met One SASSCommAQ-9800	NA	NA
	URG 3000 CSN	NA	NA
Lead (Pb) (14128)	GMW	NA	189
(85128)	R & P Partisol® -Plus 2025 Seq.	RFPS-1298-127	811
Wind Speed (61101)	Met One Model 010, 010B & 010C Wind Speed Sensor	NA	020
Wind Direction (61102)	Met One Model 020, 020B & 020C Wind Direction Sensor	NA	050
Wind & Speed (61101, 61102)	RM Young Model 5305V Wind Sensor	NA	020 050
(61101, 61102)	Viasala WMT700 UltraSonic Wind Sensor	NA	
Temperature (62106)	Met One Model 060,062 (T-diff) &064-1 Temperature Sensor	NA	
Temperature (62106)	RM Young Model 41342V Pt. Temperature Sensor	NA	041
Humidity(62201)	RH meter is a Rotronic mp601	NA	020
Humidity (62201)	Met One Model 083E-0-6 Relative Humidity Sensor	NA	012
Temp & Humidity (62101, 62201)	RM Young Model 41372v RH and Temp Sensor	NA	020
Barometric (64101)	Met One Model 092 Barometric Pressure Sensor	NA	020

	Monitor	Designation Number	Method Code
Solar Radiation (63301)	Kip & Zonen Model CMP-11 Pyranometer Model CMP-3 Pyranometer	NA	014
Transmissometer	Optec LPV-3(LED)	NA	NA
Nephelometer	Optec NGN-2	NA	NA

More information on designated reference and equivalent methods can be found at http://www.epa.gov/ttnamti1/files/ambient/criteria/reference-equivalent-methods-list.pdf.

More information on AQS parameter and methods codes can be found at the EPA AQS Codes and Descriptions web site (http://www.epa.gov/ttn/airs/airsaqs/manuals/codedescs.htm).

The table below from 40 CFR Part 58 Appendix A contains the required specifications that manufacturers of continuous analyzers have to meet to obtain federal equivalency. The testing to derive these specifications in performed in optimal laboratory conditions when instrumentation is new. Theoretically these specs should remain constant, however, in practice, long term use of these analyzers will degrade the operation and these specifications cannot always be met in field use.

Table 3.12 Minimum Data Assessment Requirements for SLAMS Sites

Method	Assessment method	Coverage	Minimum frequency	Parameters reported
Automated Methods				
1-Point QC for SO_2, NO_2, O_3, CO	Response check at concentration 0.01-0.1 ppm SO_2, NO_2, O_3, and 1-10 ppm CO	Each analyzer	Once per 2 weeks	Audit concentration[1] and measured concentration[2].
Annual performance evaluation for SO_2, NO_2, O_3, CO	See section 3.2.2 of 40CFR58 App A	Each analyzer	Once per year	Audit concentration[1] and measured concentration[2] for each level.
Flow rate verification PM_{10}, $PM_{2.5}$, $PM_{10-2.5}$	Check of sampler flow rate	Each sampler	Once every month	Audit flow rate and measured flow rate indicated by the sampler.
Semi-annual flow rate audit PM_{10}, $PM_{2.5}$,$PM_{10-2.5}$	Check of sampler flow rate using independent standard	Each sampler	Once every 6 months	Audit flow rate and measured flow rate indicated by the sampler.
Collocated sampling $PM_{2.5}$, $PM_{10-2.5}$	Collocated samplers	15%	Every 12 days	Primary sampler concentration and duplicate sampler concentration.
Performance evaluation program $PM_{2.5}$, $PM_{10-2.5}$	Collocated samplers	1. 5 valid audits for primary QA orgs, with ≤5 sites 2. 8 valid audits for primary QA orgs, with >5 sites 3. All samplers in 6 years	Over all 4 quarters	Primary sampler concentration and performance evaluation sampler concentration.
Manual Methods				
Collocated sampling PM_{10}, TSP, $PM_{10-2.5}$, $PM_{2.5}$, Pb-TSP, Pb-PM_{10}	Collocated samplers	15%	Every 12 days PSD—every 6 days	Primary sampler concentration and duplicate sampler concentration.
Flow rate verification PM_{10} (low-vol), $PM_{10-2.5}$, $PM_{2.5}$, Pb-PM_{10}	Check of sampler flow rate	Each sampler	Once every month	Audit flow rate and measured flow rate indicated by the sampler.
Flow rate verification PM_{10} (high-vol), TSP, Pb-TSP	Check of sampler flow rate	Each sampler	Once every quarter	Audit flow rate and measured flow rate indicated by the sampler.
Semi-annual flow rate audit PM_{10}, TSP, PM_{10-}	Check of sampler flow rate using	Each sampler, all locations	Once every 6 months	Audit flow rate and measured flow rate indicated by the

Method	Assessment method	Coverage	Minimum frequency	Parameters reported
$_{2.5,}$ $PM_{2.5,}$ Pb-TSP, Pb-PM_{10}	independent standard			sampler.
Pb audit strips Pb-TSP, Pb-PM_{10}	Check of analytical system with Pb audit strips	Analytical	Each quarter	Actual concentration and audit concentration.
Performance evaluation program $PM_{2.5,}$ $PM_{10-2.5}$	Collocated samplers	1. 5 valid audits for primary QA orgs, with ≤5 sites 2. 8 valid audits for primary QA orgs, with >5 sites 3. All samplers in 6 years	Over all 4 quarters	Primary sampler concentration and performance evaluation sampler concentration.
Performance evaluation program Pb-TSP, Pb-PM_{10}	Collocated samplers	1. 1 valid audit and 4 collocated samples for primary QA orgs, with >5 sites 2. 2 valid audits and 6 collocated samples for primary QA orgs, with >5 sites	Over all 4 quarters	Primary sampler concentration and performance evaluation sampler concentration. Primary sampler concentration and duplicate sampler concentration.

[1]Effective concentration for open path analyzers.

[2]Corrected concentration, if applicable, for open path analyzers.

3.2.2 SUPPORT FACILITIES FOR SAMPLING METHODS

3.2.2.1 Analytical Laboratory Methods Requirements

Two support facilities are involved in the monitoring of all criteria pollutants. The first support facility is the gravimetric laboratory. The gravimetric laboratory receives EPA supplied 46.2 mm filters from APCD, equilibrates the filters, tare weighs the filters, ships the tare weighed filters to the field operators, receives refrigerated samples, equilibrates the sampled filters, performs gross gravimetric analyses and delivers the data electronically to APCD. Laboratory temperature and humidity are maintained in acceptance ranges as defined in federal regulations 40 CFR Part 50, Appendices J, L and Q, and in EPA Quality Assurance Guidance Document 2.12 during all filter-weighing procedures. APCD and gravimetric laboratory procedures for $PM_{2.5}$, PM_{10}, TSP, and lead are described in detail in Appendices LSD1, LSD2 and LSD4 of this QAPP. Annually the APCD QA unit performs a Technical Systems Audit (TSA) and Performance Evaluation (PE) of the gravimetric laboratories to ensure the laboratories continue to meet all federal criteria and APCD contract requirements.

The second support facility is the Quality Assurance Laboratory run by the TSP within APCD. The QA Unit is responsible for maintaining the NIST traceability for most of the in-house primary laboratory transfer standards. The QA unit also certifies and/or calibrates most of the transfer standards used in the field for calibrations, verifications and audits. This laboratory uses authoritative NIST traceable (or equivalent)

standards to certify flow transfer standards, thermometers, barometers, manometers and ozone standards for APCD, local agencies, and some contractors performing work in Colorado.

3.2.2.2 Sample Shelter Requirements

The main support facility for gaseous sampling is the sample shelter. The sampling station design must encompass the operational needs of the equipment, provide an environment that supports sample integrity, and allow the operator to safely and easily service and maintain the equipment. Winter weather conditions must be considered during site selection in order to meet the station safety and serviceability requirements.

At each analyzer location in the network there is a climate-controlled, electrically stable, sample shelter. Each shelter should also contain consumable supplies, tools, a data logger, and station logs to document all manual manipulations of the analyzers, such as calibrations, checks, performance evaluations, or maintenance. There are many other items a field operator may need during a site visit that are not expected to be at each site. The site operator is expected to bring these items along. Air pollution analyzers, with the exception of high volume particulate matter samplers, low-volume particulate matter samplers, and meteorological sensors must be housed in a shelter capable of fulfilling the following requirements:

- The shelter must protect the instrumentation from any environmental stress such as vibration, corrosive chemicals, intense light, or radiation.

- The shelter must protect the instrumentation from precipitation; excessive dust and dirt; provide third wire grounding that meets local codes; and must meet federal Occupational Safety and Health Administration regulations.

- The power supply must not vary more than ±10% from 117 alternating current voltages. It is best to provide some type of voltage regulation to accomplish this.

- The shelter temperature must be maintained between 20^{o} and 30^{o} C and should not vary more than $\pm 2^{o}$C.

The table below specifies the best method to control these environmental parameters:

Table 3.13 Environment Control Parameters

Parameter	Source of specification	Method of Control
Instrument vibration	Manufacturer's specifications	Design of instrument housings, benches, etc., per manufacturer's specifications. Locate pumps outside if appropriate conditions exist.
Light	Method description or manufacturer's specifications	Shield chemicals or instruments that can be affected by natural or artificial light
Electrical voltage	Method description or manufacturer's specifications	Constant voltage transformers or regulators; separate power lines; isolated high current drain equipment such as high-vols, heating baths, pumps from regulated circuits
Temperature	Method description or manufacturer's specifications	Regulated air conditioning system 24-hour temperature recorder; use electric heating and cooling only
Humidity	Method description or manufacturer's specifications	Regulated air conditioning system; 24-hour temperature recorder

3.2.2.3 Sampling probes and Manifolds

Some important variables affecting the sampling manifold design are the diameter, length, flow rate, pressure drop, and materials of construction. With the development of NCore precursor gas monitoring, various types of probe/manifold designs were reviewed. This information can be found in the *Technical Assistance Document (TAD) for Precursor Gas Measurements in the NCore Multi-pollutant Monitoring Network* . Further information can be obtained from 40 CFR Part 58 Appendix E.

Of the probe and manifold material looked at over the years, only Pyrex® glass and Teflon® have been found to be acceptable for use as intake sampling lines for all the reactive gaseous pollutants. Furthermore, the EPA has specified borosilicate glass or FEP Teflon® as the only acceptable probe materials for delivering test atmospheres in the determination of reference or equivalent methods. Therefore, borosilicate glass (which includes Pyrex®), FEP Teflon® or their equivalent must be the only material in the sampling train (from inlet probe to the back of the analyzer) that can be in contact with the ambient air sample for existing and new SLAMS. In recent years questions have been asked about PFA (perfluoroalkoxy co-polymer). PFA is more recently formulated Teflon than FEP. Like FEP, it is translucent which is also not machined but unlike FEP can be molded into fittings. It has been accepted as equivalent to FEP Teflon® but there is no real advantage to using PFA. The APCD generally uses PFA for NO_x/NO_y and SO_2 sample lines and FEP for CO and O_3 sample lines

For volatile organic compound (VOC) monitoring at PAMS, FEP Teflon® is unacceptable as the probe material because of VOC adsorption and desorption reactions on the FEP Teflon®. Borosilicate glass and stainless steel, or its equivalent, are acceptable probe materials for VOC and carbonyl sampling. Care must be taken to ensure that the sample residence time is kept to 20 seconds or less.

When determining how to set up a sampling station with regards to probes, inlets and sampling material, monitoring organizations have the option of:

1) Using individual Teflon® sampling lines which may access the ambient air through one port (with a number of individual lines) but each line would run directly to an analyzer.

2) Using glass manifolds which allow for ambient air to enter from a single inlet, collect in the manifold and then be distributed through manifold outlet ports in individual analyzers.

Either method is appropriate and it may depend on the number of analyzers at the site, how the shelter is configured for access, and what resources are available for maintenance and cleaning.

Previously the CFR had also allowed the use of stainless steel tubing. CDPHE/APCD does still have a small amount of Stainless tubing in the use in the field and is currently in the process of removing all stainless steel tubing from reactive gas sample lines and replacing them with Teflon®. APCD hopes to have this project accomplished by the end of 2014.

i) Residence Time Determination

No matter how nonreactive the sampling probe material may be, after a period of use, reactive particulate matter is deposited on the probe walls. Therefore, the time it takes the gas to transfer from the probe inlet to the sampling device is critical. Ozone, in the presence of nitrogen oxide (NO), will show significant losses even in the most inert probe material when the residence time exceeds 20 seconds. Other studies indicate that a 10-second or less residence time is easily achievable.

Residence time is defined as the amount of time that it takes for a sample of air to travel from the opening of the inlet probe (or cane) to the inlet of the instrument and is required to be less than 20 seconds for reactive gas monitors. The residence time of pollutants within the sampling manifold is also critical. It is recommended that the residence time, within the manifold and sample lines to the instruments, be less than 10 seconds (of the total allowable 20 seconds). If the volume of the manifold does not allow this to occur, then a blower motor or other device (vacuum pump) can be used to decrease the residence time. The residence time for a manifold

system is determined in the following way. First the volume of the cane, manifold and sample lines must be determined using the following equation:

$$Total\ Volume = Cv + Mv + Lv$$

Where:
Cv = Volume of the sample cane and extensions, cm^3
Mv = Volume of the sample manifold and trap, cm^3
Lv = Volume of the instrument lines, cm^3

Each of the components of the sampling system must be measured individually. To measure the volume of the components, use the following calculation:

$$V = pi * (d/2)^2 * L$$

Where:
V = volume of the component, cm^3
pi = 3.14159
L = Length of the component, cm
d = inside diameter, cm

Once the total volume is determined, divide the volume by the flow rate of all instruments. This will give the residence time.

It has been demonstrated that there are no significant losses of reactive gas (O_3) concentrations in conventional 13 mm inside diameter sampling lines of glass or Teflon if the sample residence time is 10 seconds or less. This is true even in sample lines up to 38 m in length, which collect substantial amounts of visible contamination due to ambient aerosols. However, when the sample residence time exceeds 20 seconds, loss is detectable, and at 60 seconds the loss is nearly complete.

The air flow through the manifold must not be so great as to cause the pressure inside the manifold to be more than one inch of water below ambient. These last two conditions are in opposition to each other, but can be assessed as follows. Construct the manifold. Use a pitot tube or similar instrument to measure the flow of the sample inside the manifold. At the same time, attach a water manometer to a sampling port. Turn on the blower and measure the flow rate and the vacuum. (Remember to allow for the air demand of the instrumentation). Adjust the flow rate to fit between these two parameters. If this is impossible, the diameter of the manifold is too small.

ii) Placement of tubing on the Manifold

If the manifold that is employed at the station has multiple ports, then the placement of the instrument lines can be crucial. If a manifold is used where ambient air flows down the center tube and then travels up on both sides of the manifold to the analyzer ports, it is suggested that instruments requiring lower flows be placed towards the bottom of the manifold. The general rule of thumb states that the calibration line (if used) placement should be in a location so that the calibration gases flow past the instruments before the gas is evacuated out of the manifold. The port at the elbow of the sampling cane provides information about the cleanliness of the sampling system.

iii) Placement of Probes and Manifolds

Probes and manifolds must be placed to avoid introducing bias to the sample. Important considerations are probe height above the ground, probe length (for horizontal probes), and physical influences near the probe.

Some general guidelines for probe and manifold placement are:

- probes should not be placed next to air outlets such as exhaust fan openings
- horizontal probes must extend beyond building overhangs
- probes should not be near physical obstructions such as chimneys which can affect the air flow in the vicinity of the probe

- height of the probe above the ground depends on the pollutant being measured

Information about how far inlets probes must be located from streets and how high they must be mounted can be found in section 3.1 of this QAPP.

3.2.2.4 Probe, Tubing and Manifold Maintenance

After an adequately designed sampling probe and/or manifold has been selected and installed, the following steps will help in maintaining constant sampling conditions:

1. Conduct a leak test. For the conventional manifold, seal all ports and pump down to approximately 1.25 cm water gauge vacuum, as indicated by a vacuum gauge or manometer connected to one port. Isolate the system. The vacuum measurement should show no change at the end of a 15-min period.
2. Establish cleaning techniques and a schedule. A large diameter manifold may be cleaned by pulling a cloth on a string through it. Otherwise the manifold must be disassembled periodically and cleaned with distilled water. Soap, alcohol, or other products that may contain hydrocarbons should be avoided when cleaning the sampling train. These products may leave a residue that may affect volatile organic measurements. Visible dirt should not be allowed to accumulate.
3. Plug the ports on the manifold when sampling lines are detached.
4. Maintain a flow rate in the manifold that is either 3 to 5 times the total sampling requirements or at a rate equal the total sampling requirement plus 140 L/min. Either rate will help to reduce the sample residence time in the manifold and ensure adequate gas flow to the monitoring instruments.
5. Maintain the vacuum in the manifold <0.64 cm water gauge. Keeping the vacuum low will help to prevent the development of leaks.

For monitoring organizations that use individual sampling lines instead of manifolds, one may want to weigh the cost of cleaning lines versus replacing them.

In addition to the information presented above, the following should be considered when designing a sampling manifold:

- suspending strips of paper in front of the blower's exhaust to permit a visual check of blower operation;
- positioning air conditioner vents away from the manifold to reduce condensation of water vapor in the manifold ;
- positioning air conditioner vents away from analyzers;
- positioning sample ports of the manifold toward the ceiling to reduce the potential for accumulation of moisture in analyzer sampling lines, and using borosilicate glass, stainless steel, or their equivalent for VOC sampling manifolds at PAMS sites to avoid adsorption and desorption reactions of VOC's on FEP Teflon;
- if moisture in the sample train poses a problem (moisture can absorb gases, namely NO_x and SO_2), wrap the manifold and instrument lines with “heat wrap”, a product that has heating coils within a cloth covering that allows the manifold to be maintained at a constant temperature that does not increase the sampled air temperature by more than 3-5 degrees C above ambient temperature;
- ensuring the manifold has a moisture trap and that it is emptied often (water traps in sample lines from the manifold to the instruments should be avoided) ; and
- using water resistant particulate filters in-line with the instrument.

3.2.3 SAMPLING/MEASUREMENT FAILURE RESPONSE AND CORRECTIVE ACTIONS

The APCD corrective action procedures are designed to: (1) identify samplers out of specification, (2) identify the cause of the problems in sampler performance, (3) determine what corrective action would be appropriate to

address the problem, (4) implement the action, and (5) verify that the problem has been corrected. The criteria for all criteria pollutants are explicit in several requirements. Failure to meet strict acceptance criteria outlined in the DQO/MQO process for any single critical parameter will result in the invalidation of that data point. However, there exist several operational and systematic criteria that are more qualitative and will assist in troubleshooting potential errors.

Identification of sampler performance out of specification may occur at any point in the quality assurance cycle. Sampling problems are often identified during the performance of quality control checks such as zero, span, and precision tests or sample flow checks. Other problems may be detected during internal or external system or performance audits.

Any member of the Gaseous and Meteorological Monitoring Unit (GMM), Particulate Monitoring Unit (PM) or Quality Assurance Unit (QA) staff may perform the problem identification phase of the quality assurance cycle, and initiate the corrective action process when necessary. In any of these cases, the person who identifies the performance problem is responsible for reporting the problem to the appropriate APCD supervisor and work leads. Performance problems with automated gas samplers or meteorological equipment are reported to the supervisor and work leads of the Gaseous and Meteorological Monitoring Unit. Performance problems with manual or continuous particulate samplers are reported to the supervisor and work leads of the Particulate Monitoring Unit. The supervisor or work lead is responsible for initiating the final corrective action report to document the issue and the solution to the problem.

The supervisors or work leads of each unit, once notified about the existence of a possible problem, is responsible for directing an investigation of any data that may have been affected, and for taking action to correct the problem as quickly as possible so as not to compromise any further data collection.

The reporting of corrective actions to management is described in Section 5 of this document.

3.2.3.1 Continuous Gaseous Systems

There are several corrective actions that are frequently conducted in response to analyzer performance, which exceed the limits presented in Table 3.12. These corrective actions may include analyzer adjustment, zero/span gas delivery system maintenance or repair, analyzer recalibration, or analyzer maintenance or repair. An exceedance of any of these limits is followed by an investigation into the cause and an ambient data quality evaluation by either the PM or GMM Unit supervisor or work lead. A brief discussion of the zero, span, and audit control limits used for APCD automated sampling systems is presented in this section.

Automated nightly zero system checks: (Please see Appendix MQO of this QAPP for MQO's which include the Automated zero value control limits). Please see discussion located in the data validation SOPs in Appendices D3 of this QAPP about our current decision tree for when zero corrections are applied to the data. Zero system checks are run every night.

Automated nightly span value and precision value system checks: Warning limits (±5% for Ozone and ±7% difference for all other criteria gaseous pollutants) and action limits (±7% for Ozone and ±10% difference for all other criteria gaseous pollutants) have been established for evaluation of span test results. A series of three automated span tests within a week with calculated errors greater than the warning limit trigger an investigation into the cause of the difference. Similarly, a single span test which exceeds the action limit triggers an investigation. Span and precision level system checks are currently run every other night, alternating between span and precision levels, on the gaseous analyzers run by CDPHE/APCD and at the Lay Peak site run by ARS. The other three remote sites (Palisades, Cortez and Rifle) that are currently subcontracted to be run by ARS run both the precision and the span check levels every night.

Quality control checks: Quality Control checks are performed by the operators either manually or remotely every two weeks for each gaseous analyzer in the CDPHE/APCD operated network. For the remote sites being subcontracted to and run by ARS (Rifle, Palisades, Cortez & Lay Peak), we receive all the nightly precision level checks from ARS, and our gaseous group randomly selects one point for each two week period to be

reported to AQS as official quality control data. Data becomes suspect, a corrective action may be initiated and further investigation is warranted if a QC check is greater than ±7% for Ozone and ±10% difference for any other criteria gaseous pollutant.

Quality assurance checks: (Also called "performance evaluations" or "audits") Control limits of ±10% for warning and ±15% to pass critical criteria have been established for the APCD monitoring network. Audit errors greater than ±10% require immediate analyzer recalibration but no data adjustments, corrective actions or elimination or deletion of data is performed.

Audit errors greater than ±15% require immediate analyzer recalibration, as well as the initiation of a corrective action to review the quality of the ambient data collected from the time of the audit back to the most recent previous calibration or audit. The investigation of the quality of the ambient data in response to audit errors in excess of ±15% is conducted by QA Unit staff in consultation with the Gaseous Unit leader. This investigation consists of a review of analyzer control charts and maintenance records in an effort to determine what specific event caused the analyzer malfunction. If a specific cause can be identified, then ambient data are deleted from that point up to the time of analyzer recalibration. In the event that no specific cause of the analyzer malfunction can be identified, ambient data are deleted back to the time of the last calibration or audit. The results of audits that failed to meet the audit acceptance criteria and any corresponding corrective actions or data adjustments are listed in the Data Quality Assessment section of the Annual Data Report, which can be found at the APCD Technical Services Program Technical Documents webpage (http://www.colorado.gov/airquality/tech_doc_repository.aspx).

An example of corrective actions and data reconciliation taken for an automated sampler when a data quality objective is not met is provided below:

1) An out-of-limit result (precision value outside ±10% REFS) is seen and analyzed by the field lead person the following morning.
2) Field lead staff notifies the station's assigned field services staff member. The calibrations staff is notified in case of an audit or calibration being needed.
3) The field services staff member visits the station to inspect the analyzer and the precision source. If the precision source alone is obviously at fault, it is repaired and field lead staff is notified of this. If the following precision level is unacceptable, the calibrations staff is notified to test the analyzer. If the analyzer is obviously at fault, or if the fault cannot be isolated, the calibrations staff is notified to test the analyzer.
4) The field lead staff member is given the results of the audit/calibration. If, after an audit, repair to the analyzer is beyond the scope of the calibration staff, the field services staff member is called to do maintenance before a full calibration is done.
5) The field lead staff member determines from the audit/calibration results whether data invalidation is necessary.
6) The field lead staff member deletes any data determined to be unrepresentative from the database used to generate the file submitted to AQS.

Table 3.14 Control Limits and Typical Corrective Actions

Automated Gaseous Samplers (CO, O_3, SO_2, & NO_x)		
Operation Check	**Control Limit**	**Corrective Action**
Nightly Zero Checks	See Appendix DD of this QAPP for more specific information on acceptable zero control limits.	Investigate cause, perform appropriate corrective action
Nightly System Checks	±5% for O_3, 7% other gases (3 consecutive) - warning limit	Investigate cause, perform appropriate corrective action

	±7% for O_3, ±10% other gases Action limit – one time	
Quality Control Check	±7% for O_3, ±10% other gases	Investigate cause, perform appropriate corrective action, recalibrate analyzer if needed, perform data assessment if needed, and document corrective action in Corrective Action database which can be found on the J drive under QA Audit Programs in the Audit Notification DB
Quality Assurance Check	±10% at analyzer full-scale response	Investigate cause, perform appropriate corrective action, recalibrate analyzer
Quality Assurance Check	±15% at analyzer full-scale response	Investigate cause, perform appropriate corrective action, recalibrate analyzer if needed, perform data assessment if needed, and document corrective action in Corrective Action database which can be found on the J drive under QA Audit Programs in the Audit Notification DB

3.2.3.2 Manual Particulate Samplers

For manual systems, corrective actions may be performed in response to a sampler performance audit that exceeds the limits which are presented in Appendix MQO of this QAPP. Corrective actions typically include installation of a new motor, installation of a new pump, flow controller adjustment, or sampler recalibration. A brief discussion of control limits used for APCD manual sampling systems is presented in this section.

Routine flow checks:

$PM_{2.5}$ and PM_{10} low-volume samplers - Flow verification and leak checks are performed by local operators every 15 events.

PM_{10} and TSP high-volume samplers – For every sample the site operator records the pre and post-sample manometer readings on the field datasheet. These manometer readings are converted to flow rates by Particulate Monitoring Unit staff using information from chain of custody sample data sheets. In the event that a sampler is operating outside of acceptable limits, the sample is voided and a Particulate Monitoring Unit field staff person is dispatched to perform any necessary maintenance and recalibration of the sampler.

TSP accuracy (flow) audits: Corrective actions in the event of flow audits outside the ±10% range include sampler recalibration and adjustment of all collected TSP data back to the previous calibration or acceptable audit. The data adjustments are based on the sampler flow characteristics determined at the time of the failed audit.

Lead precision (collocated) evaluation - annual: The annual precision data quality objective can only be assessed when both sample concentrations are greater than $0.002 \mu g/m^3$. The criteria for acceptance is a difference < ±20% at the 95% confidence interval. Large differences observed at the annual time scale are typically systematic and review of all quality control and quality assurance practices are a requisite. This includes a review of all field and laboratory operations, and data management practices.

PM_{10} accuracy (flow) audits: Single point audits are conducted on PM_{10} samplers that use mass flow controllers. If the flow rate at any point exceeds ±7% from the audit flow rate, a warning is issued and the sampler is recalibrated. If the flow rate at any point exceeds ±10% from the audit flow rate the sampler is recalibrated and ambient data back to the most recent calibration or acceptable audit is invalidated. The actual flow rate of all PM_{10} samplers, corrected to standard temperature and pressure conditions, is also compared to the design flow rate of PM_{10} samplers, 1.132 cubic meters per minute. If the design flow rate difference exceeds ±10%, the corrective action is a mass flow controller adjustment and deletion of ambient data back to the most recent calibration or acceptable audit.

The bias acceptance criterion for data comparison from FRM national performance audits (NPAP) is ±10%. If it appears that there is a bias, corrective action will be initiated. The process will include an attempt to determine at what data collection stage the majority of the measurement errors are occurring. This may require that Region VIII perform a reconciliation process.

PM_{10}/TSP precision (collocated) evaluation: The precision data quality objective can only be assessed when both sample concentrations are ≥20µg/m^3 for TSP or ≥15µg/m^3 for PM_{10}. The acceptance criteria will be ≤15% at the 95% confidence interval. An assessment of individual samplers is not relevant at an annual evaluation. Large differences observed at this time scale are typically systematic and a review of all quality control and quality assurance practices are a requisite. This includes a review of all field and laboratory operations, and data management practices.

$PM_{2.5}$ QC filters (Blanks): The acceptance criteria for field blanks is ±30 µg between pre sample and post sample weighs, while lot and lab blanks are ±15 µg difference. However the mean difference based upon the number of blanks in each batch will be used for comparison against the acceptance criteria. If the mean difference of either the field or laboratory blanks is greater than ±15 µg, all the samples in the weighing session will be re-weighed. Prior to re-weighing, the laboratory balance will be checked for proper operation. If the mean weight, of either the field or lab blanks, is still out of the acceptance criteria, all samples within the weighing session will be flagged, and efforts will be made to determine the source of contamination. If the field blanks are outside of the criteria while the lab blanks are acceptable, weighing can continue on the next batch of samples while field contamination sources are investigated. If the mean difference of the laboratory blanks is greater than ±20 µg and 2 or more of the blanks were greater than ±15 µg, the laboratory weighing will stop until the issue is satisfactorily resolved.

$PM_{2.5}$ accuracy (flow) audits: Single point audits are conducted on $PM_{2.5}$ samplers that use mass flow controllers. If the flow rate at any point exceeds ±4% from the flow rate determined at the time of calibration, the corrective action is sampler recalibration and deletion of ambient data back to the most recent calibration or acceptable audit. The actual flow rate of all $PM_{2.5}$ samplers is also compared to the nominal flow rate of $PM_{2.5}$ samplers, 16.67 liter per minute. If the design flow rate difference exceeds ±5%, the corrective action is sampler recalibration and deletion of ambient data back to the most recent calibration or acceptable audit.

The bias acceptance criterion for data comparison from FRM national performance audits (PEP) is ±10%. If it appears that there is a bias, corrective action will be initiated. The process will include an attempt to determine at what data collection stages the majority of the measurement errors are occurring.

$PM_{2.5}$ and PM_{10} low-vol precision (collocated) evaluation –single monitor: Only precision pairs where both measurements are ≥ 3µg/m^3 are used to evaluate collocated low-vol PM data. The precision data quality objective of 10% coefficient of variation (CV) is based upon the evaluation of three years of collocated precision data. The goal is to ensure that precision is maintained at this level. Therefore, precision estimates for a single pair of collocated instruments, or even for a quarter, may be greater than 10% while the three year average is less than or equal to 10%. Therefore, single collocated pairs with values >10% will be flagged and reweighed. If the value remains between 10-20% the field technician will be alerted to the problem. If the CV is greater than 20% for both the initial and reweigh,

all the primary sampler data will be flagged from the last precision check and corrective action will be initiated. Paired CVs and percent differences will be control charted to determine trends. The laboratory technician will alert the QA Officer of the problem. The problem and solution will be reported and appropriately filed under response and corrective action reports. Corrective action at the instrument will include multi-point temperature, pressure, and flow rate checks as well as complete maintenance activities. Additional corrective action could include a request for vendor servicing or a request for Region VIII to implement an FRM performance evaluation.

$PM_{2.5}$ and PM_{10} low-vol precision (collocated) evaluation - annual: Only precision pairs where both measurements are $\geq 3\mu g/m^3$ are used to evaluate collocated low-vol PM data. Usually, a corrective action will be initiated and imprecision rectified before a quarter's worth of data fails to meet 10% CV. However, in the case where the quarter's CV is greater than 20%, the routine data for that monitor for that quarter will be flagged and a null code uploaded to AQS in replacement of the record. The QA Coordinator, the contract laboratory, and the Program Coordinator will work together to identify the problem and a solution. The EPA Regional Office will be alerted of the issue and may be asked to help find a common solution. The problem and solution will be reported and appropriately filed under response and corrective action reports.

Table 3.15 Manual and Continuous Particulate Samplers (TSP, $PM_{2.5}$ and PM_{10})

Operation Check	Control Limit	Corrective Action
Filter Inspection (Pre-sample)	Pinhole(s) or torn, discoloration, or contamination	Note on field datasheet and contact gravimetric laboratory for corrective actions
Filter Inspection (Post-sample)	Torn or otherwise suspect particulate bypassing 46.2 mm filter.	Note on field datasheet
Balance check (low-vol)	±0.3µg	Reweigh entire filter batch back to last passing QC point.
Balance check (high-vol)	±0.5mg	
Filter Reweighing (low-vol)	±15 µg	Reweigh entire filter batch back to last passing QC point.
Filter Reweighing (high-vol)	Pre sampled: 2.8mg Post sampled: 5.0mg	Reweigh entire filter batch back to last passing QC point.
Design Flow Check (TSP)	1.1-1.7 m^3/m	Adjust or replace mass flow controller, or recalibrate motor.
Design Flow Check (PM_{10})	1.02– 1.24 m^3/m	Adjust or replace mass flow controller, or recalibrate motor.
Design Flow Check ($PM_{2.5}$)	15.83 – 17.50 L/min	Recalibrate sampler.
Set-point Flow Audit (TSP)	±10%	Calibrate sampler and adjust TSP data
Set-point Flow Audit (PM_{10} high-vol)	±10%	Calibrate sampler and invalidate data
Set-point Flow Audit ($PM_{2.5}$ and PM_{10} low-vol)	±4%	Calibrate sampler and invalidate data

Example Corrective Actions and Data Reconciliation for a Manual Parameter:

If a PM_{10}, TSP or $PM_{2.5}$ accuracy audit fails to meet specifications cited in figure 3.12, the following steps are initiated:

- Double check the audit orifice standard's certification.
- Recheck all calculations.
- Perform additional flow measurements.
- Refer to stand alone audit procedures in Appendix QA1.

When it has been determined that a PM_{10}, TSP or $PM_{2.5}$ sampler has failed an accuracy audit, the following actions are taken (These actions are specified in quality assurance procedures):

- The quality assurance section notifies the particulate monitoring section, via the Audit Notification database, of the failed audit.

- The Particulate Monitoring Group is responsible for investigating and rectifying the situation and, if necessary, deleting affected data. Upon completion of all corrective actions and data review the Program Manager will "close-out" the audit failure by documenting all corrective actions and data implications in the Audit Notification database.

- The Particulate Monitoring Section is responsible for deleting data in the following manner:

- PM_{10} and TSP high-vol Samplers

    1. The Sample Record Sheet of each individual sample taken on the affected motor is pulled. These include those from the date of original calibration or the last valid audit; whichever is closer to the failed audit data.
    2. All samples taken on the affected motor during the period shown above are voided.
    3. The Sample Record Sheet is annotated "Sample void due to failed audit." This is initialed and entered on the Sample Record Sheet.
    4. The Particulate Monitoring Section performs a motor change and field calibration as soon as practical upon notification of the failed audit.

- $PM_{2.5}$ and PM_{10} low-vol Samplers

    1. A query is performed in the $PM_{2.5}$ database to select all samples from the failed sampler for the past two quarters.
    2. Maintenance and audit records are evaluated to determine when the last calibration, verification and audit were performed.
    3. A "failed audit" flag is set in the database flag column for all samples from the failed audit back to the most recent valid calibration, verification or audit.
    4. The Particulate Monitoring Section performs repairs and a field calibration as soon as practical upon notification of the failed audit.

Table 3.16 Manual Samplers ($PM_{2.5}$)

Item	Problem	Action	Notification
Filter Inspection (Pre-sample)	Pinhole(s) or torn, discoloration, or contamination	1.) If additional filters are available, use one of them. Void filter with pinhole, tear, discoloration, or contamination that cannot be easily removed. 2.) Use new field blank filter as a sample filter.	1.) Document on FDS. 2.) Document on FDS.

Item	Problem	Action	Notification
		3.) Obtain a new filter from lab with next shipment. 4.) Request replacements if >10%.	3.) Document on FDS. 4.) Notify EPA Region VIII, quarterly
Filter Inspection (Post-sample)	Torn or otherwise suspect particulate bypassing 46.2 mm filter.	1.) Inspect area downstream of where filter rests in sampler and determine if particulate has been bypassing filter. 2.) Inspect in-line filter before sample pump and determine if excessive leading has occurred. Replace as necessary.	1.) Document on FDS. 2.) Notify Field Manager, APCD 3.) Notify EPA Region VIII, quarterly
Sharp Cut and Very Sharp Cut Cyclones	Heavily loaded with particles.	Clean VSCC. Perform an external leak check.	Document on FFRM/SV Notify Field Manager, APCD.
Sample Flow Rate Verification	Out of Specification (±4% of transfer standard)	1.) Completely remove flow rate device, reconnect and re-perform flow rate check. 2.) Perform leak test. 3.) Check flow rate at one point (usually 16.7 LPM) to determine if flow rate is acceptable 4.) Recalibrate sampler.	1.) Document on FFRM/SV FDS. Notify Field Manager, APCD 2.) Document on FFRM/SV FDS. Notify Field Manager, APCD 3.) Document on FFRM/SV FDS. Notify Field Manager, APCD 4.) Document on FFRM/SV FDS. Notify Field Manager, APCD
Leak Test	Leak outside acceptable tolerance (80 mL/min)	1.) Completely remove flow rate device, reconnect and re-perform leak test. Try to isolate the external leaks by performing leak tests with the flow audit adapter directly above the VSCC or SCC and directly below the VSCC or SCC. Try different leak check cassettes. 2.) Be sure the VSCC or SCC is tightly screwed together, and then repeat the external leak test. If the leak test fails, inspect and clean all seals and O-rings, replace as necessary and re-perform leak test. 3.) Check sampler with different flow audit adapter or external or internal leak check cassette.	1.) Document on FFRM/SV FDS. Notify Field Manager, APCD 2.) Document on FFRM/SV FDS. Notify Field Manager, APCD and flag data since last successful leak test. 3.) Document on FFRM/SV FDS. Notify Field Manager, APCD
Sample Flow Rate	Consistently low flows documented during sample run.	1.) Check programming of sampler flow rate. 2.) Check flow with a flow rate verification filter and determine if actual flow is low. 3.) Inspect in-line filter downstream of 46.2 mm filter location, replace as necessary. 4.) Do a hard reset of the sampler. 5.) Sampler will automatically shut down if below the design flow rate for > 30 min.	1.) Document on FAS and SAE, notify Field Manager, APCD 2.) Document on FAS and SAE, notify Field Manager, APCD 3.) Notify Field Manager, APCD 4.) Notify Field Manager, APCD 5.) Notify Field Manager, APCD
Ambient Temperature Verification, and Filter Temperature Verification	Out of Specification (± 4°C of standard).	1.) Make certain thermocouples are immersed in same liquid at same point without touching sides or bottom of container. 2.) Use ice bath or warm water bath to check a different temperature. If acceptable, re-perform ambient temperature verification. 3.) Connect new thermocouple.	1.) Document on FFRM/SV FDS. Notify Field Manager, APCD 2.) Document on FFRM/SV FDS. Notify Field Manager, APCD 3.) Document on FFRM/SV FDS. Notify Field Manager, APCD

Item	Problem	Action	Notification
		4.) Check ambient temperature with another NIST traceable thermometer.	4.) Document on FFRM/SV FDS. Notify Field Manager, APCD
Ambient Pressure Verification	Out of Specification (±10 mm Hg)	1.) Make certain pressure sensors are each exposed to the ambient air and are not in direct sunlight. 2.) Call local Airport or other source of NIST traceable ambient pressure data and compare that pressure adjusted for difference in elevation, to pressure data from monitor's sensor. Pressure correction may be required. 3.) Connect new pressure sensor.	1.) Document on FFRM/SV FDS. Notify Field Manager, APCD 2.) Document on FFRM/SV FDS. Notify Field Manager, APCD. 3.) Document on FFRM/SV FDS. Notify Field Manager, APCD.
Elapsed Sample Time	Out of Specification (15 min/month)	1.) Check Programming, Verify Power Outages. 2.) Reset the clock to correct time	1.) Notify Field Manager, APCD 2.) Document on FDS
Elapsed Sample Time	Sample did not run	1.) Check Programming. 2.) Try programming sample run to start while operator is at site. Use a flow verification filter.	1.) Document on FDS. Notify Field Manager, APCD 2.) Document on FDS. Notify Field Manager, APCD.
Power	Power interruptions	Check Line Voltage.	Notify Field Manager, APCD
Power	LCD panel on, but sample not working.	Check circuit breaker, some samplers have battery back-up for data but will not work without AC power.	Document in FDS. Notify Field Manager, APCD
Data Downloading	Data will not transfer to laptop of palmtop computer	Document key information on sample data sheet. Make certain problem is resolved before data is written over in sampler microprocessor.	Notify Field Manager. Notify Field Manager, APCD

3.2.3.3 Continuous Particulate Samplers.

CDPHE/APCD has many different automated Particulate samplers in operation, many of which operate on different principles. For more information on when a corrective action is necessary for an automated particulate sampler please see Appendix MQO of this QAPP and the Associated Operator's Manuals for each Type of continuous particulate sampler. Generally for these analyzers the biggest indicator of a problem and one of the few reasons to invalidate data is a failing flow audit. Below please find a short table listing the failing flow criteria for each type of continuous particulate analyzer we currently operate:

Table 3.17 Continuous Particulate Audit Criteria

Type of continuous sampler	Design flow	Audit criteria on flow
R&P TEOM PM_{10}	16.7L/m @ inlet / 3.0L/m through filter	±10% on both
R&P TEOM $PM_{2.5}$	16.7L/m @ inlet / 3.0L/m through filter	±4% / ±6%
R&P TEOM $PM_{2.5}$ w/ FDMS	16.7L/m @ inlet / 3.0L/m through filter	±4% / ±6%
TECO TEOM 1405 $PM_{10-2.5}$	16.7L/m @ inlet / 3.0L/m	±4% / ±6% / ±10%

	through filter #1/ 1.67L/m through filter @2	
GRIMM	1.2 L/m	±20%
Aethalometer		±5%

Table 3.12 has been pulled from 40 CFR Part 58 Appendix A Table 2, and lists the minimum data assessment requirements for all SLAMS sites:

3.2.4 SAMPLING EQUIPMENT, PRESERVATION, AND HOLDING TIMES

Of all the ambient air criteria pollutants, the only ones requiring sample preservation are $PM_{2.5}$ filters. The equipment used for $PM_{2.5}$ sampling is described in 40CFR Part 50 Appendix L. The support for the sampling program begins at the origin of the 46.2 mm Teflon filters. The filters are conditioned, weighed, labeled and packaged for shipping by the laboratory staff. These filters are then sent to the field for sampling. After use, the recovery and shipping process is performed by the operator and is crucial for a successful program. See Table 3.19. See Table 3.20 for filter temperature requirements recommended for preservation of the samples.

Table 3.18 Filter Temperature Requirements ($PM_{2.5}$)

Item	Temperature Requirement	Reference
Filter temperature control during sampling and until recovery.	No more than 5º C above ambient temperature.	40 CFR Part 50, Appendix L, Section 7.4.10.
Filter temperature control from time of recovery to start of conditioning.	Protected from exposure to temperatures over 25º C.	40 CFR Part 50, Appendix L, Section 10.13.
Post sampling transport so that final weight may be determined up to 30 days after end of sample period.	4º C or less.	40 CFR Part 50, Appendix L, Section 8.3.6.

Table 3.19 Filter Holding Times ($PM_{2.5}$)

Item	Holding Time	From:	To:	Reference
Pre-weighed Filter	≤30 days	Date of Pre-weigh	Date of Sample	40 CFR Part 50, Appendix L, Section 8.3.5
Recovery of Filter	≤96 hours	Completion of sample period	Time of sample recovery	40 CFR Part 50, Appendix L, Section 10.10
Transport of Filter	<24 hours (ideally)	Time of recovery	Time placed in conditioning room	40 CFR Part 50, Appendix L, Section 10.13
Post-Sample filter Stored at <4º C.	≤30 days	Sample end date/time	Date of Post-weigh	40 CFR Part 50, Appendix L, Section 8.3.6
Post-Sample Filter Continuously Stored at <25º C.	≤ # days = 34 -º C of sample when received at laboratory.(not to exceed 30 days)	Sample end date/time	Date of Post-weigh	40 CFR Part 50, Appendix L, Section 8.3.6

3.2.5 APCD POLICY ON THE USE OF MAKEUP SAMPLES

3.2.5.1 PM_{10} and TSP high-vol Makeup Samples

The APCD allows for the makeup of PM_{10} and TSP samples due to unforeseen or extenuating circumstances. Allowing the use of makeup samples allows for flexibility in showing compliance with federal completeness criteria. Prior permission from a staff person within the Particulate Monitoring Unit is required prior to performing the makeup sample. A makeup sample must be completed within two weeks of the date when the scheduled sample was missed. A makeup sample must be run on a day when no other PM_{10} samplers are running at the site. Makeup samples are therefore not a possibility at sites that run on a daily schedule because one sampler is always running at the site. Makeup samples can only be performed at sites that operate on a 1 in 3, and 1 in 6 schedules. If a makeup sample is performed, the date when the makeup sample was actually performed must be used on the Field Data Sheet and not the date when the sample was missed.

3.2.5.2 $PM_{2.5}$ and PM_{10} low-vol Makeup Samples

The State of Colorado Air Pollution Control Division currently maintains the appropriate number of FRM instruments across the state of Colorado to protect the health and welfare of its citizens. The Division uses the R&P 2025A Partisol-Plus sequential samplers and the R&P 2000 FRM Partisol samplers in its network of FRM monitors. The Division also maintains enough samplers on hand as back-ups when instruments fail in the field. Details of the PM monitors maintained by the Division can be found in its Annual Monitoring Plan at the CDPHE/APCD/TSP Technical Documents and Reports web site (http://www.colorado.gov/airquality/tech_doc_repository.aspx).

There are many reasons why Colorado has selected sequential monitors as the backbone of its network. Sequential monitors theoretically require fewer site visits. For example, the sampler can be programmed to cover two samples at a one-in-three day frequency site in a four day period before the samples must be collected. They can also be setup to run over three day holiday periods without anyone visiting the site to prepare the sampler for a run. Since the Colorado network is set up over a large geographical area, the APCD must employ many local health department environmental staff as site operators. These site operators are busy with other local agency tasks. The sequential monitors allow them to operate a one-in-three day frequency site or a daily site and still attend to their regular duties. The single samplers are used only in locations where a one-in-six day schedule is maintained and for collocated sampling. Sometimes the samplers will fail for a variety of mechanical reasons. Sometimes a local operator has a schedule conflict that prevents them from attending their duties under this program. In any case, operators have been instructed to use make-up samples in attempt to achieve the minimum data capture goal.

For example: the preferred option for make-up day selection for every third day sampling sites is to sample on the next closest available unscheduled sample day as possible. The selection day for all sixth day sampling sites will be to sample on the next scheduled third day sample day between the scheduled every sixth day, if possible. Alternatively, the sample can be taken exactly one week from the missed sampling date on the same day of the week as the missed sample. These selection day methods should prevent bias on the part of the site operator and agencies involved in the sampling. The APCD will maintain information in the filter data sheet (FDS) archival files regarding the reasons for the missed scheduled sample day in all cases. If the reason is not included in the FDS archives, the make-up day data will not be used in the calculations of the annual or the 24-hour standards. There should be no more than five make-up samples taken per site per calendar quarter. The make-up sampling day will be no later than one week from the missed sample day in all cases.

3.3 SAMPLE HANDLING, CUSTODY PROCEDURES, AND DOCUMENTATION

This section generally describes the requirements and provisions for sample handling and custody in the field, laboratory, and transport, taking into account the nature of the samples, the maximum allowable sample holding times before analysis, and the available shipping options and schedules. This section of the QAPP describes all procedures that are necessary for ensuring that:

1. Samples are collected, transferred, stored, and analyzed by authorized personnel;
2. Sample integrity is maintained during all phases of sample handling and analyses; and
3. An accurate written record is maintained of sample handling and treatment from the time of its collection through laboratory procedures to disposal.

Proper sample custody minimizes accidents by assigning responsibility for all stages of sample handling and ensures that problems will be detected and documented if they occur. A sample is in custody if it is in actual physical possession or it is in a secured area that is restricted to authorized personnel. The level of custody necessary is dependent upon the project's DQOs. While enforcement actions necessitate stringent custody procedures, custody in other types of situations (i.e., research) may be primarily concerned only with the tracking of sample collection, handling, and analysis. Sample custody procedures are necessary to prove that the sample data correspond to the sample collected if data are intended to be legally defensible in court as

evidence. In a number of situations, a complete, detailed, unbroken chain of custody will allow the documentation and data to substitute for the physical evidence of the samples in a civil courtroom.

3.3.1 CHAIN OF CUSTODY

The rules of evidence used in legal proceedings require that procedures for identification of samples used in analyses form the basis for future evidence. An admission by the laboratory analyst that he/she cannot be positive whether he/she analyzed a particular sample could destroy the validity of the entire test report.

There are four elements in the APCD sample chain-of-custody procedures. These elements include (1) data collection, (2) sample handling and storage, (3) analysis and data processing, and (4) reporting and record keeping. Detailed information about the data collection and sample handling components of this process are provided in each of the Standard Operational Procedures. The analysis and record keeping components are detailed in the SOPs found in appendices at the back of this document. Sections B9 and B10 on Data Acquisition Management and Section D on Data Validation discuss the data processing and reporting aspects of this procedure. A brief overview of this sample custody and record keeping process is presented below.

PM_{10}/TSP Filters
The field operator will document each sample collected and a Field Data Sheet (envelope) will be filled out. Field Data Sheets (envelope) have been created by the gravimetric laboratory. The field operator is responsible for properly filling out a Field Data Sheet (envelope), changing filters and mailing exposed filters directly to the gravimetric laboratory. Data to be included on the Field Data Sheet (envelope) are: sample date, site name, sampler type and ID, motor number, filter number, cassette number (where applicable), run time, preliminary and subsequent sampler conditions, and operator name and lab technician name (where applicable). Following filter conditioning and analysis of the filter, the filter is stored at the gravimetric laboratory for up to six months. The APCD then takes custody of all samples and Field Data Sheets (envelopes) and the samples are then stored at the Technical Services Program offices. Copies of the PM_{10} and TSP Sample Record Sheets can be found in the Figures (Figure 4 for PM_{10}, and Figure 3 for TSP) at the end of Appendices E and F at the end of this QAPP document.

A copy of all calculations involved in the determination of particulate concentration is maintained on permanent electronic record within the Colorado Department of Public Health and Environment through a Microsoft Access database program.

$PM_{2.5}$ Filters
The Teflon filters will be shipped by the APCD to the gravimetric laboratory. There, they will be examined, conditioned, identified and tare-weighed by the laboratory technician. A record of each filter ID will be made upon an accepted tare-weight and will be placed in a sample filter cassette identified by the number on the filter cassette. The filter and its cassette are inserted into an anti-static bag that is labeled with the cassette ID, filter ID and the site at which the filter is to be sampled.

The Field Data Sheets (FDS) are developed at the APCD and are mailed to the gravimetric laboratory. The Field Data Sheet is unique to each site and is customized for its unique sampling schedule. Information as to when the sampler is to operate is documented on each sheet. From the FDS the gravimetric laboratory will determine the number of filters needed for the site. The gravimetric laboratory will ship the required filters and the Field Data Sheets to the site operators. At the laboratory the filters are assigned to a site but not to a sampling date. A sampling date is assigned to the filter once the filter is sampled. For each sampling date on the FDS, the field operator will write the filter ID and cassette ID for the filter used on that date. Upon completion of sampling, the summary data for the sampling event is written on the FDS. After the entire batch of filters is sampled, the filters and their FDS are returned to the gravimetric laboratory for gross weighing. Samples will be kept in a secure place between the time they are collected and the time they are analyzed and will remain secured until discarded. A written record signed or initialed by the sample handlers will document these security measures. For details regarding the Sample Custody Procedure(s) and a copy of the FDS/COC sheet can be found in Appendix PM2.

A copy of all calculations involved in the determination of particulate concentration is maintained in a permanent electronic record within the Colorado Department of Public Health and Environment through a Microsoft Access database program.

Continuous Analyzers

There are several steps during data collection and processing for automated systems. A field operator in the GMM Unit is responsible for ensuring agreement between the digital data chart backup data logger and the primary data acquisition system. Each data logger is programmed with a unique site identification number that is associated with each data value. All copies of calibration records, maintenance logs, and strip charts are maintained by the Technical Services Program.

Actual resultant data for gaseous, particulate and meteorological data are maintained on the Air Quality Subsystem (AQS) database.

3.3.2 SAMPLE CUSTODY FOR MANUAL SAMPLES

3.3.2.1 Particulate Filter Handling

PM_{10}/TSP Filters

Air sampling filter media for PM_{10} and TSP sampling are received from USEPA National Exposure Research Laboratory (NERL) in annual allotments. Each shipment of filters (quartz and fiberglass) is accompanied by documentation of the acceptability testing that was performed at NERL. A random sample of filters is visually inspected by NERL for pinholes, lines, loose fibers, coloration, and other structural defects. A random sample of filters is also inspected by NERL for certain physical and chemical properties including: thickness, brittleness, integrity, tensile strength, flow resistance, particle retention, filter size, lead (Pb) background concentration, and weight loss on ignition.

The filters are stored in the APCD storage facility in the original containers until requested by the gravimetric laboratory. Filters are typically shipped quarterly or on an as needed basis.

The accepted filters are then tare-weighed, and sent to the field operator for sampling purposes. After the sample has been taken and removed from the sampler, the field operator mails the filter back into the laboratory for gross weight and mass determination. After all analyses and data validation activities have been performed, the filters are given to an APCD staff member for extended storage in an appropriate facility. All of the particulate filters collected during a given month are stored together in order to facilitate filter retrieval.

$PM_{2.5}$/TSP Filters

Air sampling filter media for $PM_{2.5}$ sampling are received from USEPA Monitoring and Quality Assurance Group in annual allotments. Each shipment of filters (46.2mm Teflon) is accompanied by documentation of the acceptability testing that was performed for the USEPA. A random sample of filters is visually inspected by USEPA for pinholes, lines, separation of filter media from support ring, chaffing, loose material, discoloration, filter non-uniformity, and other structural defects. A random sample of filters is also inspected by USEPA for certain physical and chemical properties including: temperature stability, physical dimensions, alkalinity, moisture retention, particle retention and pressure drop.

The filters are stored in the APCD storage facility in the original containers until requested by the gravimetric laboratory. The gravimetric laboratory maintains at a minimum, a surplus of 4 weeks of filters on site. A gravimetric laboratory surplus of less than 4 weeks of filters is an indication to the lab to request more from APCD.

The accepted filters are examined, conditioned, identified and tare-weighed by the gravimetric laboratory technician. A record of each filter ID will be made upon an accepted tare-weight and will be placed in a sample filter cassette identified by the number stamped on the filter support ring. Each filter/cassette

combination is assigned to a site. The petri dish containing the filter/cassette will be labeled with the filter ID, cassette ID, tare date time, and site ID. Every filter and cassette ID will be recorded on the FDS/COC sheet.

3.3.2.2 Handling and Storage of High Concentration Filters

Filter samples with ambient concentrations near that of the NAAQS are of particular interest to the APCD. PM_{10} and $PM_{2.5}$ filters with 24 hr concentrations of >120 µg/m^3 or >35 µg/m^3, respectively, are automatically considered for chemical speciation. These samples are often submitted to private analytical laboratories for extensive chemical characterization in order to understand the relative influence of various particulate pollution sources on that day. The laboratory analyst will report all PM_{10} and $PM_{2.5}$ filters with 24 hr concentrations of >120 µg/m^3 and >35 µg/m^3, respectively, to the APCD Technical Services Program Manager. As soon as practicable, an APCD representative takes possession of the filters. The APCD representative completes an "Air Filter Custody Form" (Figure 3.5), which is filed in the filter storage box in place of the exposed filter.

Upon receipt from the gravimetric laboratory, the PM_{10} filters are placed in a field folder, which is carefully annotated with the site name, AQS ID code, sample date, filter number, air flow (L/min or m^3/min)) and concentration (µg/m^3). This field folder is then placed inside a mailing envelope, which is also annotated with the site name, sample date and concentration, and stored in the APCD freezer to await further analysis. $PM_{2.5}$ filters are stored in a freezer kept between 0 and 4^{o}C in the laboratory petri dishes that are labeled with the filter ID number.

Figure 3.6 PM_{10}/TSP Air Filter Custody Form

AIR FILTER CUSTODY FORM

Colorado Department of Health
Air Pollution Control Division
Technical Services Program

Site:

Filter No: _____ Sample Date: _____
Filter No: _____ Sample Date: _____
Filter No: _____ Sample Date: _____
Filter No: _____ Sample Date: _____

Removed from the filter storage on (date) _____, for the following reason:

_____ Storage in APCD freezer, pending analysis
_____ Shipment to contract laboratory for further analysis
_____ Demonstration purposes _____
_____
_____

Signature: _____

3.3.2.3 Particulate Filter Custody

PM_{10}/TSP Filters

After all gravimetric laboratory analyses have been completed, the particulate samples are collected by calendar month and stored in the appropriate dated filter storage box. This box is stored at the laboratory. Once all analyses have been completed, the archived filters are no longer needed in the laboratory setting and can be sent to the APCD for temporary on-site storage. APCD typically retains the filters for one year then moves the filters to an off-site storage location. The APCD Particulate Monitoring Unit leader is responsible for seeing that the long-term storage area is a dry, dust-free environment to prevent any contamination of the stored filters.

$PM_{2.5}$ Filters

After all gravimetric laboratory analyses have been performed, the $PM_{2.5}$ particulate filter samples are collected and stored on-site at the gravimetric laboratory in a walk-in freezer between 0-4^{o}C. Filters are kept at the gravimetric laboratory for one year or as long as there is a need for reanalysis. Upon completion of one year, the gravimetric laboratory requests that the APCD take custody of the filters. The APCD can request filters of interest be shipped to APCD at any time. APCD can request that the laboratory dispose of all stored filters over one year old. The APCD Particulate Monitoring Unit leader is responsible for seeing that all filters of interest are shipped to APCD and properly stored in a 0-4^{o}C refrigerated environment.

3.3.2.4 Removing Archived Filters from File

Occasionally, the need occurs to remove an archived filter from laboratory or permanent storage for further analysis or public educational purposes. Specific filters may be of extreme importance to APCD air quality planning activities. High concentration (PM_{10} ≥120 µg/m^3, $PM_{2.5}$ ≥35 µg/m^3) samples should not be used for demonstration purposes. Similarly, annual maximum or second maximum samples should not be used for demonstrations.

All requests for removal of archived filters are passed through the APCD representative to the laboratory. Filters from the gravimetric laboratory are shipped to APCD for storage or to a location of APCD's choice. Once a filter is archived with APCD's filter bank, located at the APCD main offices, a PM_{10}/TSP Air Filter Custody Form is used to remove high-vol filters from the archive bank. The PM_{10}/TSP Air Filter Custody Form is inserted in the filter storage box in place of the exposed filter (Figure 3.6). After completion of chemical analysis, any remaining portion of the TSP or PM_{10} filter is returned to storage.

3.3.3 SAMPLE CUSTODY FOR AUTOMATED SAMPLERS

The *in situ* sampling of criteria pollutants through the use of continuous analyzers does not require the use of sample custody procedures. Due to the *in situ* nature of continuous sampling, samples are never removed from the location from which they are acquired, and thus do not require a formal sample custody procedure. Acknowledgment of sample collection is done daily by means of data review. The ultimate disposition of nearly all of the air quality data collected by the APCD with automated samplers is the EPA's national ambient air quality database: the Air Quality Subsystem (AQS). Data submitted to AQS includes all gaseous and particulate pollutant concentration data as well as all meteorological data.

There is currently no provision to submit visibility (light extinction, $ß_{ext}$) data to the AQS database because a method code has not been assigned to the transmissometer. Light extinction data are maintained by APCD staff in a database on a computer in the GMM Unit.

3.4 ANALYTICAL METHODS REQUIREMENTS and TASK DESCRIPTION

Numerous analytical methods are employed by APCD in the sampling and analysis of criteria pollutants. For each pollutant type, the analytical method must be described thoroughly in a standard operating procedure. Additionally, to ensure the methods are being performed accurately, quality control and quality assurance guidelines and criteria must be developed and documented in the project's QAPP. Analytical methods are performed by both APCD and contract laboratories. It is the responsibility of the APCD to ensure that all their analytical methods have approved SOPs and quality assurance documents in place and compiled in the projects QAPP. It is also the APCD's responsibility to require all contract laboratories to provide SOPs of their

analytical methods and quality assurance/quality control documentation. These documents must meet all APCD and federal criteria prior to being employed on behalf of the APCD.

3.4.1 STANDARD OPERATING PROCEDURES

In order to perform sampling and analysis operations consistently, standard operating procedures (SOPs) must be written as part of the QAPP. Standard operating procedures (SOPs) are written documents that detail the method for an operation, analysis, or action with thoroughly prescribed techniques and steps and are officially approved as the method for performing certain routine or repetitive tasks.

SOPs should ensure consistent conformance with organizational practices, serve as training aids, provide ready reference and documentation of proper procedures, reduce work effort, reduce error occurrences in data, and improve data comparability, credibility, and defensibility. They should be sufficiently clear and written in a step-by-step format to be readily understood by a person knowledgeable in the general concept of the procedure.

SOP formatting suggestions can be found at *Guidance for the Preparation of Standard Operating Procedures (SOPs)*, QA/G-6, EPA, 2007.

SOPs should be written by individuals performing the procedures that are being standardized. SOPs for the Ambient Air Quality Monitoring Program environmental data operations must be included in QAPPs, either by reference or by inclusion of the actual method. If a method is referenced, it must be stated that the method is followed exactly or an addendum that explains changes to the method must be included in the QAPP. If a modified method will be used for an extended period of time, the method should be revised to include the changes to appropriate sections. In general, approval of SOPs occurs during the approval of the QAPP. Individuals with appropriate training and experience with the particular SOPs need to peer review the SOPs.

Additional SOPs covering laboratory procedures performed on APCD samples are required to be prepared by the laboratory performing the analysis. These SOPs have been reviewed by APCD for compliance with all federal regulations and are also included in the appendices to this QAPP.

3.4.2 GOOD LABORATORY PRACTICES

Good laboratory practices (GLPs) refer to general practices that relate to many, if not all, of the measurements made in a laboratory. They are usually independent of the SOP and cover subjects such as maintenance of facilities, records, sample management and handling, reagent control, and cleaning of laboratory glassware. In many cases the activities mentioned above may not be formally documented because they are considered common knowledge. Although not every activity in a laboratory needs to be documented, the activities that could potentially cause unnecessary measurement uncertainties, or have caused significant variance or bias, should be cause to generate a method.

In 1982, the Organization for Economic Co-operation and Development (OECD) developed principles of good laboratory practice. The intent of GLPS is to promote the quality and validity of test data by covering the process and conditions under which EDOs are planned, performed, monitored, recorded and reported.
The principles include:

- test facility organization and personnel
- quality assurance program
- facilities
- apparatus, material and reagents
- test systems
- test and reference substances
- standard operating procedures
- performance of the study

- reporting of study results
- storage and retention of records and material

3.4.3 LOCATION OF SOPS

More detailed information can be found on each specific method in the Standard Operating Procedures located in the appendices of this CDPHE/APCD/TSP QAPP.

3.5 QUALITY CONTROL REQUIREMENTS

To ensure the quality of data from air monitoring measurements, two distinct and important interrelated functions must be performed. One function is the control of the measurement process through broad quality assurance activities, such as establishing policies and procedures, developing data quality objectives, assigning roles and responsibilities, conducting oversight and reviews, and implementing corrective actions. The other function is the control of the measurement process through the implementation of specific quality control procedures, such as audits, calibrations, checks, replicates, routine self-assessments, etc. In general, the greater the control of a given monitoring system, the better will be the resulting quality of the monitoring data.

"Quality Control (QC) is the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer; operational techniques and activities are used to fulfill requirements of policy." In the case of the APCD Air Monitoring Network, QC activities are used to ensure that measurement uncertainty is maintained within acceptance criteria for the attainment of the MQO/DQO.

Quality control is both corrective and proactive in establishing techniques to prevent the generation of unacceptable data.

A summary of all the APCD QC and QA protocols can be found in tabular form classified by critical and noncritical criteria in Appendix MQO of this QAPP.

3.5.1 INTERNAL SYSTEM PERFORMANCE and QUALITY CONTROL CHECKS

Precision is the measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. In order to meet the data quality objectives for precision, the Department must ensure the entire measurement process is within statistical control.

Continuous Gaseous Analyzers operated by APCD
A manual one-point, bi- weekly, low-to-mid level quality control precision check is performed and this value is reported to AQS by the GMM group. The quality control check testing program is designed to assess the ability of an analyzer to repeatedly measure a known analyte gas at a relatively low concentration, typical of what is commonly found in ambient air. These precision tests must be performed at a minimum frequency of once every two weeks on a random basis.

Additionally, every night automated operational performance checks are performed on every gaseous analyzer in the network. The zero functions are tested every night. High level and mid to low level checks are run on alternating nights by an automated system to check analyzer performance and drift. During high or low/mid checks, analyte gas of know concentration is passed through the ambient sampling system.

The results of these operational performance checks are shown with both the actual and indicated zero values, and the indicated analyzer check values are measured against the calibration system calculated output concentration. These checks are reviewed daily by the Gaseous and Meteorological Unit staff. The data from these checks are available in on-line control charts to evaluate trends.

The control chart action and warning limits are consistent with the error calculations used to assess analyzer performance during audits. A warning limit of ±7% error in the high concentration and an action limit of ±10% error are used for all gaseous analyzers in the network except Ozone. For Ozone a warning limit of ±5% and action limit of ±7% is used. The supervisor of the Gaseous and Meteorological Unit is notified if these action or warning limits are exceeded. The corrective actions that result when these limits are exceeded are presented in Section 5 of this document, Assessment and Response Actions of the QAPP.

The need to correct data for zero drift is evaluated on a case to case basis. Appendix D3 of the QAPP will cover how zero drift evaluation and zero corrections are handled. The zero drift limits are outlined in Appendix MQO for each gaseous pollutant. The supervisor of the GMM Unit is notified if this limit is exceeded and if zero corrections are deemed necessary. The corrective actions, which result when this limit is exceeded, are presented in Section 5.5, of this QAPP.

One additional internal quality control procedure is the notation on analyzer log forms of any relevant information about the monitoring station and analyzer during site visits. Inspection of these forms, which are maintained by the GMM Unit supervisor, often provides an early indication of changes in performance and operating characteristics of the instrument. Detailed information about these station and analyzer record-keeping procedures is provided in the Standard Operational Procedures found in the appendices of this QAPP.

Continuous Ozone Analyzers operated by ARS

Every night, automated operational performance checks are performed on every gaseous analyzer in the network. The zero functions are tested every night. Both high level and mid to low level checks are run by an automated process every night to check analyzer performance and drift. During high or mid/low checks, analyte gas of known concentration is passed through the ambient sampling system. The GMM group inspects the nightly precision data provided quarterly by ARS and pulls every thirteenth low to mid level data point from the automated nightly data. Those values are then entered into the AQS system for the bi weekly quality control check.

Particulate Samplers high-vol Samplers

The quality control precision check test program for manual samplers is different than that used for automated samplers. The manual sample quality control checks rely on the comparison of the response of collocated samplers. Identical samplers are operated at several sites (currently there are three high-vol PM_{10} collocated sites) in the APCD network. One sampler is designated as the primary sampler while the other is the collocated match. The response of the sampler, in terms of atmospheric concentration ($\mu g/m^3$), is used as the actual value. The response of the identical collocated sampler provides a measure of the actual value's precision.

Collocated Monitoring Rules for PM_{10}: Twenty-five percent or more of the PM_{10} network must be collocated, and the collocated samplers should be of the same style and brand of equipment.

An additional quality control check performed for manual samplers consists of a check of sampler flow before and after the filter sample is collected. For proper operation, airflow into a TSP sampler must be in the range of 1.1 – 1.7 m^3/min, while the airflow into a PM_{10} sampler must be in the range of 1.02 – 1.24 m^3/min. The Particulate Monitoring Group leader is notified if these flow range limits are exceeded. The corrective actions, which result when these limits are exceeded, are presented in Section 5 of this QAPP. More detailed information can be found on this topic in the method specific Standard Operating Procedures (SOPs) located in the appendices of this Quality Assurance Project Plan. Currently there is only one TSP sampler operating within the APCD network, and it will likely be removed before the end of 2015.

Particulate Samplers low-vol Samplers

Flow rate verifications are performed monthly and during 15 event cleaning procedures. The monthly verifications are considered to be quality control checks and are reviewed by the Particulate Unit work lead monthly when the field data sheets are turned in. The APCD PM Group will start reporting these values to AQS by 2015.

Much like the high-vol samplers, the low-vol network also relies on comparison of collocated sampling data for quality control checks. (Currently there are two PM_{10} and two $PM_{2.5}$ collocated sites).

Evaluation of Collocated Data- Collocated measurement pairs are selected for use in the precision calculations only when both measurements are above 3µg/m^3. However, all collocated data will be reported to AQS. (0.5 is rounded up for collocation purposes.)

Collocated Monitoring Rules for $PM_{2.5}$: In order to evaluate total measurement precision, collocated monitoring will be implemented, as referenced in CFR. Therefore, for every $PM_{2.5}$ method designation:

a. At least twenty-five percent of the sites will have collocated monitors, where at least the primary monitor is designated as an FRM.

b. At least fifty percent of the monitors being used for collocation must be FRM monitors and 50% must be the same method designation as the primary monitor. If there is an odd number of collocated monitors required, bias in favor of the FRM.

Day-to-day quality control is implemented through the use of various check samples and the evaluation of data regarding sampler parameters that are collected during the run and downloaded periodically from the instruments to be kept in the PM database. The measurement quality objectives tables (Appendix MQO) contain a complete listing of critical, operational and systematic quality control criteria for the $PM_{2.5}$ and PM_{10} low-vol Program. The procedures for implementing the QC samples are included in the low-vol field SOPs found in the appendices. Table 2.6 also contains a summary of all the field and laboratory QC samples.

Three types of quality control check measurements will be made in the $PM_{2.5}$ Program:

Collocated monitoring (discussed above), monthly flow rate verifications (discussed above), and filter duplicates (discussed below in the laboratory section).

Continuous Particulate Analyzers:

Monthly Flow rate verifications are performed on the continuous particulate samplers and reported to AQS by the PM Group.

Additionally, many operational parameters are reviewed daily at each continuous particulate site through the data polling site to ensure data of appropriate quality.

Gravimetric Laboratory Quality Controls

In order to ensure that the Department can review all types of QC samples within a weighing session, the Department will use the concept of sample batches. A batch of samples will consist of all routine and QC samples collected in a two-week sample period. QC samples need to be interspersed within the batch in order to provide data quality information throughout the batch weighing session.

Filter Duplicates: The APCD requires that the gravimetric laboratory reweigh 1 in10 filters by an independent analyst. Differences between the two values cannot vary by more than ±15 µg. A reweight with a difference of more than the ±15 µg criteria results in the reweighing of all filters back to the last valid reweigh. Duplicate filter data is delivered from the gravimetric laboratory to the APCD for analysis on a bi-weekly schedule.

Blank samples are used to determine the level of contamination arising from four sources: the environment from which the sample was collected / analyzed, the reagents used in the analysis, the apparatus used, and the operator/analyst performing the data operation. Three types of blanks will be implemented in the $PM_{2.5}$ Program:

Lot blanks: Three randomly selected filters per box from three randomly selected boxes within a lot of filters, to make a total of 9 filters being tested, are used as lot blanks. Lot blanks are used to represent the physical characteristics of the lot from which it was taken. A shipment of 46.2mm filters will be periodically sent from EPA to APCD, and then from APCD to the gravimetric laboratory. Each lot shipment must be tested to determine the length of time it takes the filters to stabilize. Upon arrival of each shipment, 9 lot blanks will be randomly selected from the shipment and be subjected to the conditioning/pre-sampling weighing procedures.

The blanks will be measured every 24 hours for a minimum of one week to determine the length of time it takes to maintain a stable weight reading (15µg over 24 hours).

Field blanks: Tare weighed and non-sampled filters that are sent into the field and then returned with the batch of filters. The filters are exposed to the instrument environment without flow and returned to the lab for post field weighing. This provides an estimate of total measurement system contamination. The field blanks are measured with the rest of the returning filters and must not vary by more than ±30µg

Lab blanks: Are filters that are tare weighed and kept in the laboratory environment. This provides an estimate of contamination occurring at the weighing facility and inside the weighing room. A minimum of one lab blank will be weighed per post-sample weighing session and cannot vary by more than ±15µg from its weight during the pre-weighing session.

More detailed information can be found on quality control precision testing in the method specific Standard Operating Procedures (SOPs) located in the appendices of this Quality Assurance Project Plan. Calculations used for precision testing can be found in section 5.4 titled "Reconciliation with Project Requirements" of this document. The results of the quality control checks are submitted to the EPA AQS database within 90 days of the end of each calendar quarter. Below are some of the basic QC check calculations. Statistical confidence limits are calculated for each monitoring site using these precision test data. These statistical confidence limits for the APCD monitoring network are published annually in the Data Quality Assessment which can be found within the Annual Data Report. Corrective action for criteria that exceed the acceptance limits can be found in Section 5.5 of this QAPP.

Corrective actions for QC filters can be found in Appendix LSD2 of this QAPP.

Collocated calculations:
Difference for a single check (d) - The difference, d, for each check is calculated using Equation 1, where X represents the concentration produced from the original weight and Y represents the concentration reported for the duplicate weight.

Equation 1: $$d = |Y - X|$$

Percent Difference for a Single Check (d_i). The percentage difference, d_i for each check is calculated using Equation 2 where X_i represents the original weight and Yi represents the concentration reported for the duplicate weight.

Equation 2: $$d_i = \frac{Y_i - X_i}{(Y_i + X_i)/2} \times 100$$

Mean difference for batch (d) - The mean difference d_z for both field and lab blanks within a weighing session batch, is calculated using equation 3 where d_1 through d_n represent individual differences (calculated from equation 1) and n represents the number of blanks in the batch.

Equation 3: $$d_z = \frac{d_1 + d_2 + d_3 ... d_n}{n}$$

3.5.2 QUALITY ASSURANCE

The core elements of the APCD quality assurance program consist of unannounced regular site visits by an independent auditor to perform sampler performance checks, observe control charting to document the results of regular zero, span, and precision testing, and to perform a system audit. Information obtained by these events provides essential input into processes used by the APCD to assess the precision, accuracy, and

completeness of the ambient air quality monitoring program. APCD adheres to QA/QC protocol as prescribed in 40 CFR Part 58, Appendix A.

3.5.2.1 Accuracy

Accuracy is defined as the degree of agreement between an observed value and an accepted reference value and includes a combination of random error (precision) and systematic error (bias).

Internal performance audits
Internal performance audits are performed by the APCD quality assurance unit and occur at intervals as per the APCD MQO/DQO, which can be found in Appendix MQO of this document. The results of any internal or external performance audit performed on the APCD monitoring network may be used to initiate data validation and data quality assessment procedures. However, only the results of the random, independent accuracy audits performed by the APCD QA Unit staff are used as indicators of overall data accuracy.

Manual particulate samplers:
The APCD implements flow rate audits quarterly to assess accuracy. The audit is made by measuring the monitors normal operating flow rate using a certified flow rate transfer standard. The flow rate standard used for auditing will not be the same flow rate standard used to calibrate the analyzer. However, both the calibration standard and the audit standard may be referenced to the same primary flow rate or volume standard. The audit (actual) flow rate and the corresponding flow rate indicated by the sampler (calculated using the sampler calibration coefficients) are reported to AQS.

Continuous particulate analyzers performance audit frequency:
Particulate analyzers……quarterly (temp, pressure, flow rate, leak check)
TEOM analyzers..……...annually (mass verification)

Continuous gaseous or meteorological analyzers performance audit frequency:
Gaseous analyzers……....every 6 months
Meteorological analyzers…….Annually

Balance Checks:
Balance checks are frequent checks of the balance working standards (100 and 200 mg standards) against the balance to ensure that the balance is within acceptance criteria throughout the pre- and post-sampling weighing sessions. The gravimetric laboratory uses Ultra-class weights for its primary and secondary (working) standards. Both working standards are used at the beginning and the end of a weighing session. Additionally, the working standards are employed every 8 filters during a session. Balance check samples are recorded with the initial weights and charted.

Detailed information about how to conduct the APCD performance audit is provided in the auditing SOPs found in Appendices QA1 of the QAPP. The results of all accuracy audits are submitted to the EPA AQS database within 90 days of the end of each calendar quarter. Statistical confidence limits are calculated for each monitoring site using these accuracy audit data. These statistical confidence limits for the APCD monitoring network are published annually in the Data Quality Assessment which can be found in the Annual Data Report. Corrective action for criteria that exceed acceptable limits can be found in Section 5.5 of this QAPP.

External performance audits:
Audits performed by entities outside of the APCD are considered external audits. These audits may be conducted by EPA, an EPA subcontractor, or other possible auditors.

FRM performance evaluations:
The Federal Reference Method (FRM) Performance Evaluation is a quality assurance activity that will be used to evaluate the measurement system bias of the monitoring network. When requested by EPA or when deemed necessary, the APCD participates in external NPAP and PEP audits sponsored by EPA. Additionally, the EPA regional offices routinely perform technical systems audits and performance audits. All of these audits use

equipment and standards that are independent of those at the APCD and allows for the greatest number of degrees of separation between APCD standards and EPA standards. The NPAP program evaluates the gaseous and PM_{10}/TSP monitors and utilizes independent equipment and standards, but typically requires APCD quality assurance staff to perform the actual audit.

The PEP program evaluates $PM_{2.5}$ monitors and utilizes independent equipment, standards and staff to perform the audits, allowing for a total independent assessment. The strategy is to collocate a portable FRM $PM_{2.5}$ air sampling instrument at an established routine air monitoring site, operate both monitors in exactly the same manner, and then compare the results of the PEP monitor against the routine sampler at the site. The EPA will be implementing this program and will inform the APCD when an evaluation will be conducted. A set of pre-selected sites will be used. The evaluation will be conducted on a regularly scheduled sampling day and the filters from the evaluation instrument will be sent to a national laboratory in Region 10 for measurement. The comparison of data will be accomplished by EPA personnel using the AQS database. It must be noted that the performance evaluation is an estimate of the uncertainty of the measurement system and not the instrument. Therefore, biases may be attributed to sample handling, transportation and laboratory activities as well as to the instrument. The statistics used in the assessment are included in 40 CFR part 58 Appendix 58.

NPAP TTP audits:
On an annual basis, the EPA or an entity subcontracted by the EPA will perform NPAP through the probe (TTP) audits for at least 20% of the Colorado gaseous network stations. Please see the EPA NPAP SOP for more details.

High-vol NPAP audits:
At least every three years, the EPA will provide a high-vol orifice with unknown calibration coefficients to be taken into the field by APCD staff. This device will be used to audit at least one third of the APCD high-vol network of samplers. The blind results will be sent back to EPA for further evaluation. The EPA is no longer providing this type of audit, so this program will be discontinued until further notice.

Site evaluations to review siting criteria:
Siting evaluations will be performed at every site within the APCD network at least every two years.

3.5.2.2 Completeness

A final assessment of data completeness is performed at the end of each calendar year, after all data processing, validation, and other quality assurance procedures are completed. The completeness calculations are performed for each monitoring site in the APCD network. These data completeness results are published by the APCD in the Data Quality Assessment which can be found in the Annual Data Report. The criteria for completeness can be found in Appendix MQO. Completeness reports can also be pulled from AQS using the AMP430 report.

3.6 INSTRUMENT/EQUIPMENT TESTING, CALIBRATION and MAINTENANCE REQUIREMENTS, SUPPLIES AND CONSUMABLES

Routine preventative maintenance is performed on all APCD samplers and transfer standards according to a schedule consistent with the manufacturer's specifications. Maintenance and repairs are performed on every sampler or standard by the Unit that is responsible for operating each particular piece of equipment. If the TSP staff is unable to perform the necessary repairs, then the equipment may be shipped back to the manufacturer for further work.

More detailed information can be found on transfer standards in the Standards SOP in the appendices of this document. More specific calibration information can be found in the method specific Standard Operating Procedures (SOP) located in the appendices of this CDPHE/APCD/TSP QAPP as well as in the Operator's Manuals that are specific to each analyzer.

3.6.1 INSTRUMENTS REQUIRING CALIBRATION

3.6.1.1 Gaseous Monitors

Calibrations of all gaseous analyzers are performed by the GMM Unit with a minimum frequency of once per calendar quarter. Calibrations are also performed following any instrument maintenance that, in the judgment of the GMM Unit supervisor or technician, could potentially affect the calibration of an instrument.

An instrument calibration is the challenge of an analyzer with a minimum of four or more concentrations of gas plus a zero to establish a full range response of the analyzer. Detailed information on how a calibration is performed for each gaseous method can be found in section 9 of each method specific SOP found in Appendices GM1, GM2, GM3, GM4, GM5, GM6 and GM7 of this QAPP

The calibration is used to establish the linearity of an instrument's response and to provide an opportunity for analyzer adjustment in order to fit the analyzer response to an accepted response curve. The calibration is also used to establish an actual value for span and alternate precision test concentrations (i.e., "normal" precisions are based on external standards to certify the precision source).

3.6.1.2 Particulate Monitors

Calibrations of particulate samplers are performed by the Particulate Monitoring Group using procedures detailed in method specific SOPs found in Appendices PM1, PM2, PM3, PM4, PM5 and PM7of this QAPP. The calibrations consist of a five-point comparison of sampler flow versus pressure differential across the sampler motor.

Calibrations and motor changes are conducted at least semi-annually. A calibration is conducted whenever a different sampler motor is installed. No field maintenance is performed on any sampler that would affect the calibration.

3.6.1.3 Meteorological Monitors

Calibrations of all meteorological monitoring systems are performed by the GMM Unit with a minimum frequency of once per year with biannual calibration as an operational goal. Calibrations are also performed following any instrument maintenance that, in the judgment of the GMM Unit supervisor or technician, would potentially affect the calibration of an instrument. Specific details about calibration of the meteorological monitoring network are provided in Appendix GM8 of this QAPP.

3.6.2 CALIBRATION METHODS

Detailed information can be found on this topic in the method specific Standard Operating Procedures (SOPs) located in the appendices of this Quality Assurance Project Plan.

3.6.3 CALIBRATION FREQUENCY

More detailed information can be found on this topic in the method specific Standard Operating Procedures (SOPs) located in the appendices of this CDPHE/APCD/TSP QAPP or summarized in the MQO tables in Appendix MQO of this QAPP. In general, the gaseous analyzers are calibrated once per quarter, or whenever a problem is detected. The particulate samplers are calibrated according to schedules found in each specific pollutant type SOP, or when a problem is identified. Meteorological instruments are calibrated once per year, or when a problem has been identified.

All of these events, as well as sampler and calibration equipment maintenance, will be documented in field data records and notebooks. These records will normally be controlled by the unit leaders, and located in the labs or field sites when in use, or at the APCD's offices when being reviewed or used for data validation.

3.6.4 CALIBRATION OF LABORATORY STANDARDS

The APCD employs the use of laboratory standards for routine calibration and verification of field transfer standards. Laboratory standards must hold a certification that is, at the most, two steps removed from a NIST standard and have accuracies that are equal to or greater than those used as field transfer standards. All laboratory standards are kept in the Standards Laboratory, and comparisons of those standards to the field transfer standards occur within the protected confines of the Standards Laboratory. All laboratory standards are sent out for a NIST traceable certification on a routine or as needed basis. Table 3.20 summarizes all of the APCD's laboratory standards.

Table 3.20 Summary of Laboratory Standards

Parameter	Manufacture / Model	Accuracy	Certification
Flow Rate (10cc/min to 25 l/min)	InFlow Skid System (critical and sub-critical flow nozzles)	±0.5% (of reading)	Send to independent flow laboratory every 3 years for service and NIST calibration and/or verification
Flow Rate (500 to 10,000 l/min)	Dresser Roots Meter Model 5M125	±0.5% (from current cert.)	Return to factory or independent flow laboratory every 3 years for service and NIST calibration and/or verification
Flow Rate (5scc/min to 5000 scc/min)	Bios Model ML 500	±0.25% (of reading Volumetric)	Return to factory flow laboratory every year for service and NIST calibration and/or verification
Temperature (-8 °C to 32 °C)	VWR – ASTM Precision Mercurial Thermometer	±0.1 °C	Ice-point verification annually Multi-point NIST verification every 3 years
Pressure (14.7 inHg to 32.6 inHg)	Paroscientific Digiquartz Pressure Transducer, Model 740-16B	±0.08 hPa (±0.0024 inHg)	Return to factory every 3 years for service and NIST calibration / verification
Ozone (0 ppb to 1000 ppb)	Thermo 49C Primary Std.	1 ppb (precision) 1.08% (SRP cert)	Annual verification to EPA's SRP
Voltage (0 V to 20 V)	Extech Model CMM-17	0.0001 (resolution)	Sent in every 3 years of an independent certification
Wind Speed (100 to 10,000 rpm)	MetOne Model 053B	0.1 rpm (resolution) 0.1 rpm (time ref)	Annual factory certification
Laboratory standards not supported by APCD			
Gases Concentrations (CO, SO_2, NO_x)			
Humidity			
Mass			
Time			
Wind Direction			

3.6.5 CALIBRATION OF TRANSFER STANDARDS

The APCD employs the use of transfer standards for routine calibration and verification of field equipment. Transfer standards hold certifications that are, at the most, three steps removed from a NIST standard and have accuracies that meet all federal criteria designated in the CFR and guidance documents. All transfer standards are compared routinely to APCD's laboratory standards within the Standards Laboratory. Where the APCD does not maintain a laboratory standard, transfer standards must be sent out to contract laboratories for verification and calibration. APCD does not maintain laboratory standards for mass, flow rate (20 l/min – 500 l/min), and humidity. Table 3.21 summarizes certification requirements for all APCD transfer standards.

Table 3.21 Transfer Standards Certification Requirements

Parameter	Standard Type	Frequency	Criteria
Flow Rate	High Volume Orifice	Annual Calibration	
"	Low Volume Orifice	Annual Calibration	
"	Bios Dry Definers	Annual Verification / Calibration	within manufactures specs (device specific)
"	Mass Flow Controllers	Bi-Annual Verification / Calibration	within manufactures specs (device specific)
Gases Conc. (CO, SO_2, NO_2)	Compressed Gas	As Per Manufacture's Expiration Date	within manufactures specs (device specific).
Humidity	Hygrometer	Annual Verification / Calibration	within manufactures specs (device specific)
Mass	Ultra Class Standards	Annual Verification / Calibration	within manufactures specs (device specific)
"	TEOM Mass Verification Standards	Annual Verification / Calibration	within manufactures specs (device specific)
Pressure	Aneroid - Digital Barometers	Annual Calibration/Verification (minimum) Quarterly Verification (operational goal)	within manufactures specs (device specific)
"	Manometers	Annual Calibration/Verification	within manufactures specs (device specific)
Ozone	Calibrators	Bi Annual Verification for Stationary Sources. QA audit standards are verified Quarterly. GMM calibrating units should also be verified quarterly.	According the EPA Ozone transfer standard TAD
Temperature	Mercurial / Digital Thermometers	Annual Calibration/Verification (minimum) Quarterly Verification (operational goal)	within manufactures specs (device specific)
Time	Watches or Cell Phones	Quarterly (minimum)	± 30 sec
Voltage	Digital Volt Meters	Annual Verification / Calibration	within manufactures specs (device specific)
Wind Direction	Transit	Annual Verification / Calibration	within manufactures specs (device specific)
Wind Speed	Wind Speed Motor and Controller	Annual Verification / Calibration	within manufactures specs (device specific)

3.6.5.1 Flow Rate Standards

High Volume Orifices (PM_{10}/TSP)

Orifice flow rate transfer standards are used for calibrations and performance audits of high flow rate manual particulate samplers, commonly referred to in the industry as TSP (Total Suspended Particulate) monitors and PM_{10} monitors. The pressure differential measured across the orifice can be related to air flow. Because these devices do not provide a direct measure of air flow, they are regularly certified against a NIST traceable air flow standard. Certification of the APCD orifice transfer standards are consistent with the procedures detailed in the *EPA Quality Assurance Guidance Document 2.11 "Monitoring PM_{10} in Ambient Air Using a High-Volume Sampler Method"*.

This guidance is based on 40 CFR Part 50, Appendix M. More information regarding the verification and calibration of these standards can be found in Appendix QA3 (Standards Verification and Calibration SOP) of this QAPP.

Low Volume Orifices ($PM_{2.5}$ and other particulate analyzers)

Orifice flow rate transfer standards are used for calibrations and performance audits of low flow rate manual particulate samplers; these include $PM_{2.5}$ FRM monitor, PM_{10} low-vol, TEOM, 1405 dichot, BAM, SASS, URG, aethalometer and GRIMM monitors. All of these monitors are mass flow controlled and operate in a flow range of 1 to 22 l/min. The transfer standard utilizes an orifice that is specifically designed to be operated within these flow ranges. The pressure differential measured across the orifice can be related to flow rate though a calibration curve. Because these devices do not provide a direct measure of airflow, they are regularly certified against a NIST traceable airflow standard. Annual verifications are performed at 5 points across each calibrated range. A passing verification occurs when the average of the absolute value of the error at each point is less than 0.5%. Failing verifications require a recalibration of the orifice device. More information regarding the verification and calibration of these standards can be found in Appendix QA3 (Standards Verification and Calibration SOP) of this QAPP.

Bios DryCals (Continuous Analyzers)

APCD TSP field staff use Bios ML 500 and Bios Definers in the verification of mass flow controllers and mass flow meters in dilution type gas calibrators and other flow regulating devices used in continuous analyzers. The BIOS ML 500 is certified annually by the manufacturer. The Bios Definers are checked annually against the BIOS ML 500. Verification criteria are based upon the manufacturer's design specifications. More information regarding the verification and calibration of these standards can be found in Appendix QA3 (Standards Verification and Calibration SOP) of this QAPP.

Mass Flow Controllers (Dilution Calibrators)

APCD TSP field staff use mass flow controllers (MFC) and mass flow meters (MFM) in their gaseous dilution systems to perform audits and calibrations. During these audits and calibrations, a known mass flow rate of clean air is mixed with a known mass flow rate of high concentration analyte gas to generate the appropriate analyte concentrations.

The MFCs and MFMs are initially calibrated in the lab with a Bios ML 500 or in the field with a Bios Definer Digital Flow Meter. The initial calibration consists of a calibration point at every voltage point within the calibrator's calibration table. Depending upon the calibrator, this can be up to twenty points. Quarterly verifications are performed at 5 points across the MFC/MFM dynamic range. A passing verification occurs when the average of the absolute value of the error at each point is less than 2%. Failing verifications necessitate a recalibration of the MFC or MFM.

More information regarding the verification and calibration of these standards can be found in Appendix QA3 (Standards Verification and Calibration SOP) of this QAPP.

3.6.5.2 Gas Concentration Standards

EPA's air monitoring regulations require the use of Protocol Gases to set air pollution monitors. This protocol helps to ensure that air pollution measurements are accurate and can be trusted. It provides specialty gas producers with a recipe to make calibration gases. In past years, EPA findings showed that commercial calibration gases were too inaccurate and too unstable to use. The protocol was developed jointly by EPA, National Institute of Standards and Technology (NIST), the auto industry, and specialty gas producers. The procedure balances the government's need for accuracy with the producers' need for flexibility, low cost, and minimum external oversight. EPA verifies the quality of these gases by conducting blind tests of samples purchased from the producers' routine production.

Gaseous concentration standards used to provide test concentrations of CO, SO_2, or NO_x must be traceable to standard reference materials produced by the National Institute of Standards and Technology (NIST). The APCD uses compressed gas cylinders of CO, SO_2, and NO during calibration and audits. These

compressed gas cylinders are provided by a private supplier and have an established traceability to NIST reference standards consistent with all aspects of the *EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards*. All records of these gas concentration certifications are available for review and are maintained by the GMM Unit and the QA Unit staff.

States are also required to participate in the EPA Ambient Air Protocol Gas Verification Program to further ensure that the compressed gases being used for Ambient Air monitoring are of adequate quality.

The compressed gas cylinders used in the daily performance checks and bi-weekly quality control checks of APCD CO, SO_2 and NO_x analyzers are analyzed under this EPA protocol. For some CO analyzers, direct concentrations of cylinder gas are sampled. For all other gaseous analyzers, cylinders are diluted with zero air using calibration/dilution systems that utilize mass flow controllers.

Additionally, all gas tanks are checked in-house with a stationary gas testing system and a designated laboratory gas tank standard to verify concentrations and consistency throughout use. These tests take place upon arrival at APCD, at yearly intervals, and whenever a tank becomes suspect of changing concentration over time or a discrepancy is suspected between a set of tanks. This in-house gas testing system will be described in Appendix GM9 of this QAPP.

Zero air is supplied by either a zero air generation system or by compressed bottled ultrapure zero air from a gas supplier (≤ 0.1 ppm of pollutant) and is used during audits and calibrations. No traceability requirements are in effect.

3.6.5.3 Humidity Standards

Hygrometer

APCD TSP field staff use hygrometers to perform performance audits and calibrations on humidity sensors in the field. The APCD uses hygrometers at several meteorological sites to acquire continuous humidity measurements and the gravimetric lab uses hygrometers to continuously monitor humidity within the gravimetric laboratories. Because the APCD does not maintain a laboratory grade humidity standard, all hygrometers are shipped to a contract laboratory for annual certification. All hygrometers must meet all original manufactures specifications to achieve a passing verification.

3.6.5.4 Mass Standards

Gravimetric Laboratory Standards

The APCD maintains the use of several mass standards to audit the gravimetric laboratories that perform the routine analysis of PM_{10}/TSP and $PM_{2.5}$ filters. They are Ultra-Class standards and are stored in the Standards Laboratory. Because the APCD does not have the facilities or equipment to verify these standards, they are shipped annually to a contract metrology laboratory for certification. Certification documentation is stored in a filing cabinet within the Standards Laboratory.

TEOM Mass Standards

The APCD maintains the use of several mass standards to audit the spring constants (K_o) of the tapered oscillating element within the PM_{10} and $PM_{2.5}$ TEOMs. These standards are stored in a desiccator within the Standards Laboratory when not in use in the field. Because the APCD does not have the facilities or equipment to verify these standards, they are shipped annually to a contract metrology laboratory for certification. Certification documentation is stored in a filing cabinet within the Standards Laboratory.

3.6.5.5 Meteorological Standards

There are three primary meteorological parameters measured by the APCD: wind speed, wind direction and temperature. Traceability of temperature measurements is detailed in Section 3.6.5.8. The use of a voltage transfer standard is applicable in the maintenance and calibration procedures of the meteorological equipment and its traceability is detailed in Appendix GM8.

Wind Direction

The QA Unit and the GMM Unit maintain the use of transits and standard magnetic compasses to ensure proper meteorological tower orientation, which is used to quality assure the wind direction data collected by the APCD monitoring network. Because the APCD does not have the facilities or equipment to verify these standards (transit), it is shipped annually to a contract laboratory for certification. Certification documentation is stored in a filing cabinet within the Standards Laboratory. The direction sensors are checked using a 360° unit plate mounted to the sensor to compare the degree position to sensor output. The 360^{o} unit plate is nonadjustable and does not require verification or calibration unless physically damaged, where it would be disposed of.

Wind Speed

The APCD uses synchronous motors for checking the wind speed sensors. Electronic checks of the meteorological systems are done using a MetOne (RM Young) model 18811 electronics calibrator. This calibrator and the synchronous motors are sent to the manufacturer annually for certification.

3.6.5.6 Pressure Standards

Hand-held Digital Barometers

APCD TSP field staff use hand-held digital barometers, measuring with a resolution of 0.01" Hg, during calibration and performance audits of APCD air monitoring equipment.

At least once per year the QA staff certifies every hand held barometer used to support ACPD network field work. Additionally, it is an operational goal to have quarterly verifications performed on all transfer standard barometers by the staff member to whom the barometer has been assigned. Adjustments will be made if necessary. A laboratory grade standard (Paroscientific Digiquartz Barometer) is used for these certifications. The quartz crystal type of barometer works on fundamental principles of crystal resonance and is therefore more accurate due to high repeatability, low hysteresis and excellent stability. By comparison, the precision digital barometer is an evacuated capsule with a flexible bellows coupled through mechanical linkage to an indicator. It is less accurate than the quartz crystal type but can be transported with less risk to the reliability of its measurements and presents no damage from mercury spills. The quartz crystal type of barometer is best employed as a higher quality laboratory standard that is used to adjust and certify an aneroid barometer in the laboratory. The laboratory standard is sent back to the manufacturer at least once every three years for recertification. The laboratory standard has direct traceability by the manufacturer to a National Institute of Standards and Technology (NIST) standard. More information regarding the verification and calibration of these standards can be found in Appendix QA3 (Standards Verification and Calibration SOP) of this QAPP.

Manometers

The APCD TSP field staff Unit use digital hand-held and oil manometers to measure pressure differentials across orifices embedded in flow rate standards.

Digital hand held manometers used in the field to take measurements are certified by the QA staff annually. Verification criteria are based upon the manufactures design criteria. Adjustments will be made if necessary. A laboratory grade standard (Paroscientific Digiquartz Barometer) is used for these certifications. The laboratory standard is sent back to the manufacturer at least once every three years for recertification. The laboratory standard has direct traceability by the manufacturer to a National Institute of Standards and Technology (NIST) standard. More information regarding the verification and calibration of these standards can be found in Appendix QA3 (Standards Verification and Calibration SOP) of this QAPP.

Oil manometers are inspected for damage, leak checked, and have their oil replaced annually. Direct comparisons of these standards to the laboratory standard are not requisite in verifying the accuracy of the device. The design accuracy of oil manometers is based upon the physical properties of the oil, a leak free system, and the gradation of the measurement scale. If these three properties can be verified, then the manometer will meet its design accuracy.

3.6.5.7 Ozone Standards

In order to ensure a common basis for all APCD ozone measurements, the QA auditing and GMM calibrating transfer standards are certified against the APCD primary ozone photometer laboratory standard (TECO 49C) at least once per calendar quarter, consistent with the requirements detailed in *Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone* (October 2013). The station ozone transfer standards are certified against the laboratory standard bi-annually. The response of this laboratory ozone standard is compared annually to that of a Standard Reference Photometer (SRP) maintained by the EPA Regional Offices. These verification runs are performed annually at the Air Quality Laboratories of either EPA Region VII (Kansas City, KS) or EPA Region VIII (Denver, CO).

The verification requires a six-point comparison of the APCD laboratory standard and the SRP instrument response. The acceptance criteria from the linear regression relationship are a slope of 1.00 ± 0.03 and an intercept of ≤ 3 ppb. Consistent with EPA guidance, no corrections are made to the TSP laboratory standard responses from this linear regression when updating the transfer standards.

3.6.5.8 Temperature Standards

Hand-held Digital Thermometers

APCD TSP field staff use digital thermometers during calibration and performance audits of APCD air monitoring equipment. Quality Assurance Handbook for Air Pollution Measurements Systems, Volume IV: Meteorological Measurements, Version 2.0, EPA, March 2008, Section 3.4, provides information on calibration equipment and methods for assessing response characteristics of temperature sensors. The QA staff annually certifies all digital hand-held thermometers used in the field to take measurements. Verification criteria are based upon the manufacturer's design criteria. Additionally, it is an operational goal to have quarterly verifications performed on all transfer standard thermometers by the staff responsible for the assigned thermometer. A laboratory grade standard (Mercurial Thermometer) is used for these certifications. Prior to the annual certification of the transfer standard, an ice-point check (zero check) is performed on the laboratory standard. The laboratory standard must be within the manufacturer's design accuracy prior to the certification of all transfer standards, or have calibration relationship to the temperature standard. An equation or a curve will be established that is accurate to within 2% over the expected range of ambient temperatures at which the temperature standard is to be used, whichever is greater. The laboratory standard is sent back to the manufacturer at least once every three years for recertification. The laboratory standard has direct traceability by the manufacturer to a National Institute of Standards and Technology (NIST) standard. More information regarding the verification and calibration of these standards can be found in Appendix QA3 (Standards Verification and Calibration SOP) of this QAPP.

Infrared Thermometers

The Particulate Monitoring Unit is required to ship FRM filters at temperatures below that of 4^{o} C to the laboratory for analysis. The laboratory that is contracted to weigh the filters for APCD employs Infrared Thermometers to check the temperature of the filters received. They are often called "Laser Pointer Thermometers", because they use a laser to help aim the thermometer and they infer temperature using a portion of the thermal radiation emitted by the object of measurement. These Infrared Thermometers are verified for accuracy yearly by the contract laboratory and verified with NIST traceable thermometers during the Annual Technical Systems Audit of the contract laboratory by APCD QA staff. These thermometers have been approved for this use by the U.S. EPA Region VIII.

3.6.5.9 Time Standards

APCD TSP field staff use both digital watches and cell phones during calibration and performance audits of APCD air monitoring equipment. Quarterly verifications of time on all watches and cell phones are required and must be within ±30 seconds of the time standard. Because the APCD does not maintain a laboratory grade time standard, external sources of time must be used. Accurate time can be found from

the atomic clock in Boulder, Colorado by calling 303 499-7111 or via the Internet at http://time.gov/HTML5/.

3.6.5.10 Voltage Standards

All field personnel of the Quality Assurance Unit and the GMM Unit use voltmeters in their operations. These voltmeters must periodically be calibrated and certified against an in-house voltage lab standard. The Technical Services Program voltage laboratory standard is a Model CMM-17 voltage source manufactured by Extech. It is never moved outside of the lab except when it is sent back once per year to the manufacturer or local electronics lab for calibration and recertification. The manufacturer calibrates the CMM-17 against their own voltage laboratory standard with traceability to NIST standards and to the tolerances of the military specification MIL-STN-45662A. More information regarding the verification and calibration of these standards can be found in Appendix QA3 (Standards Verification and Calibration SOP) of this QAPP.

3.6.6 INSPECTION/ACCEPTANCE CRITERIA FOR SUPPLIES AND CONSUMABLES

This section of the QAPP establishes a system for inspecting, accepting, and documenting all supplies and consumables that may directly or indirectly affect the quality of the Air Monitoring Program. The APCD monitoring network relies on various supplies and consumables that are critical to its operation. By setting acceptance criteria for these supplies, consistency can be ensured. There are many components to the air monitoring network. Supply lists for each method, as well as the inspection and acceptance requirements for all supplies and consumable materials, are contained within each method specific SOP located in the appendices to this document.

3.6.6.1 Acceptance Criteria

Acceptance criteria must be consistent with overall project technical and quality criteria. Some of the acceptance criteria are specifically detailed in 40 CFR Part 50. Other acceptance criteria such as observation of damage due to shipping can only be performed once the equipment has arrived on site. The overall goal of these criteria is to ensure that all equipment and consumables are of sufficient quality to achieve the designated MQOs and DQOs.

3.6.6.2 Tracking and Quality Verification of Supplies and Consumables

Tracking and quality verification of supplies and consumables have two main components. The first is the need of the end user of the supply or consumable to have an item of the required quality. The second need is for the purchasing department to accurately track goods received so that payment or credit of invoices can be approved. In order to address these two issues, the following procedures outline the proper tracking and documentation procedures to follow:

1. Receiving personnel will perform a rudimentary inspection of the packages as they are received from the courier or shipping company. Note any obvious problems with a received shipment such as crushed box or wet cardboard.
2. The package will be opened, inspected and the contents will be compared against the packing slip.
3. Supplies/consumables will be compared to the acceptance criteria as described within each method SOP.
4. If there is a problem with the equipment/supply, note it on the packing list, notify the supervisor of the receiving area and immediately call the vendor.
5. If the equipment/supplies appear to be complete and in good condition, sign and date the packing list and send to accounts payable so that payment can be made in a timely manner.

6. Notify appropriate personnel that equipment/supplies are available. For items such as the 46.2 mm Teflon filters, it is critical to notify the laboratory manager of the weighing room so sufficient time for de-gassing of the filters can be allowed.
7. Stock equipment/supplies in appropriate pre-determined area.
8. Document when supplies, consumables, and equipment used throughout the $PM_{2.5}$ program are changed out. If available, include all relevant information such as model number, lot number, and serial number.

3.6.7 DATA AQUISITION

Data processing is an in-office complement to the site operation activities. Data processing provides a useful tool to identify potential analyzer performance problems. Conversely, mistakes during data processing can result in significant errors in the ambient air quality data set. More information is available about data acquisition and data validation and can be found in the Gaseous and Meteorological Data Validation (Appendix D3) and Data Logger and Central Polling (Appendix D1) SOPs.

3.6.7.1 Automated Samplers

The following is a brief summary of the data acquisition and data processing system. All data from automated analyzers are collected on on-site data loggers, which are the primary record of the data. All automated analyzers use an internal data acquisition system that can be downloaded in the event of a data logger failure. The exception to this is the Thermo 48C CO analyzer, which uses an external digital chart recorder as a backup in the event of a primary data logger system failure.

This section deals with ambient data acquisition, recovery of missing data, and data verifications. It is divided into five parts: a) Remote Acquisition of Raw Data - Description, b) Remote Acquisition of Raw Data – Operation and Maintenance, c) Central Computer – Acquisition of Data, d) Central Computer – Operation and Maintenance, e) Central Computer – Data Processing and Validation.

3.6.7.1.a Remote Site Acquisition of Data – Description

i) Description of Hardware

The APCD employs three different models of onsite Data Acquisition Systems (DAS) in the operations of its air monitoring network. These are the ESC 8816 data logger, the ESC 8832 data logger, and the Agilaire 8872 data logger. The 8816 data logger is the oldest type of data logger in the network and is a predecessor to the 8832 and 8872 data loggers. Special studies sites may use different types of data loggers to meet unique sampling system and/or data capture requirements. Each of the ESC and Agilaire data loggers are equipped to store up to 1 month of hourly averages (minimum), selectable auxiliary averages such as 1, 5, 6, or 15 min averages, zero/span/precision results, analyzer diagnostic data, and data validation flags. Each data logger also provides zero/span/precision control of each analyzer equipped with a zero/span/precision system. The APCD uses two different data acquisition systems to provide backup data in case of failure of the primary system. The backup data acquisition systems are the analyzer based on-board data acquisition systems that are unique to each manufacturer. In the event that an on-board data acquisition system is not available or its application is not practical (as with the 48C analyzer), a digital strip chart recorder is used. The digital strip chart recorder used by the TSP is the Monarch Instruments DataChart DC1250 2 channel paperless recorder. Internal data logging is available on the newer analyzers. Each site is equipped with telecommunication equipment for the purpose of transferring data from a site's data logger to the central polling server located at the CDPHE main offices. Site communications are accomplished by dialup, cellular, or DSL modems.

ii) Description of Operation

The remote site system is designed to operate unattended and, once set up, site data acquisition and control operation is automatic and user transparent. Each logger is set up with the operating parameters of each instrument via keyboard entry into the logger battery backed memory. Logger setup is fully described in the technical manuals for each data logger type. Each data logger is uniquely configured to meet the monitoring requirement for each site. In addition to the data logger itself, logger configuration files are stored on the

central polling server and may be manually downloaded from the central polling server to a remote data logger. The loggers also initiate the zero/span and zero/precision cycles on alternating day's at all gaseous monitors in the state monitoring system.

Data is collected by the data logger from the analyzer via traditional analog communications or by digital communications. Depending upon the age of the analyzer and data logger type, digital communications can be established using a Generic Serial Interface (GSI) protocol or Modbus protocol. Data collected by internal data acquisition systems, residing within individual analyzers, are stored with vendor-specific proprietary methods and can be exported as comma delimited text files. Digital data charts use the traditional analog communication protocol that is configured to collect data on a 0-1 volt scale. Data are generated from the analyzer at intervals internally set, ranging from an averaging time of 20 seconds to 5 minutes. The data is collected by the on-site data logger as near-real-time data (often every 3 to 10 seconds) and is aggregated into 1-minute averages, which are in turn aggregated into 1-hour averages. Some data streams may be stored at a third averaging interval, meteorological data can be stored as a 15-minute average, SO_2 data can be stored in a 5-minute average, and some particulate data is stored in a 6-minute average. Note that the capacity of the on-site data logger is limited to three time-based averaging intervals and that the 5-minute SO_2 average supersedes the 15-minute meteorological average. These averages are stored in battery-backed internal memory or non-volatile removable cartridge memory. Other data such as zero/span/precision, power failure, time, and messages are stored in a similar manner and remain available for direct access or computer poll for a limited amount of time.

Each logger provides data to the central polling server when requested by the central polling server. All sites are polled hourly at a minimum, with sub-hourly polls occurring on an as needed basis. Data can also be polled manually and can be viewed directly from the data logger.

3.6.7.1.b Remote Site Acquisition of Data – Operation and Maintenance

i) Daily

Daily maintenance and checks consist of an operational check of the logger and communication systems. The majority of operational checks are done on a constant basis through an hourly review of incoming data at the central offices. Should data be missing or in apparent error at central, it will be promptly investigated by Technical Services Program (TSP) personnel. Operational review of any site logger may be done at the remote site or from any modem-equipped (phone or Ethernet) computer via the particular communications software/firmware installed. The exception to this is sites that are connected serially to an Ethernet enabled modem. Connection to these data loggers requires RealPort software to be installed on a computer. Currently, the central polling computers are the only computers that are capable of connecting to these data loggers. Remote desktop protocol is available on all 8872 Agilaire data loggers. Once a connection is established and the proper passwords issued, communication with the logger is the same as at the remote site. The full communication and data logger firmware command sets are covered in the technical manual for the data logger. The clock on each data logger is automatically synchronized with the central polling system daily.

ii) Weekly

No specific weekly checks of the ESC and Agilaire loggers are necessary although a weekly on-site station check is required (see weekly procedures for analyzers). During the required station weeklies, the logger functions are used to accomplish the routine station checks. As these checks are accomplished, a check for data value agreement between the specific analyzer, logger, and strip chart/data recorder is done. Action to correct any discrepancy greater than ±1% full scale will be taken at this time.

iii) Monthly

Backup electronic data strip charts are checked monthly to ensure accuracy and operability.

iv) Quarterly

The logger's analog to digital converters are checked and recalibrated as needed. Accuracy checks and recalibrations of the logger's analog to digital converters are also done quarterly by the TSP Calibrations Unit in conjunction with the normal quarterly instrument calibrations. Consult the technical manual for the ESC data logger and TSP Calibrations Unit SOP for calibration procedures.

v) Biannually

None required.

vi) Annually

Where applicable, backup electronic data strip charts are downloaded annually and the data is archived.

3.6.7.1.c Central Computer - Acquisition of Data

i) Description of Hardware

The TSP operates two central polling systems that routinely polls remote data loggers for air quality data and archives that data in a database. The first polling server is the primary polling server that is used for polling the compliance network sites, and the second polling server is used as a developmental polling server and is also used in polling out-of-network sites operated by external agencies. The operating system on these polling servers provides for polling of remote site data loggers using dial-up and broadband modems. The central polling servers (referred to as "Central") are Windows-based servers running software developed by Agilaire LLC according to EPA and TSP general specifications and requirements for data collection, and are compatible with the firmware programming in the ESC and Agilaire data loggers. TSP has configured the software to specific TSP needs and operational parameters. The primary repository for data, and the engine for information assembly, is the Microsoft SQL Server operated and maintained by the Governor's Office of Information Technology. The TSP maintains a database owner position responsible for logical maintenance of the data system. Network printers complete the hardware located at Central.

ii) Description of Software

The TSP uses the Agilaire AirVision™ software for its central data management system. AirVision™ is a centralized data management and polling software that is used to manage data polling, data logger configurations, calibration configurations, data storage, data processing, and data validation. AirVision™ supports an open system of modular drivers that can be added to provide connectivity to many sources of data. The driver manages the details of data collection and uses standard interface to exchange data with AirVision™'s core. Third parties and end users can construct new drivers for AirVision™, providing an open solution to manage future requirements. AirVision™ is designed specifically along the concept that eventually networks (or significant parts or networks) will consist of smart instruments connected to a central AirVision™ data management hub through broadband connections. To normalize these data sources, AirVision™ uses an open system that allows any end user or company to develop drivers for a particular data source. The driver incorporates all the necessary knowledge and logic to collect data and return data to the database through a standardized data access layer.

To optimize quality assurance, AirVision™ opens up the process between data collection and final reporting through an open modular approach. Open Data Processors can be scheduled and triggered by the Task Manager to automate some data quality evaluations while also controlling the points of data access and display, such as AIRNow and web presentation. The Automatic Data Validation Processor Module (ADVP) assigns a quality grade (1-10) for each data point based initially on instrument/data logger flags, but allows users to generate rules that affect the quality code. The ADVP can be triggered to run automatically after data collection to grade each data point, and the quality grade can be used to prevent suspect or bad data from being published to the web or shared with other organizations. The grades can also be used to focus quality assurance efforts on the most suspect data points. Data can be compared against other parameters at the same site, different sites (spatial testing), or historical composite values for that particular parameter and/or site (e.g., comparing this hour's value to the same hour and day of the week over the previous five years). ADVP functions also include persistency checks.

iii) Operation

The primary function of Central is to gather hourly averages from the remote data loggers and archive that data in a user friendly repository. Instrument zero/span/precision data is also collected in a like manner.

3.6.7.1.d Central Computer - Operation and Maintenance

i) Daily Tasks

1. Task managers within Air Vision poll data from remote air quality monitoring sites at the top of each hour, at a minimum. Some sites may be polled at a greater frequency depending upon data needs. Data from each site is stored in a SQL database and made available for review and analysis after polling has been completed.

2. Ambient data on the AirVision™ Central polling computer is reviewed every business day in the morning, the previous 24 hours (or 3 days on Mondays) worth of data is reviewed for completeness and accuracy. This data review is used to determine if a physical site visit is required.

3. Low level (precision) and high level (span) test gas sequences are run on alternate days. The precision and span level tests are followed by a zero test and a two-minute recovery period. The results are reviewed each morning and plotted on control charts. It is the responsibility of one individual within TSP to review the daily zero/span/precision results, plot them on the control charts, and notify the technician responsible of any out of control condition. "Out of control" is defined as:

   a. trending toward warning limit as defined on the control chart

   b. points plotted exceeding the warning limit

   c. points plotted exceeding the action limit as defined on the control chart

ii) As Required Tasks

1. Microsoft Sever Updates – It is State policy to provide security updates to all State personal computers and servers. Automatic security patch uploads are not performed on the polling servers due to unforeseen consequences that might be caused by the upload. Manual security patch uploads are performed as needed on the developmental polling server to evaluate server operability prior to deployment on the primary polling server.

2. AirVision™ Updates – AirVision™ software updates are deployed on both the developmental and primary polling server as updates are made available.

3.6.7.1.e Central Computer – Data Processing and Validation

Data processing is a sequence of operations performed on data by validation staff, or by a computer, in order to extract information or make the data usable. Data collected at remote air quality monitoring sites are aggregated, organized, validated and archived in accordance with federal regulations. The data flowchart below is a high level overview of how data is processed, from its inception to its archival on the AQS system. Some nodes within the flowchart will be further expanded in individual SOPs to provide more details of the summarized node.

Data validation procedures are activities performed after data collection and processing in order to screen out erroneous values from the final ambient air quality data set. Ultimately, it is a process that the APCD uses to ensure the data is clean, correct, and useful. In addition to the data screening function, the data validation process can be used to identify errors in a data collection system. Generally, data validation is most efficiently performed by those most familiar with the data collection systems.

The TSP performs a daily and a monthly review of data. The daily review consists of a review of all the previous day's ambient data and the previous night's quality control performance tests. This data

is reviewed to identify errors in the analytical and data collection systems. Suspect and invalid data can be identified and flagged at the time of this evaluation. Problems identified during the daily review can be immediately disseminated to field staff for troubleshooting and repair. The monthly review consists of three separate reviews: 1) preliminary review of hourly ambient data for all parameters; included in this are the development of the monthly data package, an evaluation of diagnostic data, and an evaluation of nightly performance test zeros for the zero drift adjustment of ambient data; 2) primary review of hourly ambient data for all parameters; included in this are an evaluation of findings made by the preliminary data reviewer, an evaluation of all quality control data, review of all station log sheets and "messages to central", coding of all invalid and suspect measurements within the AirVision™ system, an evaluation for zero adjustment of ambient data, and the actual zero adjustment of data within AirVision™; 3) quality assurance review of ambient data for all parameters; included in this are a review of all findings made by the preliminary and primary data reviewers and a review of all ambient data, quality control data, and log sheets to determine completeness and accuracy of the validation process. Quality assurance reviewer comments are documented and returned to the primary data reviewer for additional evaluations and corrective actions if necessary. In the event of failed accuracy audits or precision tests, the Quality Assurance Unit or Gaseous and Meteorological Monitoring Unit may conduct additional investigations.

The Governor's Office of Information and Technology oversees the back operations of system databases. The AVData, AVData_External, and ZSPTracking databases that house all the continuous data are backed up nightly Monday through Friday. This backup is stored on a hard drive, and can be accessed within a couple of hours. This copy is retained for 23 hours and is overwritten on the next nightly backup routine. At the end of each week, backup copies of the databases are written to tape and stored for 12 weeks. A rolling 12 week supply of weekly backups is retained at all times.

A running 3-year hard copy file system is maintained at the APCD offices containing all logs and reports generated by maintenance, audits, calibrations, and automated systems. (Note: Staff responsible for this part of the procedure must have a thorough understanding of computers (Excel, Access), of the ambient monitoring network system configuration and operation, and of the ESC and Agilaire software packages and how each module interacts with others). Also an understanding of EPA guidelines and requirements for acceptable treatment of ambient air quality data is necessary. These requirements and guidelines can be found in EPA's "*Redbook, Volume I & II*".

3.6.7.2 Data Acquisition for Manual Samplers

A detailed description of the data acquisition and data processing procedures for the high-volume particulate and low-volume particulate samples can be found in Appendix D2 and Appendix D4, respectively. The following is a summary of those systems.

Data Acquisition for high-vol PM_{10} and TSP Filters

The data collection process begins at the gravimetric laboratory when a tare weight is assigned to an equilibrated filter and stored within the gravimetric laboratory's filter database. The tare weighed filter is then shipped to a field sampling location for sampling. Prior to the sampling day, the field operator installs the filter into a sampler, turns on the sampler and notes the sampler's pre sampling manometer reading on the field data sheet. Other fields on the Field Data Sheet are also filled in at this time. The field operator turns off the sampler and adjusts the timer, allowing the sampler to operate on the designated sampling day. Upon completion of sampling, the field operator returns to the site, manually turns on the sampler and notes the sampler's post manometer reading along with other pertinent information on the Field Data Sheet. The sample is removed and sent back to the gravimetric laboratory. The filters are sent from the Gravimetric Laboratory back to TSP within APCD. At TSP the Field Data Sheet information is entered into the particulate database (PMT). After data entry has occurred, filters are sent back to the Laboratory for post sample weighing. Once equilibrated in the gravimetric laboratory, the filer is gross weighed and the weight is entered into the laboratory filter (MTL) database. Theoretically, on a bi-weekly schedule the gravimetric laboratory electronically transfers all data to the APCD where it is uploaded into the PMT database. Sampler calibration coefficients are used with the sampler's pre and post manometer and timer readings to establish a flow rate. The difference in the gross and tare weighs are combined with the flow rate to the 24-hour concentration. The

data is then uploaded to the AQS system once all QC and QA checks have been performed on the data. More detailed information regarding these procedures can be found in Appendix PM1 (Field SOP for TSP and PM_{10} High Volume Filters), Appendix LSD1 (Laboratory SOP for TSP High Volume Filters), and Appendix D2 (Data Management Operations for Filter-based Particulate Sampling SOP)

Data Acquisition for low-vol $PM_{2.5}$ and PM_{10} Filters

The data collection process begins at the gravimetric laboratory when a tare weight is assigned to an equilibrated filter and stored within the gravimetric laboratory's filter database. The tare weighed filter is then shipped to a field sampling location for sampling. Prior to the sampling day, the field operator installs the filter into a sampler, and enters all pertinent sample and scheduling information into the sampler's computer system. The field operator allows the sampler to operate on the designated sampling day. Upon completion of sampling, the field operator returns to the site and notes all pertinent sampling information on the Field Data Sheet. The sample is removed and sent back to the gravimetric laboratory in coolers at 0-4^{o}C. Copies of the field sheets are sent to TAP within APCD, and there the information from the field data sheets is entered into the particulate (PMT) database. Once equilibrated in the gravimetric laboratory, the filter is gross weighed and the weight is entered into the laboratory (MTL) filter database. On a bi-weekly or monthly schedule the gravimetric laboratory electronically transfers all data to APCD where it is uploaded into the PMT database. Either data from the Field Data Sheets or electronic data downloaded from the sampler can be used to determine the sampling flow rate. The difference in the gross and tare weighs are combined with the flow rate to the 24-hour concentration. The data is then uploaded to the AQS system once all data validation checks have been performed on the data. More detailed information regarding these procedures can be found in, Appendix PM2 (Field SOP for $PM_{2.5}$ Low Volume Filters), Appendix IML1 (IML's $PM_{2.5}$ Laboratory QAPP), Appendix LSD2 (LSD Laboratory SOP for low-vol gravimetric) and Appendix D2 (Data Management Operations for Filter-based Particulate Sampling SOP).

3.6.7.3 Data Acquisition of Non-Direct Measurement Data

The Ambient Air Quality Monitoring Program relies on data that are generated through field and laboratory operations; however, other significant data are obtained from sources outside the APCD. This section lists this data and addresses quality issues related to the Ambient Air Quality Monitoring Program.

Chemical and Physical Properties Data

Physical and chemical properties data and conversion constants are often required in the processing of raw data into reporting units. This type of information that has not already been specified in the monitoring regulations will be obtained from nationally and internationally recognized sources. Other data sources may be used with approval of the Air Division QA Officer. The following sources may be used in the Ambient Air Quality Monitoring Program without prior approval:

- ✓ National Institute of Standards and Technology (NIST)
- ✓ ISO, IUPAC, ANSI, and other widely-recognized national and international standards organizations
- ✓ U.S. EPA Region VIII and OAQPS
- ✓ The current edition of certain standard handbooks may be used without prior approval of the APCD Air Division QA Officer. Two that are relevant to the fine particulate monitoring program are CRC Press' Handbook of Chemistry and Physics, and Lange's Handbook.

Sampler Operation and Manufacturers' Literature

Another important source of information needed for sampler operation is manufacturers' literature. Operations manuals and users' manuals frequently provide numerical information and equations pertaining to specific equipment. APCD personnel are cautioned that such information is sometimes in error and that appropriate cross-checks should be made to verify the reasonableness of information contained in manuals. Whenever possible, the field operators will compare physical and chemical constants in the operators manuals to those given in the sources listed above. If discrepancies are found, determine the correct value by contacting the manufacturer. The field operators will make notations to correct all errors found in operation/operator manuals and ask the vendor to issue an errata sheet discussing the changes or download an updated manual from the

vendor's website. The Department will also contact the Region VIII Office to inform them of these errors. The following types of errors are commonly found in such manuals:

- ✓ Insufficient precision
- ✓ Outdated values for physical constants
- ✓ Typographical errors
- ✓ Incorrectly specified units
- ✓ Inconsistent values within a manual
- ✓ Use of different reference conditions than those called for in EPA regulations
- ✓ Missing or incomplete directions

Geographic Location

Another type of data that will commonly be used in conjunction with the $PM_{2.5}$ Ambient Air Quality Monitoring Program is geographic information. For the current sites, the Department will locate these sites using global positioning systems (GPS) that meet EPA Locational Data Policy of 25 meters accuracy. USGS maps were used as the primary means for locating and siting stations in the existing network. Geographic locations of APCD monitoring sites that are no longer in operation will not be re-determined.

Historical Monitoring Information of the APCD

The APCD has operated a network of ambient air monitoring stations since 1965. Historical monitoring data and summary information derived from that data may be used in conjunction with current monitoring results to calculate and report trends in pollutant concentrations. In calculating historical trends, it is important to verify that historical data are fully comparable to current monitoring data. If different methodologies were used to gather the historical data, biases and other inaccuracies must be described in trends reports based on that data. Direct comparisons of $PM_{2.5}$ with historical TSP or $PM_{2.5}$ data will not be reported or used to estimate trends. Dichotomous sampler data (fine portion) may be used to establish trends in $PM_{2.5}$ concentration; however, evidence must be presented to demonstrate that results of the two methods are comparable.

External Monitoring Databases

It is the policy of the APCD that no data obtained from the Internet, computer bulletin boards, or databases from outside organizations shall be used in creating reportable data or published reports without approval of the Air Division QA Officer. This policy is intended to ensure the use of high quality data in APCD publications. Data from the EPA AQS database may be used in published reports with appropriate caution. Care must be taken in reviewing/using any data that contain flags or data qualifiers. If data is flagged, such data shall not be utilized unless it is clear that the data still meets critical QA/QC requirements. It is impossible to ensure that a database such as AQS is completely free from errors including outliers and biases, so caution and skepticism is called for when comparing APCD data from other reporting agencies as reported in AQS. Users should review available QA/QC information to ensure that the external data are comparable with APCD measurements and that the original data generator had an acceptable QA program in place.

Lead and Speciated Particulate Data

The APCD has been routinely monitoring airborne lead since the 1980s. Early data is likely to be problematic because of different particle size cut points and because of significantly higher detection limits. Lead data (PM_{10}) acquired since 1980, and continuing in parallel with the current program, has improved analytical sensitivity due to a change in the analytical method. However, caution is needed in directly comparing this data with the $PM_{2.5}$ data because of the difference in size fractions.

U.S. Weather Service Data

Meteorological information is gathered from the U.S. Weather Service station. Parameters include: temperature, relative humidity, barometric pressure, rainfall, wind speed, wind direction, cloud type/layers, percentage cloud cover and visibility range. Historically, these data have not been used to calculate pollutant concentration values for any of the APCD monitoring sites. However, NWS data are often included in summary reports. No changes to the way in which these data are collected are anticipated due to the addition of the Fine Particulate data to the APCD ambient air monitoring program.

3.7 DATA MANAGEMENT REQUIREMENTS

3.7.1 DATA VALIDATION AND VERIFICATION

Data validation procedures are activities performed after data collection and processing in order to screen out erroneous values from the final ambient air quality data set. In addition to this data screening function, the data validation process can be used to identify errors in a data collection system. Generally, this data validation is most efficiently and effectively performed by those closest to the data collection systems.

3.7.1.1 Automated Samplers

The APCD currently uses a system of data validation, which consists of a visual review of on-line data and preliminary computer printouts, manual additions or deletions and final certification as detailed in Appendix D4 on Particulate Validation. The supervisor of the GMM Unit and the works leads of the GGM and PM units also routinely conduct data comparison reviews. In addition, the validation scheme includes a regular comparison of a representative number of strip chart values with final data logger values. In the event of failed accuracy audits or precision tests, additional testing may be conducted and an investigation may ensue. A detailed description of the data validation and verification procedures for automated samplers can be found in Appendices D3 and D4 (Data Validation SOPS for Particulate, Gaseous, and Meteorological Data).

Description
Throughout the month, all raw ambient air quality data, strip charts, site logs, zero/span/precision charts, maintenance reports, automated computer reports, audit performance reports, field data sheets, quality control charts, flow rate verifications and calibration reports are assembled in the GGM and PM units in one central location for each unit. Data completion checks, data quality verification reviews and various other comparison reviews are performed, and then everything is filed as permanent records. Every month, a structured review of all the data collected the previous month is conducted to ensure maximum data are collected and that known and determined invalid data are deleted.

Electronic copies of all records are maintained, updated and backed-up regularly. Additionally, a running 3-year hard copy file system is maintained at the TSP offices containing all logs and reports generated by maintenance, audits, calibrations and automated systems. (Note: Staff responsible for this part of the procedure must have a thorough understanding of PC computer DOS, Excel, of the State's monitoring system configuration and operation, and of the ESC software package and how each module interacts with others.) Also an understanding of EPA guidelines and requirements for acceptable treatment of ambient air quality data is necessary. These requirements and guidelines can be found in EPA's *QA Handbook for Air Pollution Measurement Systems Volume II.* Additional Guidance can be found in Guidance on Environmental Data Verification and Data Validation, QA/G-8, EPA 2002, reviewed 2008, http://www.epa.gov/QUALITY/qs-docs/g8-final.pdf.

Software provided by Environmental Systems Corporation and Agilaire (upgraded or modified by TSP), as well as the many databases that TSP designs and maintains, are used to verify and validate data before submission to AQS.

3.7.1.2 Manual Samplers

One level of data verification and validation occurs at the gravimetric laboratories and another level of data verification and validation occurs at the APCD. Detailed data verification and validation procedures occurring at the gravimetric laboratory are detailed in the gravimetric laboratory SOP found in Appendices IML1, LSD1, and LSD2 at the end of this QAPP. Additionally, detailed data verification and validation procedures occurring at the APCD are described in the data processing SOP appended as Appendices D2, D3, and D4 at the end of this QAPP.

Description
After a sample batch is compiled, a thorough review of the data will be conducted for completeness and data entry accuracy. All raw data that are hand entered from data sheets will be checked prior to entry to the

appropriate database. Once the data are entered, the data will be reviewed for routine data outliers and conformance to acceptance criteria. Unacceptable or questionable data will be flagged or deleted appropriately. All flagged data will be reviewed a second time to ensure that the values were entered correctly.

Validation of measurement data requires two stages, one at the measurement value level and another at the batch level. Records of all invalid samples shall be retained in the appropriate database. Information regarding the invalidation can be inferred through the data flag qualifier. Logbook notes and filed data sheets shall have more detailed information regarding the reason a sample was flagged. These documents shall remain with the field operator, at the monitoring site, or in long-term archive.

3.7.2 DATA TRANSMITTAL

3.7.2.1 Data Transfer to the Permanent Data Table

Once the data has passed the laboratory quality assurance criteria, it is electronically transferred in a spreadsheet format to the data managers within the monitoring group. This only occurs for filter based samples that are weighed at a gravimetric laboratory. This procedure is generally done on a bi-weekly basis but it can vary with the laboratory workload. Database macros upload and format the data into database tables within each pertinent database. Upon completion of data verification and validation procedures the data is the uploaded the AQS system.

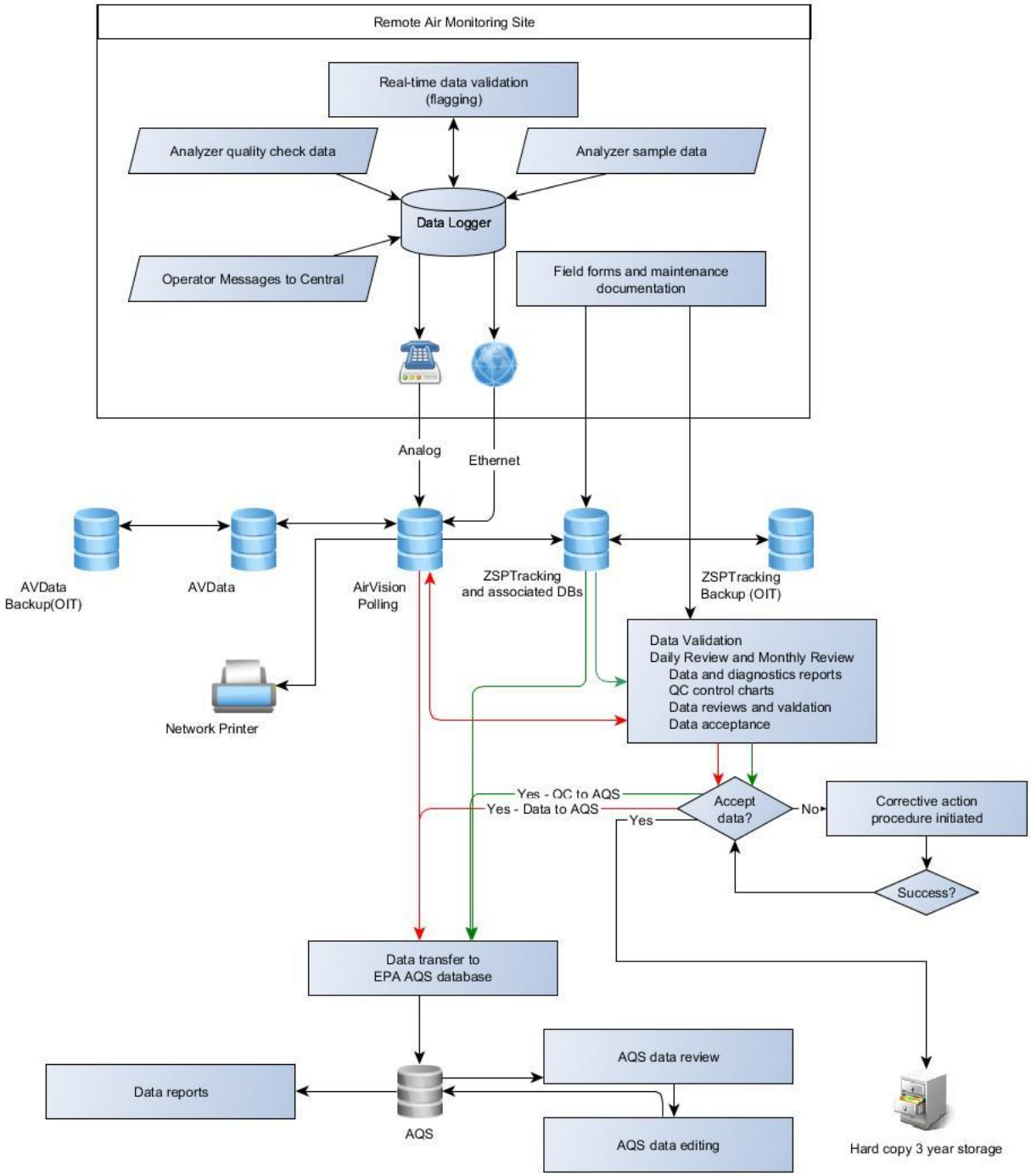
3.7.2.2 Data Transfer to AQS

AQS is the system administered by the US Environmental Protection Agency (EPA) used to assess the status of the Nation's air quality. The system includes a repository of ambient concentrations of air pollutants and associated meteorological data as well as the software used to add and maintain this data. The AQS system includes ambient air data collected by the EPA, state, local and tribal agencies. EPA's National Air Data Group (NADG) within the Office of Air Quality Planning and Standards (OAQPS) administers the AQS system. Access to the system can be achieved at EPA's Technology Transfer Network (TTN) Air Quality Systems (AQS) website: http://epa.gov/ttn/airs/airsaqs/index.htm.

There are several staff level people within the APCD that have received AQS training by EPA and are qualified to upload and download data from the AQS system. However, to avoid confusion, a single person within the TSP Program typically uploads all data from within the division to the AQS system. Data from the individual monitoring units and the Quality Assurance Unit are electronically transferred to the designated TSP AQS staff person for uploading to the AQS system.

Prior to uploading the data to the AQS system the data must be formatted into a pipe delimited format that is compatible with the AQS system. Information regarding data formatting can be found in EPA's guidance document "*AQS Coding Manual*." The most recent version as of the writing of this QAPP is version 3.1, March 14, 2014. It is the responsibility of the person generating the data to correctly format and validate the data prior to submitting it for uploading. Detailed information for the data handling and data formatting procedures for continuous monitors, sample based monitors and QA activities can be found in Appendix MQO.

Figure 3.7 Gaseous and Meteorological Data Processing and Data Validation Flowchart



4.0 ASSESSMENTS (CHECK)

4.1 TECHNICAL SYSTEMS ASSESSMENT

This section of the QAPP describes the internal and external checks necessary to ensure that the data collection is conducted as planned. An assessment, in this QAPP, is defined as an evaluation process used to measure the performance and effectiveness of the network and the measurements that have been obtained.

The results of quality assurance assessments indicate whether the control efforts are adequate or need to be improved. Documentation of all quality assurance and quality control efforts implemented during the data collection, analysis and reporting phases is important to data users, who can then consider the impact of these control efforts on the data quality. Both qualitative and quantitative assessments of the effectiveness of these control efforts will identify those areas most likely to impact the data quality and to what extent. Periodic assessments of SLAMS data quality are required to be reported to EPA. Assessments can be performed by an external agency such as the EPA or internally by quality assurance staff or by unit supervisors. In order to ensure the adequate performance of the quality system, the APCD will participate in the following assessment activities:

Assessments of APCD performed by External Entities
- Technical Systems Audits
- Readiness Reviews
- National Performance Audit Program (NPAP)
- FRM Performance Audit Program (PEP)
- NATTS audits
- Quality Audits

Internal Assessments performed by APCD (see section 4.2)
- Technical Systems audits
- Audits of Data Quality / Data Quality Assessments
- Peer Review
- Operational Surveillance
- Quality Control Checks (see Appendix MQO)
- Performance Audits
- System Audits / Siting Evaluations
- Reports to Management (see section 5.5)

Several External assessment and project planning tools are used to evaluate program structure and sampling activities. APCD will assist the EPA in performing these assessments by providing requested information, and taking measurements with EPA auditing materials and devices.

4.1.1 EXTRANAL TECHNICAL SYSTEMS ASSESSMENTS/AUDITS (TSA)

These audits are performed every three years on the AOCD Ambient Air Monitoring networks by Region VIII EPA staff. This audit is based on Appendix H of the QA Handbook Volume II, May 2013. Any issues found by EPA auditors will be addressed within 30 days of notification from EPA of an existing or potential problem.

4.1.2 MANAGEMENT SYSTEMS REVIEWS

A management system review (MSR) is a qualitative assessment of a data collection operation or organization to establish whether the prevailing quality management structure, policies, practices and procedures are adequate for ensuring that the type and quality of data needed are obtained. Management systems reviews of the Ambient Air Monitoring Program are conducted every three years by the Office of the Director of the EPA. The MSR will use appropriate federal regulations and the QAPP to determine the adequate operation of the air program and its related quality system. The quality assurance activities of all criteria pollutants will be part of the MSR. Divisions to be included in the MSR include the QA, Air, and Program Support Divisions.

The Director's staff will report its findings to the appropriate Divisions within 30 days of completion of the MSR. Follow-up and progress on corrective action will be determined during regularly scheduled division directors meetings

4.1.3 READINESS REVIEW

A readiness review is a technical check to determine if all components of the project are in place so that work can commence on a specific phase of a project. The EPA may choose to perform this assessment.

4.1.4 NATIONAL PERFORMANCE EVALAUTION PROGRAM (NPEP)

Monitoring plans or the QAPP shall provide for the implementation of a program of independent and adequate audits of all monitors providing data for SLAMS and PSD including the provision of adequate resources for such audit programs. A monitoring plan (or QAPP), which provides for monitoring organization participation in EPA's National Performance Audit Program (NPAP) and the PM Performance Evaluation Program (PEP) program, and which indicates the consent of the monitoring organization for EPA to apply an appropriate portion of the grant funds, which EPA would otherwise award to the monitoring organization for monitoring activities, will be deemed by EPA to meet this requirement. Section 2.4 of 40 CFR Part 58, Appendix A.

The NPEP's goal is to assess the proficiency of agencies that are operating monitors in the SLAMS/NCore/PSD networks. To accomplish this, the NPEP has established acceptable limits or performance criteria based on the data quality needs of the SLAMS/NCore/PSD requirements for each of the audit materials and devices used in the NPEP.

4.1.4.1 National Performance Audit Program (NPAP)

All audit devices and materials used in the NPAP are certified as to their true value and that certification is traceable to a NIST standard material or device wherever possible. The audit materials used in the NPAP are as representative and comparable as possible to the calibration materials and actual air samples used and/or collected in the SLAMS/NCore/PSD networks. The audit material/gas cylinder ranges used in the NPAP are specified in the Federal Register.

The Through the Probe (TTP) NPAP Proficiency Evaluation (PE) Audit is used for determining total bias for National Ambient Air Quality Standard (NAAQS) Criteria Pollutant gases. The performance evaluation gas samples are dynamically generated and independently verified by EPA funded personnel onsite. The test gas samples are delivered to and through the entire ambient air monitoring sampling system of the organization being evaluated, starting with entry into the monitoring station's sampling inlet, or "probe".

The NPAP lead (Pb) strip audits are used for determining laboratory efficiency.

Table 4.1 NPAP Audit Criteria

NPAP Audit	EPA determined limits
SO_2, NO_2, O_3, and CO	Mean absolute % difference < 15%
Pb (analytical)	% difference < ±15% for 1 or more levels

4.1.4.2 Low Volume Particulate Monitors Performance Evaluation Program (PM PEP)

The PEP is an independent assessment used to estimate total measurement system bias. These evaluations will be performed under the PM Performance Evaluation Program (PEP) (40 CFR Part 58 App A section 2.4) or a comparable program. Performance evaluations will be performed on the SLAMS monitors annually within each primary quality assurance organization. For primary quality assurance organizations with greater than five monitoring sites, eight valid performance evaluation audits must be collected and reported each year. A valid performance evaluation audit means that both the primary monitor and PEP audit concentrations are valid and above 3 $\mu g/m^3$. Additionally, each year, every designated FRM or FEM within a primary quality assurance organization must:

(1) Have each method designation evaluated each year; and,

(2) Have all FRM or FEM samplers subject to a PEP audit at least once every six years, which equates to approximately 15 percent of the monitoring sites audited each year.

4.1.4.3 High Volume Particulate Performance Evaluations

The National Performance Evaluation Program no longer supports High Volume particulate performance audits. To satisfy the requirement of having an external entity provide independent audits every three years, Region VIII periodically provides APCD with a "blind" high volume orifice to go in the field and conduct audits. These "blind" audit results are then sent back to Region VIII for analysis.

4.1.4.4 NATTS Audits

Approximately every 3 years, the EPA sends out a contracted agency to perform an audit of the NATTS operations.

4.1.4.5 Quality Audits

Starting in 2014, and approximately every three years after that, the EPA Region VIII Quality Group will perform a quality audit of the CDPHE Environmental Programs where documentation and CDPHE structure will be evaluated.

4.2 PERFORMANCE AUDITS OF MEASUREMENT AND ANALYTICAL SYSTEMS

4.2.1 TECHNICAL SYSTEMS ASSESSMENTS/AUDITS (TSA)

The technical systems audit (TSA) is a thorough and systematic on-site qualitative audit where facilities, equipment, personnel, training, procedures, and record keeping are examined for conformance with the QAPP. These visits may include a tour of field and/or laboratory operations. At least every other year, APCD will perform a TSA on any sub-contracted work to ensure that consistency is being met throughout the state network according to the QAPP.

The TSP audit team performing the TSA will focus its attention on three main areas:

- Field - Handling, sampling, sample shipping.
- Laboratory - Pre-sampling weighing, sample shipping and receiving, post-sampling weighing, archiving, and associated QA/QC.
- Data management - Information collection, flagging, data editing, security, upload.

Key personnel to be interviewed during the audit are those individuals with responsibilities for planning, field operations, laboratory operations, QA/QC, data management, and reporting.

To increase uniformity of the TSA, an audit checklist will be developed and used.

The audit team will prepare a brief written summary of findings for the QA officer, organized into the following areas: planning, field operations, laboratory operations, quality assurance/quality control, data management and reporting. Problems with specific areas will be discussed and an attempt will be made to rank then in order of their potential impact on data quality.

Measurement uncertainty will be estimated for both automated and manual methods. Terminology associated with measurement uncertainty can be found within 40 CFR Part 58 Appendix A section 1.2 and includes:

(a) Precision. A measurement of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions, expressed generally in terms of the standard deviation.
(b) Bias. The systematic or persistent distortion of a measurement process which causes errors in one direction.
(c) Accuracy. The degree of agreement between an observed value and an accepted reference value. Accuracy includes a combination of random error (imprecision) and systematic error (bias) components which are due to sampling and analytical operations.
(d) Completeness. A measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct, normal conditions.
(e) Detectability. The low critical range value of a characteristic that a method specific procedure can reliably discern.

Estimates of data quality will be calculated on the basis of single monitors and aggregated to all monitors.

The audit team will prepare a brief written summary of findings, organized into the following areas: planning, field operations, laboratory operations, quality assurance/quality control, data management and reporting. Problems with specific areas will be discussed and an attempt will be made to rank them in order of their potential impact on data quality.

The audit finding form has been designed such that one is filled out for each major deficiency that requires formal corrective action, and may also be used by the QA Unit at times other than during a TSA. The finding should include items like: pollutant(s) impacted, estimated time period of deficiency, site(s) affected, and reason of action. The finding form will inform the Department about serious problems that may compromise the quality of the data and therefore require specific corrective actions. They are initiated by the QA Unit and discussed at the debriefing. During the debriefing, if the audited group is in agreement with the finding, the form is signed by the Program Manager or his designee during the exit interview. If a disagreement occurs, the QA Unit will record the opinions of the group audited and set a time at some later date to address the findings.

Post-Audit Activities- The major post-audit activity is the preparation of the systems audit report. The report will include:

- audit title and any other identifying information
- audit team leaders, audit team participants and audited participants
- background information about the project
- purpose of the audit
- dates of the audit
- particular measurement phase or parameters that were audited
- brief description of the audit process
- summary and conclusions of the audit and corrective action requirements
- attachments or appendices that include all audit evaluations and audit finding forms

To prepare the report, the audit team will meet and compare observations with collected documents and results of interviews and discussions with key personnel. Expected QA Project Plan implementation is compared with observed accomplishments and deficiencies and the audit findings are reviewed in detail. Within thirty (30) calendar days of the completion of the audit, the audit report will be prepared and submitted. The systems audit report will be submitted to the appropriate program managers and appropriately filed.

If the program has written comments or questions concerning the audit report, the QA Unit will review and incorporate them as appropriate, and subsequently prepare and resubmit a report in final form within thirty (30) days of receipt of the written comments. The report will include an agreed upon schedule for corrective action implementation.

Follow-up and Corrective Action Requirements: The QA Unit and the audited monitoring group may work together to solve required corrective actions. As part of corrective action and follow-up, an audit finding response will be generated by the audited monitoring group for each finding form submitted. The audit finding response form is signed off by the audited monitoring group and sent to the QA unit who reviews and accepts the corrective action. The audited monitoring group will complete the audit response form within 30 days of acceptance of the audit report.

4.2.2 PEER REVIEW

Peer review is not a TSA, nor strictly an internal QA function, as it may encompass non-QA aspects of a project and is primarily designed for scientific review. Reviewers are chosen who have technical expertise comparable to the projects performers but who are independent of the project. ADQs and peer reviews ensure that the project activities:

- are technically adequate,
- are competently performed,
- are properly documented,
- satisfy established technical requirements, and
- satisfy established QA requirements.

In addition, peer reviews assess the assumptions, calculations, extrapolations, alternative interpretations, methods, acceptance criteria, and conclusions documented in the project's report.

4.2.3 INTERNAL PERFORMANCE AUDITS

The GMM Unit staff frequently performs assessment audits on gaseous analyzers operated by the APCD. These assessment audits provide a means of gauging the response of the analyzer before calibration adjustments or repairs are made. Prior to the instrument calibration, GMM Unit staff introduce a known gas concentration near the full-scale response of the instrument. If the instrument response shows an error greater than ±7%, a full multi-point assessment audit is conducted prior to an analyzer adjustment. The results of these assessment audits are reported to the GMM Unit supervisor, but the results are not submitted to the EPA AQS database.

Performance Evaluation, also called accuracy audits, of all gaseous and particulate analyzers are performed by QA Unit staff with equipment independent of that used for instrument calibration. Monitors to be audited are selected at random. The EPA requires that 25% of the analyzers for each pollutant parameter be monitored each quarter, with a minimum audit frequency of one audit per analyzer per year. The APCD internal goal is to perform two accuracy audits on each analyzer per year. Audit procedures are detailed in Appendix Q1 within the Appendices of this document.

Accuracy at an individual audit point during accuracy and assessment audits is established by calculating the degree of agreement between the monitor response (indicated value) and an accepted reference device (actual value). Accuracy may be expressed as the percentage of difference from the reference standard using the following calculation:

$$\% \text{ Difference} = ((I-A)/A) * 100$$

where

I = Indicated value
A = Actual value

For the Division's gaseous analyzers, an analyzer full-scale response is calculated from the audit data using a least-squares regression of the actual and indicated values. The analyzer full-scale error is calculated using the following equation:

$$\% \text{ Full-scale error} = ((((FS * m) + I) / FS) * 100$$

where

FS = Analyzer full-scale response
m = Regression slope
I = Regression intercept

The actual and indicated values of each particulate and gaseous accuracy audit are submitted to the EPA Air Quality Systems (AQS) database within 90 days of the end of each calendar quarter. These audit results are then statistically analyzed and reported as quarterly and annual accuracy probability limits.

4.2.4 INTERNAL DATA AUDITS

Data verification and validation are the two key steps in the data assessment process. Data verification is primarily an evaluation of performance against a pre-determined requirement given in a document such as a standard operating procedure. Data validation focuses on particular data needs for a project, as stated in a project-specific document such as a Quality Assurance Project Plan. Furthermore, data verification is performed during or at the culmination of field or laboratory data collection activities, whereas data validation is conducted subsequently, almost always by a party independent of both the data collector and the data user. Within the APCD it is the responsibility of each monitoring group to perform data verification procedures. It is the QA Unit's and the monitoring groups responsibility to perform the data validation procedures in accordance with EPA's *Guidance on Environmental Data Verification and Data Validation (EPA GA/G-8)* guidance document. Data verification and validation procedures for gaseous and particulate data are given in the data processing SOPs (D1, D2, D3, and D4). Federal guidance requires data to be uploaded to the EPA AQS data archival system 90 days after completion of a calendar quarter in which the data was collected. Data validation is typically assessed annually and documented in the Annual Data Report. Because data verification

is assessed on a quarterly schedule and data validation assessment is typically not performed until after the data has been uploaded to the AQS system, it is the purpose of the internal data audit to perform some data validation procedures on a quarterly schedule so that problems can be identified more quickly and not be allowed to persist for potentially a year before being identified.

It is the goal of the APCD to perform quarterly data audits to verify that data is being properly verified and uploaded to the AQS system. Federal guidance requires data to be uploaded to the EPA AQS data archival system 90 days after completion of a calendar quarter in which that data was collected. The uploading of data to the AQS system occurs continuously throughout the quarter and is not done in a single batch. Ideally, a data audit would occur prior to submission of data to the AQS system. However, because different data verification procedures occur at different times for different pollutant types, trying to develop a data audit procedure that incorporates all data prior to uploading to the AQS system is unrealistic. Therefore, the internal data audit procedure will evaluate data that exists in the AQS system. The data audit will occur after the 90-day criterion when all data was to have been uploaded to the AQS system. The data audit can cover, but are not limited to, the following:

- Evaluate if all continuous and particulate raw data has met the 90-day AQS criterion
- Evaluate if all continuous and particulate precision data has met the 90-day AQS criterion
- Evaluate if all continuous and particulate accuracy data has met the 90-day AQS criterion
- Evaluate accuracy data and identify audits that do not meet criteria
- Evaluate precision data and identify checks that do not meet criteria
- Evaluate completeness
- Evaluate bias
- Quasi-randomly select a range of raw hourly data from the central computer for each continuous pollutant type and verify its accuracy within the AQS system
- Quasi-randomly select several particulate filters and manually calculate their 24 hour concentration independent of the PMT system and verify their accuracy against the PMT and AQS systems

All but the last two evaluations listed are currently performed on an annual basis when the Data Quality Assessment (DQA) is done, and is published each year within the Colorado Annual Data Report (discussed further in section 5 under Reports to Management).

Full implementation of a final quarterly QA data audit including the last two functions listed above will be developed by the recently expanded QA Unit and documented in the future in Appendix DQ.

4.2.5 INTERNAL SYSTEMS AUDITS

The APCD goal is to conduct a systems audit every two years at each of the gaseous and particulate monitoring sites. The system audit questionnaire was based on 40CFR Part 58 Appendices D & E. These system audits are intended to provide information about general operating conditions at the stations. Information about conformance with siting requirements, probe locations, station record keeping, operating procedures, and safety is collected during these audits. Systems audits are performed by the QA Unit staff. The completed system audit forms are transmitted to the PM or GMM Unit supervisors for evaluation and implementation of any corrective actions. All information recorded is kept in the Monitoring Sites Database. At their discretion, EPA national or regional headquarters may perform system audits of any monitoring sites in the APCD monitoring network.

4.3 SURVEILLANCE OF OPERATIONS

A brief summary of assessment tools, the frequency at which they should occur and the personnel responsible for coordinating each activity can be found in Table 2.2. Details about whom the assessment activity should be reported to and within what time frame it should be completed are contained in Table 5.2. Information about assessment tools not included within these tables can be found within each assessment tool description in this section or in the following section 5.

4.4 AUDIT OF DATA QUALITY (ADQ)

An ADQ reveals how the data are handled, what judgments were made, and whether uncorrected mistakes were made. ADQs can often identify the means to correct systematic data reduction errors. An ADQ will be performed every year and will also be part of the TSA (every 3 years). Therefore, sufficient time and effort will be devoted to this activity so that the auditor or auditing team has a clear understanding and complete documentation of data flow. Pertinent ADQ questions will appear on the TSA check sheets to ensure that the data collected at each stage maintains its integrity. The ADQ will serve as an effective framework for organizing the extensive amount of information gathered during the audits of laboratory, field monitoring, and support functions within the agency. The ADQ will have the same reporting/corrective action requirements as the TSA.

4.4.1 DATA QUALITY ASSESSMENTS (DQA)

A data quality assessment (DQA) is the statistical analysis of environmental data to determine whether the quality of data is adequate to support the decision, which are based on the DQOs. Data are appropriate if the level of uncertainty of a decision based on the data is acceptable. The DQA process is described in detail in *Guidance for the Data Quality Assessment Process*, EPA QA/G-9 and is summarized below. The calculations that must be performed to prepare the DQA are in section 5.4 of this QAPP.

1. Review the data quality objectives (DQOs) and sampling design of the program: review the DQO and develop one, if it has not already been done. Define statistical hypothesis, tolerance limits, and/or confidence intervals.

2. Conduct preliminary data review. Review Precision & Accuracy (P&A) and other available QA reports and calculate summary statistics, plots and graphs. Look for patterns, relationships, or anomalies.

3. Select the statistical test: select the best test for analysis based on the preliminary review, and identify underlying assumptions about the data for that test.

4. Verify test assumptions: decide whether the underlying assumptions made by the selected test hold true for the data and the consequences.

5. Perform the statistical test: perform test and document inferences. Evaluate the performance for future use.

Data quality assessments will be included in the Annual Data Report. Details of these reports are discussed in Section 5.4. Published Annual Data Reports can be found at the APCD/ TSP website under "Technical Documents and Reports," http://www.colorado.gov/airquality/tech_doc_repository.aspx.

Periodic assessments of SLAMS data quality are required to be reported to EPA (40 CFR 58 Appendix A, Section 1.4). The CDPHE Air Division's Annual Data Report, which contains the Data Quality Assessment (DQA), is issued to meet this requirement. This report describes the quality objectives for measurement data and how those objectives have been met. The Data Quality Assessment also provides for the review of the SLAMS air quality surveillance system on an annual basis to determine if the system meets the monitoring objectives defined in 40 CFR Part 58, Appendix D. Such review will identify needed modifications to the

network such as termination or relocation of unnecessary stations or establishment of new stations that are necessary.

The Data Quality Assessment will include QA/QC information for each ambient air pollutant in the APCD monitoring network. These sections are organized by ambient air pollutant category. Each section includes the following topics:

- program overview and update
- quality objectives for measurement data
- data quality assessment

For reporting measurement uncertainties, the Data Quality Assessment contains the following summary information required by 40 CFR 58 Appendix A:

- Flow Rate Audits
- Collocated Federal Reference Method Samplers
- Collocated Equivalent Samplers of Same Designation
- Assessment of Bias Using the FRM Audit Procedure

4.5 QUALITATIVE AND QUANTITATIVE COMPARISONS OF ACCEPTANCE CRITERIA

In addition to the annual DQA, data comparisons are made on a regular basis throughout the network in the form of Quality control checks, flow rate verifications, nightly precision/span/zero checks, and performance audits. All acceptance criteria are checked when any of these internal checks are performed. Any non-conformance to acceptance criteria is investigated immediately by the monitoring unit responsible for the analyzer or sampler in question.

4.6 INTERIM ASSESSMENTS OF DATA QUALITY

QC and QA data is reviewed and submitted to AQS quarterly. Data validation and verification procedures are discussed in section 5 and in the Data Handling Appendices of this QAPP document.

4.7 EVALUATION OF UNCONVENTIONAL MEASUREMENTS

At this time no Unconventional Measurements are being collected by APCD/TSP. Generally, when non-criteria measurements are made, it is either for site selection or special study purposes, and the data are evaluated by the Unit supervisors and the QA Unit.

4.8 EVALUATION OF UNCONVENTIONAL MONITORING PROJECTS

At this time, no Unconventional Monitoring projects are being conducted by APCD/TSP. Generally, when non-criteria projects occur, the data is treated the same way (when possible) as criteria data.

5.0 REVIEW, EVALUATION OF USABILITY, AND REPORTING REQUIREMENTS (ACT)

5.1 DATA VERIFICATION AND VALIDATION TARGETS AND METHODS

The purpose of this section is to specify the criteria for determining the degree to which the collected data has met its quality specifications. The potential effect of any deviations from the QAPP should also be estimated to determine the usability of the data. This section will describe how the APCD will verify and validate the data collection operations associated with the ambient air-monitoring network

Verification can be defined as confirmation by examination and provision of objective evidence that specified requirements have been fulfilled. The process of verification effectively ensures the accuracy of data and is often used in comparison with reference standards.

Validation can be defined as confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled. The method validation process effectively develops the QA acceptance criteria or specific performance criteria.

Although there are a number of objectives of ambient air data, the major objective for the APCD network is for comparison to the NAAQS standard, and therefore, this will be identified as its' intended use. Earlier sections describe in detail how data collection activities will be implemented to meet the data quality objectives of the Program. Review and approval of this QAPP by the Department and EPA provide initial agreement that the process described in the QAPP will provide data of adequate quality. In order to verify and validate the phases of the data collection operation, the APCD will use various qualitative assessments (e.g., technical systems audits, network review) to verify that the QAPP is being followed, and will rely on the various quality control samples, inserted at various phases of the data collection operation, to validate that the data will meet the MQO described in Appendix MQO.

5.1.1 SAMPLING DESIGN

Section 3 discusses the sampling design for the network established by APCD. It covers the number of sites required, their location, and the frequency of data collection. The objective of the sampling design is to represent the population of interest at adequate levels of spatial and temporal resolution. Most of these requirements have been described in the Code of Federal Regulations. However, it is the responsibility of APCD to ensure that the intent of the regulations are properly administered and carried out.

5.1.1.1 Sampling Design Verification

Verification of the sampling design will occur through the following:

Network Design Plan Conformation: The Network Design Plan that discusses the initial deployment of the network must be submitted, reviewed and approved by EPA prior to implementation. This process verifies the initial sampling design.

Internal Network Reviews: Once a year, the APCD will perform a network review to determine whether the network objectives are still being met and that the sites are meeting the CFR siting criteria.

External Network Reviews: Every three years the EPA Regional Office will conduct a network review to determine whether the network objectives, as described in the Network Design Plan, are meeting the CFR siting criteria.

5.1.1.2 Sampling Design Validation

The ambient air data derived from the sites will be used to validate the sampling design. APCD may also use saturation monitors as well as special purpose monitors to validate that the monitors are properly sited and that

the sampling design will meet the objectives of the network. This information will be included in network review documentation and appropriately communicated to the EPA Regional Office. In addition, the processes described in Section 3 will be used to confirm the network design.

5.1.2 SAMPLE COLLECTION PROCEDURES

5.1.2.1 Sample Collection Verification

Sample collection procedures are described in detail in Section 3 and are developed to ensure proper sampling and to maintain sample integrity. The following processes will be used to verify the sample collection activities:

Internal Technical Systems Audits: will be required every three years as described in Section 4.

External Technical Systems Audits: will be conducted by the EPA Regional VIII Office every three years.

Both types of technical systems audits will be used to verify that the sample collection activity is being performed as described in this QAPP and the SOPs. Deviations from the sample collection activity will be noted in audit finding forms and corrected using the procedures described in Section 4.

5.1.2.2 Sample Collection Validation

The sample collection activity is just one phase of the measurement process. The use of QC samples that have been placed throughout the measurement process can help validate the activities occurring at each phase. The review of QC data, such as the collocated sampling data, field blanks, performance evaluations, and the sampling equipment verification checks that are described in Appendix MQO and in method specific SOPs, can be used to validate the data collection activities. Any data that indicates unacceptable levels of bias or precision or a tendency (trend on a control chart) will be flagged and investigated. This investigation could lead to a discovery of inappropriate sampling activities.

5.1.3 SAMPLE HANDLING

Sections 3.2, 3.3 and specific method SOPs detail the requirements for sample handling, including the types of sample containers, the preservation methods used to ensure that they are appropriate to the nature of the sample, and the type of data generated from the sample. Due to the size of the filters and the nature of the collected particles, sample handling is one of the phases where inappropriate techniques can have a significant effect on sample integrity and data quality.

5.1.3.1 Verification of Sample Handling

As mentioned in the above section, both internal and external technical systems audits will be performed to ensure that the specifications mentioned in the QAPP are being followed. The audits include checks on the identity of the sample (e.g., proper labeling and chain-of-custody records), packaging in the field, and proper storage conditions (e.g., chain-of-custody and storage records) to ensure that the sample continues to be representative of its native environment as it moves through the data collection operation.

5.1.3.2 Validation of Sample Handling

Similar to the validation of sampling activities, the review of data from collocated sampling, field blanks, and the FRM performance evaluations, that are described in Section 3.5 and specific method SOPs, can be used to validate the sample handling activities. Acceptable precision and bias in these samples would lead one to believe that the sample handling activities are adequate. Any data that indicates unacceptable levels of bias or precision or a tendency (trend on a control chart) will be flagged and investigated. This investigation could lead to a discovery of inappropriate sample handling activities that require corrective action.

5.1.4 ANALYTICAL PROCEDURES

The method-specific SOPs found in the appendices of this document detail the requirements for analytical measurements. The methods include acceptance criteria and Appendix DQO spells out all MQO acceptance criteria for all methods used in APCD ambient air monitoring. Any deviations from the QA Handbook MQOs are addressed in Appendix MQO. SOPs for laboratory and subcontracted data collectors are also included in the Appendices.

5.1.4.1 Verification of Analytical Procedures

As mentioned in the above sections, both internal and external technical systems audits will be performed to ensure that the analytical method specifications mentioned in the QAPP are being followed. The audits will include checks on the identity of the sample. Deviations from the analytical procedures will be noted in audit finding forms and corrected using the procedures described in Section 5.5.

5.1.4.2 Validation of Analytical Procedures

Similar to the validation of sampling activities, the review of data from nightly zero and span checks, lab blanks, field blanks, calibration checks, laboratory duplicates and other method QC checks that are described in Sections 3.5 and 3.7, and in the data verification and validation SOP, can be used to validate the analytical procedures. Acceptable precision and bias in these samples indicate that the analytical procedures are adequate. Any data that indicates unacceptable levels of bias or precision or a tendency (trend on a control chart) will be flagged and investigated as described in Section 3.5. This investigation can lead to a discovery of inappropriate analytical procedures, requiring corrective action.

5.1.5 QUALITY CONTROL

Sections 3.5 and 3.7 and the method-specific SOPs in the appendices of this QAPP specify the QC checks that are to be performed during sample collection, handling and analysis. These include analyses of precision, zero/span, flow rate, check standards, blanks, spikes and replicates, which provide indications of the quality of data being produced by specified components of the measurement process. For each specified QC check, the procedure, acceptance criteria and corrective action are specified.

5.1.5.1 Verification of Quality Control

As mentioned in the above sections, both internal and external technical systems audits will be performed to ensure that the quality control method specifications mentioned in the QAPP are being followed.

5.1.5.2 Validation of Quality Control Procedures

Validation activities of many of the other data collection phases mentioned in this subsection use the quality control data to validate the proper and adequate implementation of that phase. Therefore, validation of QC procedures will require a review of the documentation of the corrective actions that were taken when QC checks failed to meet the acceptance criteria, and the potential effect of the corrective actions on the validity of the routine data. Section 3.5 describes the techniques used to document QC review/corrective action activities.

5.1.6 CALIBRATION

The method-specific SOPs and QAPPs found in the appendices of this document, as well as the field (Section 3.2) and the analytical sections (Section 3.4), detail the calibration activities and requirements for the critical pieces of equipment in the APCD ambient air network.

5.1.6.1 Verification of Calibration Procedures

Both internal and external technical systems audits will be performed to ensure that the calibration specifications and corrective actions mentioned in the QAPP are being followed. Deviations from the calibration procedures will be noted in audit finding forms and corrected using the procedures described in Section 5.5.

5.1.6.2 Validation of Calibration Procedures

Similar to the validation of sampling activities, the review of calibration data that is described in Sections 3.5 and 3.7 can be used to validate calibration procedures. Calibration data within all acceptance criteria indicates that the sample collection or measurement devices are operating properly. Any data that indicates unacceptable levels of bias or precision or a tendency (trend on a control chart) will be flagged and investigated as described in Section 3.5 or 3.7. This investigation can lead to a discovery of inappropriate calibration procedures or equipment problems requiring corrective action as detailed in the section 5.5.2. Validation would include the review of the documentation to ensure corrective action was taken as prescribed in the QAPP.

5.1.7 DATA REDUCTION AND PROCESSING

5.1.7.1 Verification of Data Reduction and Processing Procedures

Both internal and external technical systems audits will be performed to ensure that the data reduction and processing activities mentioned in the QAPP are being followed.

5.1.7.2 Validation of Data Reduction and Processing Procedures

As part of the routine audits of data quality, or at any time that changes are made to the DAS, a number of sample IDs, chosen at random will be identified. All raw data files, including the following will be selected:

- Pre-sampling weighing activity (where applicable)
- Pre-sampling
- Sampling (sampler download information)
- Calibration - the calibration information represented from that sampling period
- Sample handling/custody (where applicable)
- Post-sampling weighing (where applicable)
- Corrective action
- Data reduction
- Bracketing QC charts

This raw data will be reviewed and final concentrations will be calculated by hand to determine if the final values submitted to AQS compare to the hand calculations. The data will also be reviewed to ensure that associated flags or any other data qualifiers have been appropriately associated with the data and that appropriate corrective actions were taken.

5.2 QUANTITATIVE AND QUALITATIVE EVALUTAIONS OF USEABILITY

More detailed information on Data Validation and Data Verification can be found in the Data Handling Appendices (D2, D3, and D4). If data is deemed to be of unacceptable quality, it is null coded in AQS. If data is deemed to useable but with minor non-critical criteria flaws, then that data is imported to AQS with a qualifier code. These codes can be found is Appendix D5.

The purpose of this section is to describe in detail the process for validating (determining if data satisfy QAPP-defined requirements) and verifying (ensuring that conclusions can be correctly drawn) network data.

Many of the processes for verifying and validating the measurement phases of the ambient air quality network data collection operation have been discussed in Section 5.1. If these processes, as written in this QAPP and its related SOPs, are followed, and the sites are representative of the boundary conditions for which they were selected, one would expect to achieve the APCD Ambient Air Quality Network DQOs. However, exceptional field events may occur and field and laboratory activities may negatively affect the integrity of samples. In addition, it is expected that some of the QC checks will fail to meet the acceptance criteria. Information about problems that affect the integrity of data is identified in the form of flags (Appendix D5 or null codes). It is important to determine how these failures affect the routine data. The review of this routine data and their associated QC data will be verified and validated on a sample batch basis. The sample batch is the most efficient entity for verification/validation activities. It is assumed that if measurement uncertainty can be controlled within acceptance criteria at a batch level, then the overall measurement uncertainty will be maintained within the precision and bias DQOs.

5.2.1 PROCESS FOR VALIDATING DATA

Each sample or data point should be verified to ensure that the procedures used to generate the data (as identified in Appendix MQO of the QAPP) were implemented as specified. Acceptance criteria have been developed for important components of the procedures, along with suitable codes for characterizing each sample's or data point's deviation from the procedure. Data validation activities should determine how seriously a sample deviated beyond the acceptable limit so that the potential effects of the deviation can be evaluated in the Data Quality Assessment.

For some methods, the criteria have been subdivided according to their significance and how relevant those criteria are to data quality. The three subcategories of criteria are critical, operational and systematic.

Critical criteria are those that were deemed critical to maintaining the integrity of a sample or group of samples. Observations that do not meet each and every criterion for critical criteria should be invalidated unless there is a compelling reason and justification for not doing so. Basically, the sample or group of samples for which one or more of these criteria are not met is invalid until proven otherwise. The cause of not operating within the acceptable range for each of the violated criteria must be investigated and minimized to reduce the likelihood that additional samples will be invalidated.

Operational criteria are those that are important for maintaining and evaluating the quality of the data collection. Violation of a criterion or a number of criteria may be cause for invalidation. The decision should consider other quality control information that may or may not indicate that the data are acceptable for the parameter being controlled. Therefore, the sample or group of samples for which one or more of these criteria are not met is suspect unless other quality control information demonstrates otherwise. The reason for not meeting the criteria MUST be investigated, mitigated or justified.

Finally, systematic criteria are those criteria that are important for the correct interpretation of the data but do not usually impact the validity of a sample or group of samples. For example, the data quality objectives are included in this table. If the data quality objectives are not met, this does not invalidate any of the samples but it may impact the error rate associated with the attainment/non-attainment decision.

For each criterion, the tables in Section 10 include (1) the operational range that is acceptable, (2) the frequency with which compliance is to be evaluated, (3) the number of samples that are impacted if violation of a criterion occurs (possible values include single filters, a batch of filters, or a group of filters from a specific instrument), (4) sections of 40 CFR and (5) Method 2.12 that describe the criterion. The table also indicates whether samples violating the criterion must be flagged before entering them into AQS.

This validation template has been developed based on the current state of knowledge. The template should evolve as new information is discovered about the impact of the various criteria on the error in the resulting mass estimate. Interactions of the criteria, whether synergistic or antagonistic, should also be incorporated when the impact of these interactions becomes quantified. Due to the potential misuse of invalid data, data

that are invalidated will not be uploaded to AQS. Invalid data will be retained in APCD's network database and will be used in internal technical systems audits and in the development of new field and laboratory procedures.

5.2.1.1 Verification of Sample Batches

After a sample batch is completed, a thorough review of the data will be conducted for completeness and data entry accuracy. All raw data that is hand entered on data sheets will be double keyed into the DAS. The entries are compared to reduce the possibility of entry and transcription errors. Once the data is entered into the DAS, the system will review the data for routine data outliers and data outside of acceptance criteria. These data will be flagged appropriately. All flagged data will be reevaluated to ensure that the correct values have been properly entered. Details of these activities are discussed in Section 3.7. The data qualifiers or flags and codes can be found in Appendix D5.

Appendix D5 provides a list of flags and codes to be inserted in the DAS next to samples that have been invalidated. The following Table (5.1) obtained from 40 CFR Part 58 Appendix A gives a list of Minimum Data Assessment requirements. The basic acceptance criteria for particulate sample validation can be found in Table 2.6. APCD's goals for quality data in the network are summarized in more detail in the validation assessment acceptance criteria contained in Appendix MQO. Also, method-specific details on acceptance criteria can be found in the individual method SOPs located the appendices to this document.

APCD will maintain records on any invalidated samples or sample sets, as well as the reasons for invalidation and the associated flags and codes.

5.2.1.2 Validation of Data

Validation of measurement data will require two stages, one at the measurement value level, and the second at the batch level. Records of all invalid samples will be filed. Information will include a brief summary of why the sample was invalidated along with the associated flags. This record will be available on the DAS. At least one code will be associated with each invalid sample. Additional codes may also be associated with an invalid sample to help define the cause of the sample becoming invalidated. Certain criteria based upon CFR and field operator/laboratory technician judgment have been developed that will be used to invalidate a sample or measurement.

Table 5.1 Minimum Data Assessment Requirements

Method	Assessment Method	Coverage	Minimum Frequency	Parameter Reported
Automated Methods				
1-Point QC for SO_2, NO_2, O_3 and CO	Response check at conc. 0.01-0.1 ppm SO_2, NO_2, O_3, and 1-10 ppm CO	Each analyzer	Once per 2 weeks	Audit concentration[1] and measured concentration[2]
Annual performance evaluation for SO_2, NO_2, O_3 and CO	See Section 3.2.2 CFR 58 Appendix A	Each analyzer	Once per year	Audit concentration[1] and measured concentration[2] for each level
Flow Rate verification PM_{10}, $PM_{2.5}$ and $PM_{10\text{-}2.5}$	Check of sampler flow rate	Each sampler	Once every month	Audit flow rate and measured flow rate indicated by sampler
Semi-annual flow rate audit PM_{10}, $PM_{2.5}$ and $PM_{10\text{-}2.5}$	Check of sampler flow rate using independent standard	Each sampler	Once every 6 months	Audit flow rate and measured flow rate indicated by sampler
Collocated sampling $PM_{2.5}$ and $PM_{10\text{-}2.5}$	Collocated samplers	15%	Every 12 days	Primary sampler concentration and duplicate sampler concentration
PEP $PM_{2.5}$ and $PM_{10\text{-}2.5}$	Collocated samplers	1. 5 valid audits for primary QA orgs, with ≤ 5 sites 2. 8 valid audits for primary QA orgs with > 5 sites 3. All samplers in 6 years	Over all 4 quarters	Primary sampler concentration and performance evaluation sampler concentration
Manual Methods				
Collocated sampling PM_{10}, TSP, $PM_{2.5}$ and $PM_{10\text{-}2.5}$	Collocated samplers	15%	Every 12 days PSD - every 6 days.	Primary sampler concentration and duplicate sampler concentration.
Flow rate verification PM_{10}(low Vol), $PM_{2.5}$ and $PM_{10\text{-}2.5}$	Check of sampler flow rate	Each sampler	Once every month	Audit flow rate and measured flow rate indicated by sampler
Flow rate verification PM_{10}(high Vol) , TSP	Check of sampler flow rate	Each sampler	Once every quarter	Audit flow rate and measured flow rate indicated by sampler
Semi-annual flow rate audit PM_{10}, TSP, $PM_{2.5}$ and $PM_{10\text{-}2.5}$	Check of sampler flow rate using independent standard	Each sampler, all locations	Once every 6 months	Audit flow rate and measured flow rate indicated by sampler
Manual Methods Lead	1. Check of sample flow rate as to TSP 2. Check of analytical system with Pb audit strips	1. Each sampler 2. Analytical	1. Include with TSP 2. Each quarter	1. Same as for TSP 2. Actual concentration
PEP $PM_{2.5}$ and $PM_{10\text{-}2.5}$	Collocated samplers	1. 5 valid audits for primary QA orgs, with ≤ 5 sites 2. 8 valid audits for primary QA orgs with > 5 sites 3. All samplers in 6 years	Over all 4 quarters	Primary sampler concentration and performance evaluation sampler concentration

[1] Effective concentration for open path analyzers
[2] Corrected concentration, if applicable, for open path analyzers

5.3 POTENTIAL LIMITATIONS on DATA INTERPRETATION

(THIS SECTION TO BE DEVELOPED AT A LATER DATE)

5.4 RECONCILIATION with PROJECT REQUIREMENTS

The DQOs for the APCD ambient air monitoring network are defined by regulatory guidance and can be found in Appendix MQO. Reconciliation with the DQO involves reviewing both routine and QA/QC data to determine whether the DQOs have been met and that the data is adequate for its intended use. The process of evaluating collected data against the DQOs has been termed as "Data Quality Assessment" (DQA).

Guidance on the DQA process can be found in the document titled *Guidance for Data Quality Assessment* (EPA QA/G-9). DQA is built on the fundamental premise: "*Data quality, as a concept, is meaningful only when it relates to the intended use of the data.*" By using the DQA Process, one can answer the fundamental questions:

1. Can the decision (or estimate) be made with the desired confidence, given the quality of the data set?

2. How well can the sampling design be expected to perform over a wide range of possible outcomes?

DQA determines how well the validated data can support their intended use.

5.4.1 FIVE STEPS OF THE DQA PROCESS

As described in *EPA QA/G-9*, the DQA process is comprised of five steps. The steps are detailed below:

1. **Review the Data Quality Objectives (DQOs) and Sampling Design:** Review the DQO outputs to ensure that they are still applicable. If DQOs have not been developed, specify DQOs before evaluating the data (e.g., for environmental decisions, define the statistical hypothesis and specify tolerable limits on decision errors; for estimation problems, define an acceptable confidence level or probability interval width). Review the sampling design and data collection documentation for consistency with the DQOs.
2. **Conduct a Preliminary Data Review:** Review QA reports, calculate basic statistics, and generate graphs of the data. Use this information to learn about the structure of the data and identify patterns, relationships, or potential anomalies.
3. **Select the Statistical Test:** Select the most appropriate procedure for summarizing and analyzing the data, based on the review of the DQOs, the sampling design and the preliminary data review. Identify the key underlying assumptions that must hold for the statistical procedures to be valid.
4. **Verify the Assumptions of the Statistical Test:** Evaluate whether the underlying assumptions hold, or whether departures are acceptable, given the actual data and other information about the study.
5. **Draw Conclusions from the Data:** Perform the calculations required for the statistical test and document the inferences drawn as a result of these calculations. If the design is to be used again, evaluate the performance of the sampling design.

5.4.1.1 Data Quality Assessment

Even though DQOs, based upon the EPA QA/G-4 guidance, have not been developed for all criteria pollutants, a process very similar to this approach was originally used. In addition, State and local organizations collect enough types of QA/QC data to estimate the quality of the data and should be able to express the confidence in that information.

Current requirements for DQA reporting and required calculations can be found in 40 CFR Part 58 Appendix A. Additionally, the EPA provides a Data Assessment Statistics Calculator (DASC tool) which can be found on EPA's website: http://www.epa.gov/ttnamti1/qareport.html. It is not required to use this tool, it is made available for those that do not have other statistical software available to use.

More detailed information on DQA's can be found at EPA QA/G-9R and EPS QA/G-9S.

Precision and Bias Estimation for CO, NO_2, O_3 and SO_2

Following are the equations for calculating integrated precision probability intervals from 40CFR Part 58 Appendix A. At the end of each calendar quarter, an integrated precision probability interval is aggregated by site and by primary quality assurance organization for CO, NO_2, O_3 and SO_2, and by primary quality assurance organization for PM_{10} and lead.

Estimates of Precision for CO, NO_2, O_3 and SO_2

Estimates of the precision of automated methods are calculated from the results of random biweekly precision checks as specified in Section 3.1 of 40 CFR Pt. 58, Appendix A.

Single Analyzer Precision Estimate –CO, NO_2, O_3 and SO_2

For each CO, NO_2, O_3 or SO_2 analyzer where estimates of precision are required, they are to be calculated as follows: the percent difference (d_i) for each precision check for a specific analyzer is calculated using Equation 1, where Y_i is the concentration indicated by the analyzer for the i^{th} precision check and X_i is the known concentration for the i^{th} precision check, as follows:

Equation 1: (40 CFR, Part 58, App. A, eq. 1)

$$d_i = \frac{Y_i - X_i}{X_i} \times 100$$

The precision estimator is the coefficient of variation upper bound and is calculated using Equation 2:

Equation 2: (40 CFR, Part 58, App. A, eq. 2)

$$CV = \sqrt{\frac{n \times \sum_{i=1}^{n} d_i^{\,2} - \left(\sum_{i=1}^{n} d_i\right)^2}{n(n-1)}} \times \sqrt{\frac{n-1}{X^2_{0.1,\,n-1}}}$$

where $X^2_{0.1,\,n-1}$ is the 10^{th} percentile of the chi-square distribution with n-1 degrees of freedom.

Reporting Organization Precision Estimate - CO, NO_2, O_3 and SO_2

For each pollutant type where estimates of precision are required, they are to be calculated as per Section D3.2.1.1 with the following difference: the d_is are from the precision checks from all the analyzers of a pollutant type, not from just a single analyzer.

Estimates of Precision for CO, NO_2, O_3 and SO_2

The estimates of bias are calculated using the one-point QC checks for CO, NO_2, O_3 and SO_2 as described in section 3.2.1 of 40 CFR 58 Appendix A and for the PEP program for $PM_{10\text{-}2.5}$ as described in section 3.2.8 and 3.3.8 of 40 CFR 58 Appendix A. At the end of each calendar quarter, an integrated bias probability interval for all SLAMS analyzers in the reporting organization is calculated for each pollutant type and for each analyzer.

Single Analyzer Bias Estimates - CO, NO_2, O_3 and SO_2

The bias estimator is an upper bound on the mean absolute value of the percent difference as described in Equation 3.

Equation 3: (40CFR, Part 58, App. A, eq. 3)

$$|AB| = AB + t_{0.95,n-1} \times \frac{AS}{\sqrt{n}}$$

where n is the number of single point checks being aggregated, $t_{0.95,\ n-1}$ is the 95th quantile of a t-distribution with n-1 degrees of freedom, the quantity AB is the mean of the absolute values of the d_is (see Equation 1), which is calculated using Equation 4:

Equation 4: (40CFR, Part 58, App. A, eq. 4)

$$AB = \frac{1}{n} \times \sum_{i=1}^{n} |d_i|$$

and the quantity of AS is the standard deviation of the absolute value of the d_is, which is calculated using Equation 5:

Equation 5: (40CFR, Part58, App. A, eq. 5)

$$AS = \sqrt{\frac{n \times \sum_{i=1}^{n} |d_i|^2 - \left(\sum_{i=1}^{n} |d_i| \right)^2}{n(n-1)}}$$

Assigning a Sign (positive/negative) to the Bias Estimate

Since the bias estimate statistic as calculated in Equation 3 uses absolute values, it does not have a tendency (positive or negative) associated with it. A sign will be designated by rank ordering the percent differences of the QC check samples from a given site for a particular assessment interval.

Calculate the 25th and 75th percentile of the percent differences for each site. The absolute bias upper bound should be flagged as positive if both percentiles are positive, and should be flagged negative if both percentiles are negative. The absolute bias upper bound would not be flagged if the 25th and 75th percentiles are of different signs.

Validation of Bias

The bias estimate can be validated using the QA audit results. These results are used to verify the results obtained from the one-point QC checks and to validate those results across a range of concentration levels. To quantify this annually at the site/analyzer level and at the 3-year primary reporting organization level, probability limits are calculated from the one-point QC checks using Equations 6 and 7:

Equation 6: (40CFR, Part 58, App. A, eq. 6)

$$\textbf{\textit{Upper Probability Limit}} = m + 1.96 \times S$$

Equation 7: (40CFR, Part 58, App. A, eq. 7)

$$\textbf{\textit{Lower Probability Limit}} = m - 1.96 \times S$$

where m is the mean:

Equation 8: (40CFR, Part 58, App. A, eq. 8)

$$m = \frac{1}{k} \times \sum_{i=1}^{k} d_i$$

where k is the total number of one-point QC checks for the interval being evaluated and S is the standard deviation of the percent differences as follows:

Equation 9: (40CFR, Part 58, App. A, eq. 9)

$$S = \sqrt{\frac{k \times \sum_{i=1}^{k} d_i^2 - \left(\sum_{i=1}^{k} d_i \right)^2}{k(k-1)}}$$

QA Audit Percent Differences

Percent differences for the QA audits are calculated using Equation 1 and can be compared to the probability intervals for the respective analyzer at the reporting organization level. Ninety-five percent of the individual percent differences (all concentration levels) for the QA audits should be captured within the probability intervals for the analyzer and/or reporting organization.

Reporting Organization Bias Estimate - CO, NO_2, O_3 and SO_2

For each pollutant type where estimates of precision are required, they are to be calculated as above with the following difference: the d_is from the precision checks from all the analyzers of a pollutant type are used, not just the d_is from a single analyzer.

Precision and Bias Estimation for PM_{10} and TSP

Estimates of precision of manual methods are calculated from the results obtained from collocated samplers as described in section 3.3.1 of 40 CFR 58 Appendix A. At the end of each calendar quarter, a precision estimate for all collocated samplers operating in the reporting organization is calculated and bias estimates from one-point flow rate verifications obtained in the reporting organization are calculated.

Precision Estimation for Reporting Organization – PM_{10} and TSP

Precision is estimated via duplicate measurements from a collocated sampler of the same type. It is recommended that the precision be aggregated at the primary reporting organization level quarterly, annually, and at the 3-year level. At low concentrations, agreement between the measurements of collocated samplers, expressed as percent differences, may be relatively poor. For this reason, collocated measurement pairs are selected for use in the precision calculations only when both measurements are above a specified level. These levels can be obtained from the MQO tables located in Appendix MQO of this QAPP. For each selected measurement pair, the percent difference (di) is calculated, using Equation 10, as follows:

Equation 10: (40CFR, Part 58, App. A, eq. 10)

$$d_i = \frac{Y_i - X_i}{(Y_i + X_i)/2} \times 100$$

where Y_i is the pollutant concentration measurement obtained from the duplicate sampler and X_i is the concentration measurement obtained from the primary sampler designated for reporting air quality for the site.

The coefficient of variation upper bound is calculated using Equation 11:

Equation 11: (40CFR, Part 58, App. A, eq. 11)

$$CV = \sqrt{\frac{n \times \sum_{i=1}^{n} d_i^{\,2} - \left(\sum_{i=1}^{n} d_i\right)^2}{2n(n-1)}} \times \sqrt{\frac{n-1}{X^2_{0.1,\,n-1}}}$$

where n is the number of valid data pairs being aggregated and $X^2_{0.1,\,n-1}$ is the 10th percentile of the chi-square distribution with n-1 degrees of freedom. The factor of two in the denominator accounts for the fact that each d_i is calculated from two values, each with associated error.

Bias Estimation for Reporting Organization – PM_{10} and TSP.

Bias is estimated using the one-point flow rate verifications. The bias estimator is an upper bound on the mean absolute value of the percent difference as described in Equation 12.

Equation 12: (40CFR, Part 58, App. A, eq. 3)

$$|AB| = AB + t_{0.95,n-1} \times \frac{AS}{\sqrt{n}}$$

where n is the number of point checks being aggregated, $t_{0.95,\,n-1}$ is the 95th quantile of a t-distribution with n-1 degrees of freedom, the quantity AB is the mean of the absolute values of the d_is (see Equation 1), which is calculated using Equation 13:

Equation 13: (40CFR, Part 58, App. A, eq. 4)

$$AB = \frac{1}{n} \times \sum_{i=1}^{n} |d_i|$$

and the quantity of AS is the standard deviation of the absolute value of the d_is and is calculated using Equation 14:

Equation 14: (40CFR, Part 58, App. A, eq. 5)

$$AS = \sqrt{\frac{n \times \sum_{i=1}^{n} |d_i|^2 - \left(\sum_{i=1}^{n} |d_i|\right)^2}{n(n-1)}}$$

Assigning a Sign (positive/negative) to the Bias Estimate

Since the bias estimate statistic as calculated in Equation 3 uses absolute values, it does not have a tendency (positive or negative) associated with it. A sign will be designated by rank ordering the percent differences of the QC check samples from a given site for a particular assessment interval.

Calculate the 25th and 75th percentile of the percent differences for each site. The absolute bias upper bound should be flagged as positive if both percentiles are positive, and should be flagged negative if both percentiles

are negative. The absolute bias upper bound would not be flagged if the 25th and 75th percentiles are of different signs.

Validation of Bias
The bias estimate can be validated using the QA audit results. These results are used to verify the results obtained from the one-point QC flow rate checks. To quantify this annually and at the 3-year primary reporting organization level, probability limits are calculated from the one-point QC flow rate checks using Equations 15 and 16:

Equation 15: (40CFR, Part 58, App. A, eq. 6)

$$\textbf{\textit{Upper Probability Limit}} = m + 1.96 \times S$$

Equation 16: (40CFR, Part 58, App. A, eq. 7)

$$\textbf{\textit{Lower Probability Limit}} = m - 1.96 \times S$$

where m is the mean:

Equation 17: (40CFR, Part 58, App. A, eq. 8)

$$m = \frac{1}{k} \times \sum_{i=1}^{k} d_i$$

where k is the total number of one-point QC flow rate checks for the interval being evaluated and S is the standard deviation of the percent differences as follows:

Equation 18: (40CFR, Part 58, App. A, eq. 9)

$$S = \sqrt{\frac{k \times \sum_{i=1}^{k} d_i^2 - \left(\sum_{i=1}^{k} d_i \right)^2}{k(k-1)}}$$

QA Audit Percent Differences
Percent differences for the QA audits, calculated using Equation 1, can be compared to the probability intervals for the respective analyzer at the reporting organization level. Ninety-five percent of the individual percent differences (all concentration levels) for the QA audits should be captured within the probability intervals for the analyzer and/or reporting organization.

***NOTE**: The APCD does not collect QC one-point flow verifications. Instead an increased number of QA audits are performed. In the determination of bias, these QA one-point flow rate audits are used. The validation of bias is therefore not performed because the QA audits are used in the determination of bias.*

Precision and Bias Estimation for $PM_{2.5}$ and $PM_{10-2.5}$

Estimates of precision of manual methods are calculated from the results obtained from collocated samplers as described in section 3.3.1 of 40 CFR 58 Appendix A. At the end of each calendar quarter, precision and bias estimates are calculated. These estimates can be aggregated by sampler or by reporting organization. The statistics used in these aggregates are the same, only the data used in computing them are different.

Precision Estimation for $PM_{2.5}$ and $PM_{10\text{-}2.5}$

Precision for collocated instruments for $PM_{2.5}$ and $PM_{10\text{-}2.5}$ may be estimated where both the primary and collocated instruments are the same method designation and when the method designations are not similar. Precision is estimated via duplicate measurements from collocated samplers of the same type. It is recommended that the precision, at a minimum be aggregated at the primary reporting organization level quarterly, annually, and at the 3-year level. At low concentrations, agreement between the measurements of collocated samplers, expressed as percent differences, may be relatively poor. For this reason, collocated measurement pairs are selected for use in the precision calculations only when both measurements are above a specified level. These levels can be obtained from the MQO tables located in Part A of this QAPP. For each selected measurement pair, the percent difference (di) is calculated, using Equation 19, as follows:

Equation 19: (40CFR, Part 58, App. A, eq. 10)

$$d_i = \frac{Y_i - X_i}{(Y_i + X_i)/2} \times 100$$

where Y_i is the pollutant concentration measurement obtained from the duplicate sampler and X_i is the concentration measurement obtained from the primary sampler designated for reporting air quality for the site.

The coefficient of variation upper bound is calculated using Equation 20:

Equation 20: (40CFR, Part 58, App. A, eq. 10)

$$CV = \sqrt{\frac{n \times \sum_{i=1}^{n} d_i^{\,2} - \left(\sum_{i=1}^{n} d_i\right)^2}{2n(n-1)}} \times \sqrt{\frac{n-1}{X^2_{0.1,\,n-1}}}$$

where n is the number of valid data pairs being aggregated and $X^2_{0.1,\,n-1}$ is the 10^{th} percentile of the chi-square distribution with n-1 degrees of freedom. The factor of two in the denominator adjusts for the fact that each d_i is calculated from two values, each with associated error.

Bias Estimation for $PM_{2.5}$ and $PM_{10\text{-}2.5}$

The determination of bias for $PM_{2.5}$ and $PM_{10\text{-}2.5}$ is different. The estimation of bias for $PM_{10\text{-}2.5}$ is the same as that used for the continuous monitors and PM_{10}. The estimation of bias for $PM_{2.5}$ is performed by comparison against the PEP sampler.

Bias Estimation for $PM_{10\text{-}2.5}$

Bias is estimated using the one-point flow rate verifications. The bias estimator is an upper bound on the mean absolute value of the percent difference, as described in Equation 21.

Equation 21: (40CFR, Part 58, App. A, eq. 3)

$$|AB| = AB + t_{0.95,n-1} \times \frac{AS}{\sqrt{n}}$$

where n is the number of point checks being aggregated, $t_{0.95,\,n-1}$ is the 95^{th} quantile of a t-distribution with n-1 degrees of freedom, the quantity AB is the mean of the absolute values of the d_is (see Equation 1), which is calculated using Equation 22:

Equation 22: (40CFR, Part 58, App. A, eq. 4)

$$AB = \frac{1}{n} \times \sum_{i=1}^{n} |d_i|$$

and the quantity of AS is the standard deviation of the absolute value of the d_is, which is calculated using Equation 23:

Equation 23: (40CFR, Part 58, App. A, eq. 5)

$$AS = \sqrt{\frac{n \times \sum_{i=1}^{n} |d_i|^2 - \left(\sum_{i=1}^{n} |d_i| \right)^2}{n(n-1)}}$$

Assigning a Sign (positive/negative) to the Bias Estimate

Since the bias estimate statistic as calculated in equation 3 uses absolute values, it does not have a tendency (positive or negative) associated with it. A sign will be designated by rank ordering the percent differences of the QC check samples from a given site for a particular assessment interval.

Calculate the 25th and 75th percentile of the percent differences for each site. The absolute bias upper bound should be flagged as positive if both percentiles are positive, and should be flagged as negative if both percentiles are negative. The absolute bias upper bound would not be flagged if the 25th and 75th percentiles are of different signs.

Validation of Bias

The bias estimate can be validated using the QA audit results. These results are used to verify the results obtained from the one-point QC flow rate checks. To quantify this annually and at the 3-year primary reporting organization level, probability limits are calculated from the one-point QC flow rate checks using Equations 24 and 25:

Equation 24: (40CFR, Part 58, App. A, eq. 6)

$$\textbf{\textit{Upper Probability Limit}} = m + 1.96 \times S$$

Equation 25: (40CFR, Part 58, App. A, eq. 7)

$$\textbf{\textit{Lower Probability Limit}} = m - 1.96 \times S$$

where m is the mean:

Equation 26: (40CFR, Part 58, App. A, eq. 8)

$$m = \frac{1}{k} \times \sum_{i=1}^{k} d_i$$

where k is the total number of one-point QC flow rate checks for the interval being evaluated and S is the standard deviation of the percent differences as follows:

Equation 27: (40CFR, Part 58, App. A, eq. 9)

$$S = \sqrt{\frac{k \times \sum_{i=1}^{k} d_i^2 - \left(\sum_{i=1}^{k} d_i \right)^2}{k(k-1)}}$$

QA Audit Percent Differences

Percent differences for the QA audits calculated using Equation 1 can be compared to the probability intervals for the respective analyzer at the reporting organization level. Ninety-five percent of the individual percent differences (all concentration levels) for the QA audits should be captured within the probability intervals for the analyzer and/or reporting organization.

Bias Estimation for $PM_{2.5}$

The $PM_{2.5}$ bias estimate is calculated using the paired routine and the PEP monitor data described in Section 3.2.6 of 40 CFR 58 Appendix A. Calculate the percent (d_i) using Equation 28:

Equation 28: (40CFR, Part 58, App. A, eq. 1)

$$d_i = \frac{Y_i - X_i}{X_i} \times 100$$

where Y_i is the measured concentration from the APCD primary monitor and X_i is the concentration from the PEP monitor.

The paired data would only be considered valid if both concentrations are greater than the minimum values specified in the MQO tables given in Section A of this QAPP. Estimates of bias are presented for various levels of aggregation, sometimes aggregating over time, sometimes aggregating over samplers, and sometimes aggregating over both time and samplers. These various levels of aggregation are achieved using the same basic statistic.

This statistic averages the individual biases described in Equation 27 to the desired level of aggregation using Equation 29:

Equation 29: (40CFR, Part 58, App. A, eq. 12)

$$D = \frac{1}{n_j} \times \sum_{i=1}^{n_j} d_i$$

where n_j is the number of pairs and d_i, d_2 and d_{nj} are the biases for each of the pairs to be averaged.

Confidence intervals can be constructed for these average bias estimates in Equation 30 using Equations 31 and 32:

Equation 30: (40CFR, Part 58, App. A, eq. 13)

$$Upper\ 90\%\ Confidence\ \ Interval = D + t_{0.95,df} \times \frac{s}{\sqrt{n_j}}$$

Equation 31: (40CFR, Part 58, App. A, eq. 14)

$$Lower\ 90\%\ Confidence\ \ Interval = D - t_{0.95,df} \times \frac{s}{\sqrt{n_j}}$$

where $t_{0.95,df}$ is the 95th quantile of a t-distribution with degrees of freedom df = n_j-1, and s is an estimate of the variability of the average bias calculated using Equation 31:

Equation 32: (40CFR, Part 58, App. A, eq. 15)

$$s = \sqrt{\frac{\sum_{i=1}^{n_j}(d_i - D)^2}{n_j - 1}}$$

Precision and Bias Estimation for Lead

Precision Estimation for Lead

Precision for collocated instruments for lead may be estimated where both the primary and collocated instruments are the same method designation. Precision is estimated via duplicate measurements from collocated samplers of the same type. At low concentrations, agreement between the measurements of collocated samplers, expressed as percent differences, may be relatively poor. For this reason, collocated measurement pairs are selected for use in the precision calculations only when both measurements are above a specified level. These levels can be obtained from the MQO tables located in Part A of this QAPP. For each selected measurement pair, the percent difference (d_i) is calculated, using Equation 33, as follows:

Equation 33: (40CFR, Part 58, App. A, eq. 10)

$$d_i = \frac{Y_i - X_i}{(Y_i + X_i)/2} \times 100$$

where Y_i is the pollutant concentration measurement obtained from the duplicate sampler and X_i is the concentration measurement obtained from the primary sampler designated for reporting air quality for the site.

The coefficient of variation upper bound is calculated using Equation 34:

Equation 34: (40CFR, Part 58, App. A, eq. 10)

$$CV = \sqrt{\frac{n \times \sum_{i=1}^{n} d_i^{\,2} - \left(\sum_{i=1}^{n} d_i\right)^2}{2n(n-1)}} \times \sqrt{\frac{n-1}{X^2_{0.1,\,n-1}}}$$

where n is the number of valid data pairs being aggregated and $X^2_{0.1,\,n-1}$ is the 10th percentile of the chi-square distribution with n-1 degrees of freedom. The factor of two in the denominator adjusts for the fact that each d_i is calculated from two values, each with associated error.

Bias Estimation for Lead

In order to estimate bias, the information from the flow rate audits and the Pb strip audits need to be combined as described below. To be consistent with the formulas for the gases, the recommended procedures are to

work with relative errors of the lead measurements. The relative error in the concentration is related to the relative error in the volume and the relative error in the mass measurements using Equation 35:

Equation 35: (40CFR, Part 58 App. A, eq. 16, Federal Register Jan 17, 2006, proposed rules - http://www.gpo.gov/fdsys/pkg/FR-2006-01-17/pdf/06-179.pdf

$$rel.\,error = \frac{(measured\ conc. - audit\ conc.)}{audit\ conc.}$$

$$= \left(\frac{1}{1 + rel.\,error}\right)(rel.\,mass\ error - rel.\,volume\ error)$$

As with the gases, an upper bound for the absolute bias is desired. Using Equation 36, the absolute value of the relative (concentration) error is bounded by Equation 36:

Equation 36: (40CFR, Part 58 App. A, eq. 17, Federal Register Jan 17, 2006, proposed rules - http://www.gpo.gov/fdsys/pkg/FR-2006-01-17/pdf/06-179.pdf)

$$|rel.\,error| \le \frac{|rel.\,mass\ error| + |rel.\,volume\ error|}{1 - |rel.\,volume\ error|}$$

The quality indicator data collected are then used to place bounds on each part of Equation 35 separately.

Flow Rate Calculations

Bias is estimated using the one-point flow rate verifications. The bias estimator is an upper bound on the mean absolute value of the percent difference as described in Equation 37.

Equation 37: (40CFR, Part 58, App. A, eq. 3)

$$|AB| = AB + t_{0.95,n-1} \times \frac{AS}{\sqrt{n}}$$

where n is the number of single point checks being aggregated, $t_{0.95,\ n-1}$ is the 95th quantile of a t-distribution with n-1 degrees of freedom, the quantity AB is the mean of the absolute values of the d_is (see Equation 1), which is calculated using Equation 38:

Equation 38: (40CFR, Part 58, App. A, eq. 4)

$$AB = \frac{1}{n} \times \sum_{i=1}^{n} |d_i|$$

and the quantity of AS is the standard deviation of the absolute value of the d_is, which is calculated using Equation 39:

Equation 39: (40CFR, Part 58, App. A, eq. 5)

$$AS = \sqrt{\frac{n \times \sum_{i=1}^{n} |d_i|^2 - \left(\sum_{i=1}^{n} |d_i|\right)^2}{n(n-1)}}$$

Since the bias estimate statistic as calculated in Equation 3 uses absolute values, it does not have a tendency (positive or negative) associated with it. A sign will be designated by rank ordering the percent differences of the QC check samples from a given site for a particular assessment interval.

Calculate the 25th and 75th percentile of the percent differences for each site. The absolute bias upper bound should be flagged as positive if both percentiles are positive, and should be flagged as negative if both percentiles are negative. The absolute bias upper bound would not be flagged if the 25th and 75th percentiles are of different signs.

Lead Strip Calculations

Similarly, bias is estimated using the differences in mass from lead strip audits. The bias estimator is an upper bound on the mean absolute value of the percent difference as described in Equation 40.

Equation 40: (40CFR, Part 58, App. A, eq. 3)

$$|AB| = AB + t_{0.95,n-1} \times \frac{AS}{\sqrt{n}}$$

where n is the number of single point checks being aggregated, $t_{0.95,\ n-1}$ is the 95th quantile of a t-distribution with n-1 degrees of freedom, the quantity AB is the mean of the absolute values of the d_is (see Equation 1), which is calculated using Equation 41:

Equation 41: (40CFR, Part 58, App. A, eq. 4)

$$AB = \frac{1}{n} \times \sum_{i=1}^{n} |d_i|$$

and the quantity of AS is the standard deviation of the absolute value of the d_is, which is calculated using Equation 42:

Equation 42: (40CFR, Part 58, App. A, eq. 5)

$$AS = \sqrt{\frac{n \times \sum_{i=1}^{n} |d_i|^2 - \left(\sum_{i=1}^{n} |d_i| \right)^2}{n(n-1)}}$$

Since the bias estimate statistic as calculated in Equation 3 uses absolute values, it does not have a tendency (positive or negative) associated with it. A sign will be designated by rank ordering the percent differences of the QC check samples from a given site for a particular assessment interval.

Calculate the 25th and 75th percentile of the percent differences for each site. The absolute bias upper bound should be flagged as positive if both percentiles are positive, and should be flagged as negative if both percentiles are negative. The absolute bias upper bound would not be flagged if the 25th and 75th percentiles are of different signs.

Final Bias Calculations

Finally, the absolute bias upper bound is given by combining the absolute bias estimates of the flow rate and lead strips using Equation 43.

Equation 43: (40CFR, Part 58 App. A, eq. 18, Federal Register Jan 17, 2006, proposed rules - http://www.gpo.gov/fdsys/pkg/FR-2006-01-17/pdf/06-179.pdf)

$$|bias| = \frac{|mass\ bias| + |vol.\ bias|}{100 - |vol.\ bias|} \times 100$$

where the numerator and denominator have been multiplied by 100 since everything is expressed as a percentage.

5.4.1.2 Action Plan Based on Conclusions from DQA

A thorough DQA process will be completed during the spring of each year for the previous year's data.

For this section, APCD will assume that the assumptions used for developing the DQOs have been met. If this is not the case, APCD must first revisit the impact of this violation on the bias and precision limits determined by the DQO process.

5.4.1.2.a Total Network Compliance (last two sections still need review)

If the DQA indicates every monitor for a single pollutant type in the APCD network is collecting data that are within the precision and bias goals determined by that pollutant type's DQOs, it will be considered in compliance and all data will be considered valid.

If it is concluded from the DQA process that all monitors are operating within the bias and precision criteria, then APCD will pursue action to reduce the QA/QC burden. The basic idea is that once APCD has demonstrated that it can operate within the precision and bias limits, it is reasonable to dedicate some of the QA/QC resources to other duties/tasks, such as modifying its QA monitoring or reducing some of its QC monitoring frequency, as long as all federal minimum criteria are met. Possible courses of action include the following:

- Modifying the QA Monitoring Network. 40 CFR Part 58 requires that each QA monitor be the same designation as the primary monitor, in the case that the primary monitor is an FRM. Since the initially deployed samplers will all be FRMs, this means that the sites operating sequential samplers will have to collocate a sequential sampler. Once it is demonstrated that the data collected from the network are within tolerable levels of errors, APCD may request that it be allowed to collocate with a single-day sampler instead.

- Reducing QC Requirements. QC is integral to any ambient air monitoring network and is particularly important to new networks. However, once it is demonstrated that the data collected from the network are within tolerable levels of errors, APCD may request a reduction in the number of QC checks. However, during any of the annual DQA processes, if it is determined that the errors in the data are approaching or exceeding either the bias limits or the precision limits, then APCD will continue to adhere to current QA/QC protocol as prescribed in Section A7.

5.4.1.2.b Partial Network Compliance

If the DQA indicates at least one monitor for a single pollutant type in the APCD is collecting data that are not within the precision and bias goals determined by the DQOs, it will be considered out of compliance and data back to the last QC or QA check is subject to be invalidated.

If and when the data from at least one of the collocated sites or manual precision check violates the DQO bias and/or precision limits, then APCD will conduct an investigation to uncover the cause of the violation. If all collocated sites or manual precision checks performed by APCD violate the DQOs (across monitor designations), then the cause will be investigated at the APCD level (operator training) or higher (laboratory QC, problems with method designation). If only one site violates the DQOs, the cause is more likely specific to that site (particular operator, problem with site). The tools for getting to the root of the problem include:

data from the collocated network (APCD, nearby reporting organizations, national), data from other monitors in the region, data from performance evaluations (APCD, nearby reporting organizations, national) and QC checks. Some particular courses of action include the following:

- Determine the level of aggregation at which the DQOs are violated. The DQA process can identify which monitors are having problems since the DQOs were developed at a monitor level. To determine the level at which corrective action is to be taken, it must be determined whether the violation of the DQOs is due to problems unique to one or two sites, unique to APCD, or caused by a broader problem, like a particular sampler demonstrating poor QA on a national level. APCD understands that AQS will generate QA reports summarizing bias and precision statistics at the national and reporting organization levels, and by method designation. These reports will assist APCD in determining the appropriate level at which the DQOs are being violated. The procedure for determining the level of violation is:

    - Review national reports for the method designations for which APCD's DQA process indicated a violation. If large bias or imprecision is seen at the national level, APCD will request assistance from the Regional Office and OAQPS. If no problem is seen at the national level, APCD will proceed looking at the QA reports specific to its neighboring reporting organizations.

    - Review neighboring reporting organizations' precision and bias reports for the method designations for which APCD's DQA process indicated a violation. If large bias or imprecision is seen in the neighboring organizations, APCD will request assistance from the Regional Office. If no problem is seen in the neighboring reporting organizations, APCD will proceed by looking at the QA reports specific to APCD.

    - Within APCD, if the violations occur across method designations, then laboratory QC and training will be reviewed.

    - Within APCD, if the violations occur for only one method designation, the FRM performance evaluation data will be reviewed for confirmation with the collocated data. The FRM performance evaluation data may show that one of the monitors has a problem and must be repaired or replaced. APCD will also use the national FRM performance evaluation summaries to see if APCD is unique or like the national network. If APCD is similar to the national picture, then assistance will be requested from the Regional Office and OAQPS. The results from the neighboring reporting organizations will also be reviewed. If the violations seem unique to APCD, APCD will continue investigating all the pieces that comprise the data.

- Communication with Regional Office. If a violation of the bias and precision DQOs is found, APCD will remain in close contact with the Region VIII Office both for assistance and for communication.

- Extensive Review of Quarterly Data until DQOs Achieved. APCD will continue to review extensively the quarterly QA reports and the QC summaries until the bias and precision limits are attained.

5.5 REPORTS TO MANAGEMENT

This section describes the quality-related reports and communications to management necessary to support SLAMS/NCore network operations and the associated data acquisition, validation, assessment, and reporting.

Important benefits of regular QA reports to management include the opportunity to alert the management of data quality problems, to propose viable solutions to problems, and to procure necessary additional resources. Quality assessment, including the evaluation of the technical systems, the measurement of performance, and the assessment of data, is conducted to help insure that measurement results meet program objectives and to insure that necessary corrective actions are taken early, when they will be most effective.

Effective communication among all personnel is an integral part of a quality system. Regular, planned quality reporting provides a means for tracking the following:

- adherence to scheduled delivery of data and reports
- documentation of deviations from approved QA and test plans, and the impact of these deviations on data quality
- analysis of the potential uncertainties in decisions based on the data

In addition to the External and Internal Assessments described in sections 4.1 and 4.2, the reports listed in Table 5-2 will be delivered to management. If the report was discussed in section 4, it will not be discussed again here in section 5.

Required reports to management for the air monitoring program in general are discussed in various sections of 40 CFR Parts 50, 53, and 58. Guidance for the management report format and content are provided in guidance developed by EPA's Quality Assurance Division (QAD) and the Office of Air Quality Planning and Standards (OAQPS). A brief summary of reports, the frequency at which they should occur, the personnel responsible for producing each report, to whom the report should be delivered (in addition to the QA Officer), and within what time frame it should be completed, can be found in Table 5.2.

Table 5.2 Reports to Management

Type	Prepared By	Prepared For	Frequency	Due
TSA	EPA Region VIII	EPA/APCD Management/Public	Every 3 Years	30 Days After Activity
NATTS Audit	EPA OAQPS	EPA/APCD Management/Public	Every 3 Years	30 Days After Activity
Quality Audit	EPA region VIII	EPA/APCD Management/Public	Every 3 Years	30 Days After Activity
Data Quality Assessment	QA Unit	EPA/APCD Management/Public	Annually, published within Data Quality Report	Within 4 Months After End of Calendar Year
Annual Data Report	QA Unit	EPA/APCD Management/Public	Annually	Within 6 Months After End of Calendar Year
Data Certification	QA Officer	EPA	Annually	Due May 1st of following year
Annual Network Monitoring Plan	QA Unit	EPA/APCD Management/Public	Annually	June 30, of current year
5-Year Network Assessment	QA Unit	EPA/APCD Management/Public	Every 5 years	Within 6 Months after calendar years 2014, 2019, every 5 years
Internal Performance Evaluation Summary	QA Unit	QA Officer	Quarterly	1 Month After End of Quarter
National Performance Audit Program Results (NPEP, TTP)	EPA	QA Officer and GMM or PM Supervisor	As Received	Within 30 Days of Receipt
Corrective Actions	QA, GMM, or PM staff	QA Officer and GMM or PM Supervisor	As Needed	Within 48 Hours of Problem Identification
Exceptional Event Reports	All TSP	EPA/APCD Management/Public	As Needed	With EPA concurrence

5.5.1 RESPONSIBLE ORGANIZATIONS

This section outlines the responsibilities of individuals within the monitoring organization for preparing quality reports, evaluating their impact, and implementing follow-up actions. Changes made in one area or procedure may affect another part of the project. Only by defining clear-cut lines of communication and responsibility can all the affected elements of the monitoring network remain current with such changes. The documentation for all changes will be maintained and included in the reports to management. The following paragraphs describe key personnel involved with QA reporting.

Executive Director of the Colorado Department of Public Health and Environment - The ultimate responsibility for the quality of the data and the technical operation of the ambient air monitoring network rests with the Executive Director of CDPHE. The Director's responsibilities with respect to air quality reporting are delegated to the Air Pollution Control Division Director.

Director of the Air Pollution Control Division - The responsibility for the quality of the data and the technical operation of the ambient air-monitoring network rests with the Director of the APCD. The Director's responsibilities with respect to air quality reporting are delegated to the manager of the Technical Services Program. These responsibilities include defining and implementing the document management and quality assurance systems for the ambient air-monitoring network.

Technical Services Program Manager - The TSP Manager is responsible for operation of the air quality network and for assuring the timely submittal of quarterly and annual data summary reports. The TSP Manager serves as the Quality Assurance Officer and works closely with the staff quality assurance analysts in implementation of QA procedures, arranging for audits and reporting QA data.

QA Supervisor - The QA Unit is responsible for establishing QA policies and systems employed by the APCD. The QA Unit is responsible for management and administrative aspects of the APCD QA program, including coordinating audits and preparing required reports, such as network plans, network assessments, data quality assessments, data reports and data certification. The QA Unit is responsible for day-to-day conduct of QA activities for the Ambient Air Monitoring Program. The responsibilities for QA reports to management include the following:

- 5-Year Network Assessment
- Annual Data Quality Assessment
- Annual Data Report
- Annual Network Review
- Annual Data Certification
- APCD TSP QMP, review and update every 3 years
- APCD TSP QAPP, review and update every 5 years
- SOPs, review and update every 5 years or as needed
- External Laboratory TSA reports
- Quarterly audit reports
- Training documentation

Gaseous & Meteorological Monitoring Supervisor – The GMM Supervisor Manager is responsible for coordinating the information management activities for gaseous SLAMS/NCore data and meteorological data. Specific responsibilities related to management reports include:

- Quarterly data reports including quality control summaries
- Exceptional event reports for gaseous exceedences
- Network modification reports for new, discontinued, and changes to existing sites with gaseous parameters
- Gaseous SOPs

- Contracts and Budgets
- Training documentation

Particulate Monitoring Supervisor - The Particulate Monitoring Supervisor is responsible for oversight and implementation of all compliance particulate monitoring within the APCD. Specific responsibilities related to management reports include, but are not limited to:

- Quarterly data reports including quality control summaries
- Exceptional event reports for particulate exceedences
- Network modification reports for new, discontinued, and changes to existing sites with particulate parameters
- Particulate SOPs
- Contracts and Budgets
- Training documentation

Field and Laboratory Staff - Individual technicians and analysts are not normally responsible for authoring reports to management. However, they participate in the process by generating control charts, identifying the need for new Response/Corrective Action Reports, and maintaining other quality-related information used to prepare QA reports.

5.5.2 CORRECTIVE ACTIONS

The corrective action reporting procedures will be followed whenever a problem is found such as a safety defect, an operational problem, or a failure to comply with procedures. A separate form will be used for each problem identified. The Corrective Action/Maintenance Report is one of the most important ongoing reports to management because it documents primary QA activities that can be used in preparing other summary reports. As part of the annual data quality assessment and development of the Annual Quality Assurance Report, all ambient air quality data are evaluated against the data quality objectives presented in Section A7-1. Corrective actions are implemented for those instances where the data quality objectives are not met. Detailed information regarding corrective actions can be viewed in Section B2.3 and in the operational field SOPs for each pollutant type.

Any member of the GMM Unit, Particulate Monitoring, or QA Unit staff may identify and report any quality assurance problem. In any of these cases, the person who identifies the performance problem is responsible for reporting the problem to the appropriate APCD supervisor. Performance problems with automated samplers are reported to the supervisor of the GMM Unit. Performance problems with manual samplers are reported to the Particulate Monitoring Supervisor. The supervisor is responsible for initiating the corrective action process and report.

The Corrective Action/Maintenance Report procedure is designed as a closed-loop system. The Corrective Action/Maintenance Report form identifies the originator, the problem, who reported or identified the problem, and may suggest a solution. The form also indicates the name of the persons or persons who is assigned to correct the problem. The assignment of personnel to address the problem and the schedule for completion will be filled in by the Unit Supervisor. The Corrective Action/Maintenance Report procedure closes the loop by requiring that the recipient state on the form how the problem was resolved and the effectiveness of the solution. Copies of the Corrective Action/Maintenance Report will be distributed twice: first when the problem has been identified and the action has been scheduled; and second when the correction has been completed. The originator, the field or laboratory branch manager, and the QA Unit will be included in both distributions.

The Quality Assurance Unit utilizes the Audit Notification Database to notify unit leaders of failed audits. This database is located on the internal network at J://QA Audit Programs/Audit Notification DB/Audit Notification.mdb. Utilizing the data input form (Figure 5.2), the QA analyst will fill in all notification fields

and store the record to a database table. Upon saving the record, the database will generate an automatic email, directed to the unit supervisor, informing that a new record has been added to the database. The unit supervisor can open the database and, utilizing a dropdown box, select the record and view its contents. Upon notification of a problem, the unit supervisor will fill out a Corrective Action or Maintenance Form (Figure 5.1) and submit it to a qualified staff member to be implemented. The person performing the corrective actions fills out what corrective actions were performed on the Corrective Action/Maintenance Form and returns it to the supervisor once the problem has been corrected. The supervisor will then update the Audit Notification Database, entering in what corrective actions were performed, and mark the record as completed ("closed"). On a quarterly schedule the QA Unit will periodically check the database for "open-ended" audits and inquire about their status. It is the responsibility of the quality assurance analyst to inform the unit leaders of failed audits via the Audit Notification Database, and it's the unit leaders' responsibility to see that all corrective actions are performed and the data record in the Audit Notification Database is properly completed and "closed-out."

Figure 5.1 Corrective Action / Maintenance Form

MAINTENANCE REPORT

DATE_____
STATION_____
ASSIGNED TO_____
ORIGINATED BY_____
ANALYZER or EQUIPMENT_____ S/N_____

MALFUNCTION DESCRIPTION OR COMPLAINT

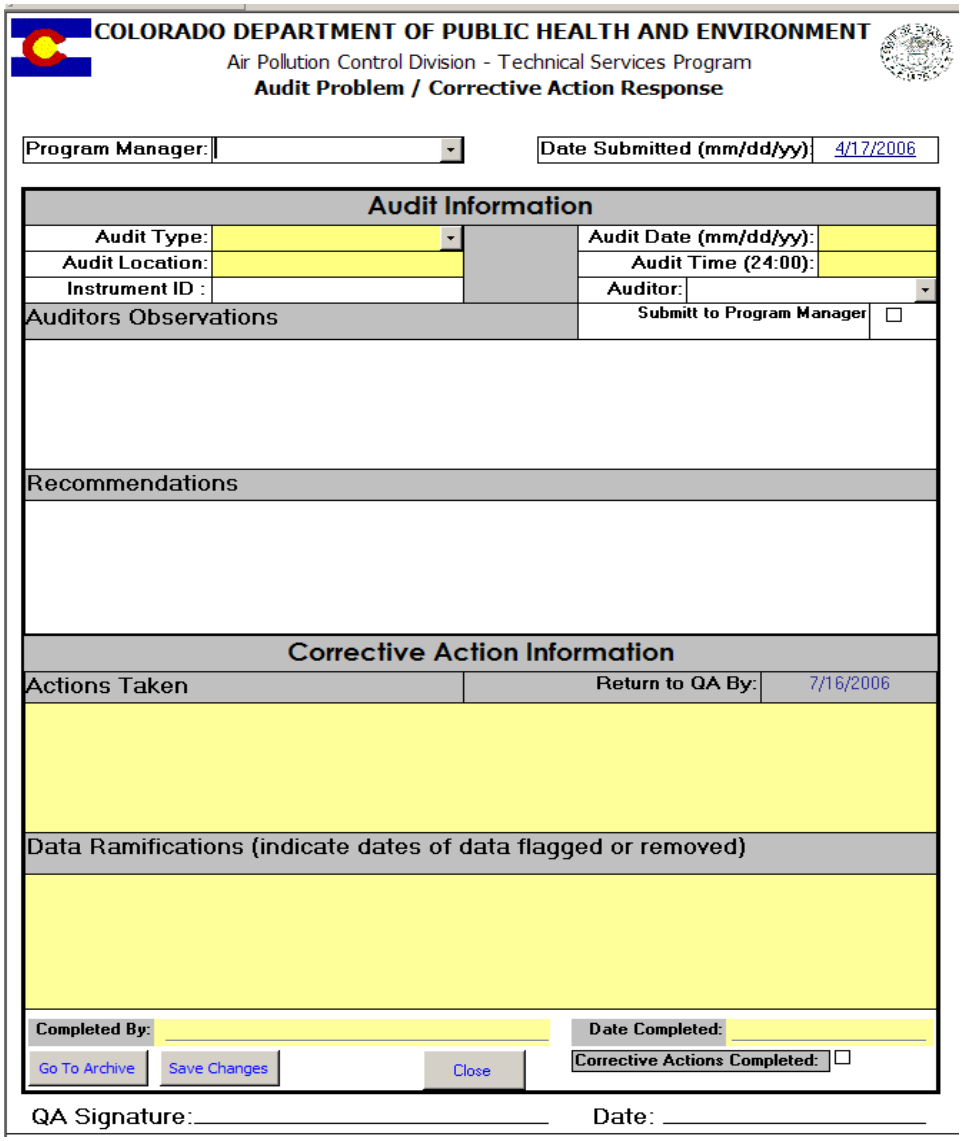
ACTION TAKEN

DATA TO BE DELETED (IF ANY)
ENTER EXACT DATES AND DATA HOURS

COMPLETED BY_____
COMPLETION DATE_____

20 Dec 2000 j:\zsfiles\forms\form.xls : mrf

Figure 5.2 Audit Notification Database Form



5.5.3 ANNUAL NETWORK MONITORING PLANS

APCD will perform an annual review of the State Monitoring Network. Conformance with network requirements of the Ambient Air Monitoring Network set forth in 40 CFR Part 58 Appendices D and E are determined through annual network reviews of the ambient air quality monitoring system. The network review is used to determine how well a particular air monitoring network is achieving its required air monitoring objective and how it should be modified to continue to meet its objective. Since the EPA Regions are also required to perform these reviews, the Department will coordinate its activity with the Region in order to perform the activity at the same time (if possible). The Technical Services Program will be responsible for conducting the network review. EPA Region VIII will review and comment on, if necessary, the annual

Colorado Annual Network Monitoring Plan report, which can be found at http://www.colorado.gov/airquality/tech_doc_repository.aspx.

The following criteria will be considered during the review:

- date of last review
- summary of all current analyzers in operation and at which sites they are located
- areas where attainment/nonattainment re-designations are taking place or are likely to take place
- proposed network modifications since the last network review

In addition, pollutant-specific priorities may be considered (e.g., newly designated nonattainment areas, "problem areas," etc.).

5.5.4 5-YEAR MONITORING NETWORK ASSESSMENT

The U.S. Environmental Protection Agency (EPA) finalized an amendment to the ambient air monitoring regulations on October 17, 2006. As part of this amendment, the EPA added the following requirement for state or local monitoring agencies to conduct a network assessment once every five years [40 CFR 58.10(d)].

"(d) The State, or where applicable local, agency shall perform and submit to the EPA Regional Administrator an assessment of the air quality surveillance system every 5 years to determine, at a minimum, if the network meets the monitoring objectives defined in appendix D to this part, whether new sites are needed, whether existing sites are no longer needed and can be terminated, and whether new technologies are appropriate for incorporation into the ambient air monitoring network. The network assessment must consider the ability of existing and proposed sites to support air quality characterization for areas with relatively high populations of susceptible individuals (e.g., children with asthma), and, for any sites that are being proposed for discontinuance, the effect on data users other than the agency itself, such as nearby States and Tribes or health effects studies. For $PM_{2.5}$, the assessment also must identify needed changes to population-oriented sites. The State, or where applicable local, agency must submit a copy of this 5-year assessment, along with a revised annual network plan, to the Regional Administrator. The first assessment is due July 1, 2010."

Guidance for writing these documents can be found in "EPA Ambient Air Monitoring Network Assessment Guidance, Analytical Techniques for Technical Assessments of Ambient Air
Monitoring Networks" (February 2007) and in "Designing a Network Assessment for an Ambient Air Monitoring Program" (2010).

Prior to the implementation of the network assessment, significant data and information pertaining to the review will be compiled and evaluated. Such information might include the following:

- network files (including updated site information and site photographs)
- AQS reports (AMP220, AMP225, AMP380, AMP390, AMP450, AMP600, others)
- air quality summaries for the past five years for the monitors in the network
- emissions trends reports for major metropolitan areas
- emission information, such as emission density maps for the region in which the monitor is located, and emission maps showing the major sources of emissions
- National Weather Service summaries for the monitoring network area

Upon receiving the information, it will be checked to ensure it is current. Discrepancies will be noted on the checklist and resolved during the review. Files and/or photographs that need to be updated will also be identified. The following categories will be emphasized during network assessments:

Number of Monitors - For SLAMS, the number of monitors required for ambient air monitoring depends upon the measurement objectives that are discussed in 40 CFR Part 58, with additional details in the *Guidance*

for Network Design and Optimum Exposure for $PM_{2.5}$ and PM_{10} 1997. Adequacy of the network will be determined by using the following information:

- maps of historical monitoring data
- maps of emission densities
- dispersion modeling
- special studies/saturation sampling
- best professional judgment
- SIP requirements
- revised monitoring strategies (e.g., lead strategy, reengineering air monitoring network)

Location of Monitors - For SLAMS, the location of monitors is not specified in the regulations, but is determined by the Regional Office and State agencies on a case-by-case basis to meet the monitoring objectives specified in 40 CFR Part 58 Appendix D. Adequacy of the location of monitors can only be determined on the basis of stated objectives. Maps, graphical overlays, and GIS-based information will be helpful in visualizing or assessing the adequacy of monitor locations. Plots of potential emissions and/or historical monitoring data versus monitor locations will also be used.

During the network review, the stated objective for each monitoring location or site will be "reconfirmed" and the spatial scale "reverified" and then compared to each location to determine whether these objectives can still be attained at the present location.

Conformance to 40 CFR Part 58 Appendix E - Probe Siting Requirements: Applicable siting criteria for SLAMS and Ncore are specified in 40 CFR 58 Appendix E. The on-site visit will consist of physical measurements and observations to determine compliance with the Appendix E requirements, such as height above ground level, distance from trees, paved or vegetative ground cover, etc. Since many of the Appendix E requirements will not change within one year, this check at each site will be performed every 3 years (See Table B1-2).

Prior to the site visit, the reviewer will obtain and review the following:

- most recent hard copy of site description (including any photographs)
- data on the seasons with the greatest potential for high concentrations of specified pollutants
- predominant wind direction by season

A checklist similar to that used by the EPA Regional offices during their scheduled network reviews will be used. This checklist can be found in the *SLAMS/NCore/PAMS Network Review Guidance* that is intended to assist the reviewers in determining conformance with Appendix E. In addition to the items on the checklist, the reviewer will also perform the following tasks:

- ensure that the inlet is clean
- check equipment for missing parts, frayed cords, damage, etc.
- record findings in a field notebook and/or checklist
- take photographs/videotape in the 8 cardinal directions
- document site conditions, with additional photographs/videotape

Other Discussion Topics: In addition to the items included in the checklists, other subjects for discussion as part of the network review and overall adequacy of the monitoring program will include:

- installation of new monitors
- relocation of existing monitors
- siting criteria problems and suggested solutions
- problems with data submittals and data completeness
- maintenance and replacement of existing monitors and related equipment
- quality assurance problems
- air quality studies and special monitoring programs

- other issues
- proposed regulations
- funding

A report of the network review will be written within two months of the review and appropriately filed.

5.5.5 ANNUAL DATA REPORT AND DATA QUALITY ASSESSMENT

The QA Unit produces an Annual Data Report which is published for the public on the CDPHE/APCD/TSP website under Technical Documents and Reports at http://www.colorado.gov/airquality/tech_doc_repository.aspx. The purpose of the annual air quality data report is to address changes in ambient air quality as measured by APCD monitors. Information gathering for these reviews will be coordinated through the TSP Program Manager and unit leaders. Supervisors and other personnel will assist as necessary to provide information and support. The Technical Services Program Manager is responsible for assuring that the information provided in this report is used in future planning. The Director of the APCD and the Technical Services Program are jointly responsible for implementing other review findings impacting data quality.

Quality assurance of air monitoring systems includes two distinct and interrelated components. One component of quality assurance is the control of the measurement process through the implementation of quality control policies and procedures and prompt implementation of corrective actions when certain quality control limits are exceeded. The other component is the assessment of the quality of the monitoring data, which is the end product of the measurement process. It is essential that the ambient air quality data collected by the APCD be of high quality.

The core elements of the APCD quality assurance program consists of regularly scheduled preventive maintenance of all sampling systems, frequent monitoring site visits and sampler performance checks, control charting to document the results of regular zero, span, and precision testing, and a program of internal and external performance and system audits. Information provided by these elements of the quality assurance program are essential inputs into the process used by the APCD to assess the precision, accuracy, and completeness of the ambient air quality monitoring program.

The results of all accuracy audits and precision tests are submitted to the Air Quality Subsystem (AQS) database within 90 days of the end of the quarter as mandated by EPA reporting requirements. The audit and precision results are reviewed and analyzed by the QA Unit prior to submittal. Documentation of all accuracy audit and precision test records are maintained by QA Unit staff and available for public review.

The quality control and quality assurance results obtained through routine testing of the instruments used in the air monitoring program are essential inputs to the APCD data validation activities. Specific details about these data validation and documentation procedures are provided in Appendices D2, D3, and DQ the APCD QAPP.

Annually he APCD QA Unit prepares a Data Quality Assessment as discussed earlier in both sections 4 and 5, which provides information on the quality assurance activities performed by APCD staff. This report provides statistical evaluations on data quality objectives, such as completeness, precision, accuracy, and bias for all parameters monitored by the APCD network. The assessment details the results of all system and performance audits performed on the APCD network and provides specific information about the corrective actions, data adjustments, and data invalidation performed in response to these audits.

5.5.6 DATA CERTIFICATION

Certification signals that the monitoring agency has loaded all of its data for the year and has completed the monitoring agency's normal validation process. The responsible official certifies that (i) the ambient concentration data and the quality assurance data are completely submitted to AQS, and that (ii) the ambient

data are accurate to the best of his or her knowledge, taking into consideration the quality assurance findings. The first part means that all of the ambient data and all of the quality assurance data that were collected, and that have completed and passed the monitoring agency's data validation process, have been submitted to AQS. The second part means that the official has considered the results of periodic quality control checks and any other relevant performance assessments.

State and local government monitoring organizations must certify their data. A state official should certify all data submitted for affected monitors in that state, except where responsibility for compliance with 40 CFR Part 58 requirements has been delegated to a local monitoring agency. Note that even where multiple monitoring organizations are considered to be within a single Primary Quality Assurance Organization, the certification may come from the state level, or from each local agency that has delegated responsibilities for compliance with 40 CFR Part 58.

All data from SLAMS monitoring stations must be certified including:

- Federal reference method (FRM) or Federal equivalent method (FEM) monitors for CO, NO_2, SO_2 (hourly and 5-minute average data), ozone, lead, PM_{10}, $PM_{10-2.5}$, and $PM_{2.5}$
- Other required continuous $PM_{2.5}$ monitors
- Filter-based $PM_{2.5}$ speciation monitors - (total mass and speciated components)
- Additional NCore station precursor gas monitors for $NO/NO_x/NO_y$
- PAMS data (ozone, $NO/NO_x/NO_2$, VOC, carbonyl, NH_3, and HNO_3 if collected)

Data from special purpose monitors (SPMs) must also be certified if the SPM is a FRM, FEM, or ARM monitor, and meets the QA requirements of 40 CFR 58 Appendix A. Unless the Regional Administrator has approved an alternative to the QA requirements of Appendix A, an SPM using an FRM or FEM method is required to meet the requirements of Appendix A, so it should be presumed to do so and data from it should be certified.

A data certification letter sent to the applicable EPA Regional Administrator, signed by the senior air pollution monitoring personnel from the monitoring agency or his or her designee. The letter must include the specific statements given in the response to Paragraph 1 above in this section. The letter must be clear regarding what combinations of site, monitor, pollutant, and POC are the subject of the certification statement.

AQS report(s): AMP600 data certification report and the AMP450NC Quick Look summary report (if necessary) for non-criteria pollutants.

In concurrence with the DQA evaluation, all of the data and associated QC and QA for the previous year are reviewed independently by the QA Officer. This review provides an independent annual check on the quality control and quality assurance data, as well as a second check (or sometimes third review) of the annual ambient air data that has been collected throughout the year. After all the data has been reviewed and accepted, the AMP 600 and AMP450NC reports are generated and a data certification letter is written, signed, and sent to Region VIII for final approval of the data that has been submitted to AQS.

5.5.7 EXCEPTIONAL EVENTS

Exceptional events are events for which the normal planning and regulatory process established by the Clean Air Act (CAA) are not appropriate. In this rulemaking action, EPA is finalizing a proposal to implement section 319(b)(3)(B) and section 107(d)(3) authority to exclude air quality monitoring data from regulatory determinations related to exceedances or violations of the National Ambient Air Quality Standards (NAAQS) and avoid designating an area as nonattainment, redesignating an area as nonattainment, or reclassifying an existing nonattainment area to a higher classification if a State adequately demonstrates that an exceptional event has caused an exceedance or violation of a NAAQS. The EPA is also requiring States to take reasonable measures to mitigate the impacts of an exceptional event. The final rule as described by 40 CFR Parts 50 and 51 is effective as of May 21, 2007.

EPA has established procedures and criteria related to the identification, evaluation, interpretation, and use of air quality monitoring data related to any NAAQS where States petition EPA to exclude data that are affected by exceptional events. Section 319 of the "Clean Air Act - Air Quality Monitoring" defines an event as an exceptional event if the event: (1) affects air quality; (2) is an event that is not reasonably controllable or preventable; (3) is an event caused by human activity that is unlikely to recur at a particular location or a natural event; and (4) is determined by EPA to be an exceptional event. The statutory definition of exceptional event specifically excludes stagnation of air masses or meteorological inversions, a meteorological event involving high temperatures or lack of precipitation, or air pollution relating to source noncompliance.

Section 319(b)(3)(B)(i) requires a State air quality agency to demonstrate through ''reliable, accurate data that is promptly produced'' that an exceptional event occurred. Section 319(b)(3)(B)(ii) requires that ''a clear causal relationship'' be established between a measured exceedance of a NAAQS and the exceptional event demonstrating ''that the exceptional event caused a specific air pollution concentration at a particular location.'' In addition, section 319(b)(3)(B)(iii) requires a public process to determine whether an event is an exceptional event. Finally, section 319(b)(3)(B)(iv) requires criteria and procedures for a Governor to petition the Administrator to exclude air quality monitoring data that is directly due to exceptional events from use in determinations with respect to exceedances or violations of the NAAQS.

The term exceedance refers to a measured or modeled concentration greater than the level of one or more for a pollutant. The NAAQS are also set with particular averaging periods (e.g., 3 years for ozone and $PM_{2.5}$) such that a violation of the NAAQS for ozone and $PM_{2.5}$ requires an average annual concentration level specified by Appendix I and N to 40 CFR 50 to be greater than the level of the NAAQS.

On May 10, 2013, the U.S. Environmental Protection Agency (EPA) issued interim guidance to help air agencies manage air quality data recorded during "exceptional events." Exceptional events include natural events such as high winds, wildfires, and volcanic or seismic activities. EPA's interim guidance will ensure that public health is protected, while providing air agencies with the flexibility that they need to show that monitoring data from these unique events should be excluded for regulatory purposes.

The interim guidance includes a memorandum and two attachments that clarify key provisions of the 2007 Exceptional Events Rule (EER) and respond to questions and issues that have arisen since the rule was promulgated. The interim guidance also includes examples of approved demonstrations on the EPA's website at http://www.epa.gov/ttn/analysis/exevents.htm. The attachments to the memorandum include the following documents:

- The "Interim Exceptional Events Rule Frequently Asked Questions" document (the interim Q&A document) provides interim responses to questions that have arisen since the EPA promulgated the EER.

- The "Interim Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds Under the Exceptional Events Rule" (the High Winds Guidance document) is a resource for air agencies when flagging data and preparing demonstration packages for high wind dust events that have affected PM_{10} and $PM_{2.5}$ concentrations. The interim document applies the provisions of the EER and the general guidance conveyed in the guidance memorandum and in the interim Q&A document to the particular situation of a high wind dust event.

Implementation Guidance to Support Data Exclusion Requests for Wildfire-related Events that may affect Ozone Concentrations

- EPA recognizes the need for separate guidance to address the preparation of demonstrations to support data exclusion requests for wildfire-related events that may have affected ozone concentrations.

- EPA anticipates developing this guidance within the same time frame as the Exceptional

Event Rule revisions, with draft guidance available in late 2013 or early 2014 and a final guidance available in late 2014 or early 2015. EPA expects to provide opportunities for stakeholder input on this guidance.

Today's interim guidance clarifies EPA's intention to provide recommendations and to indicate the EPA's current thinking on exceptional event issues, rather than conveying requirements not already stated in the Clean Air Act and the Exceptional Events Rule.

Additionally, the EPA revised the interim guidance materials to correct typographical errors, to make editorial changes to reflect the December 14, 2012 promulgation of the $PM_{2.5}$ NAAQS, and to reflect terminology consistent with the ongoing ozone NAAQS review.

More details on interim guidance can be found at:
http://www.epa.gov/ttn/analysis/docs/exceptevents_guidememo_130510.pdf
Frequently asked questions can be found at:
http://www.epa.gov/ttn/analysis/docs/EER_QA_Doc_5-10-13_r3.pdf
Interim Guidance on High Wind Events can be found at:
http://www.epa.gov/ttn/analysis/docs/exceptevents_highwinds_guide_130510.pdf
Other useful tools to prepare an exceptional event document, as well as examples of these documents can be found at the EPA Treatment of Data Influenced by Exceptional Events website:
http://www.epa.gov/ttn/analysis/exevents.htm

5.5.8 DATA, QUALITY CONTORL & QUALITY ASSURANCE REPORTING REQUIREMENTS

Required accuracy and precision data are to be reported on the same schedule as quarterly monitoring data submittals. The required reporting periods and due dates are listed in Table 5.3.

Table 5.3 Quarterly Reporting Schedule

Reporting Period	Due on or Before
January 1-March 31	June 30
April 1-June 30	September 30
July 1-September 30	December 31
October 1-December 31	March 31 (following year)

In accord with the Federal Register Notice of July 18, 1997, all QA/QC data collected will be reported and will be flagged appropriately. This data includes: "results from invalid tests, from tests carried out during a time period for which ambient data immediately prior or subsequent to the tests were invalidated for appropriate reasons, and from tests of methods or analyzers not approved for use in SLAMS monitoring networks" (40 CFR Part 58 Appendix A, Section 4, revised July 18, 1997). *(This reference may no longer be accurate. It will be updated after next 40CFR58 Appendix A revisions)*

Air quality data submitted for each reporting period will be edited, validated, and entered into the AQS using the procedures described in the AQS Users Guide, Version 1.0.0 July 31, 2013 and in the AQS Data Coding Manual, Version 3.1 March 2014. The GMM and PM work leads will be responsible for assuring all data is validated and verified in a timely fashion, so the QA Officer can perform the final data review before submission to AQS within the reporting schedule deadlines.

5.5.9 CONTROL CHARTS

Control charts are used extensively for reviewing and evaluating quality control data for all ambient air data.

The GMM unit performs nightly zero, precision and span instrument checks as well as manual biweekly gaseous quality control checks which are reviewed every morning for all gaseous samplers in the network through the AirVision® software.

The gravimetric laboratory keeps control charts for the balance check weights, the duplicate filter weights, the lab and field blanks, and the humidity and temperature room conditions through the MTL data handling system.

Control charts for primary and field transfer standards are kept to evaluate performance of each transfer standard.