Interagency Monitoring of Protected Visual Environments (IMPROVE) Network

QUALITY ASSURANCE PROJECT PLAN

Version 2.0

Prepared by the IMPROVE Network for:

U.S. Environmental Protection Agency

Office of State Air Partnerships

Research Triangle Park, NC 27711

EPA and NPS Interagency Agreement Nos. DW-014-92539701 and A2501-068-014-073494

QA Track ID: OAR-OSAP-AQAD-0034699-QP-0

Updated: May 2026

Period of Applicability for this QAPP starts on the date of the EPA Quality Assurance Manager's signature and ends five years after that date or until a new version is approved.

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DOCUMENT HISTORY

Revision	Release Date	Coordinating Author	Section(s) Modified	Brief Description of Modifications
1.0	March 2016	Scott Copeland		
2.0	June 2026	Bonne Ford	All	Updated all activity descriptions and procedures, references to SOPs/TIs, organizational chart, and brought into conformance with new EPA QAPP guidelines.

FOREWORD

The following document is a Quality Assurance Project Plan (QAPP) for the environmental information operations of the Aerosol Monitoring Network component of the IMPROVE (Interagency Monitoring of Protected Visual Environments) Visibility Monitoring Program. This QAPP outlines the project organization, data quality objectives, environmental information operations, and responsibilities of the many organizations involved in the IMPROVE network. The Quality Management Plan (Interagency Monitoring of Protected Visual Environments (IMPROVE) Network Quality Management Plan v2.0) outlines the management structure and roles of the organizations and is available through the IMPROVE website (https://vista.cira.colostate.edu/Improve/) along with all other quality documents and report referenced within this document.

This QAPP was generated using the EPA Quality Assurance (QA) regulations and guidance as described in the *EPA Quality Assurance Project Plan Standard (CIO 2105-S-02).* All pertinent elements of the QAPP regulations and guidance are addressed in this document.

ACKNOWLEDGEMENTS

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LIST OF ACRONYMS AND ABBREVIATIONS

AQMT	Air Quality Management Team at UC Davis
AQRC	Air Quality Research Center at UC Davis
AQS	Air Quality System database
ARS	Air Resource Specialists
BLM	Bureau of Land Management
CAA	Clean Air Act
CFR	Code of Federal Regulations
CIA	Class I Area
CIRA	Cooperative Institute for Research in the Atmosphere
COC	Chain-of-Custody
CRM	Certified Reference Material
CSN	Chemical Speciation Network
DQA	Data Quality Assessment
DQI	Data Quality Indicator
DQO	Data Quality Objective
DRI	Desert Research Institute
EDXRF	Energy dispersive X-ray fluorescence
EPA	U.S. Environmental Protection Agency
FED	Federal Land Manager Environmental Database
FLM	Federal Land Managers
HIPS	Hybrid Integrating Plate and Sphere system, an analytical technique for measuring light absorption
IC	Ion chromatography, analytical technique to determine concentration of ions
IMPROVE	Interagency Monitoring of Protected Visual Environments
MARAMA	Mid-Atlantic Regional Air Management Association
MDL	Method Detection Limit
MQAG	Monitoring and Quality Assurance Group
MQL	Minimum Quantifiable Level
MQOs	Measurement Quality Objectives
MSR	Management System Reviews
MTL	Mettler Toledo
NAAQS	National Ambient Air Quality Standards
NESCAUM	Northeast States for Coordinated Air Use Management
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPS ARD	National Park Service Air Resources Division

OSAP	Office of State Air Partnerships
PE	Performance Evaluation
PM	Particulate matter
$PM_{2.5}$	Particulate matter less than 2.5 micrometers in aerodynamic diameter
PM_{10}	Particulate matter less than 10 micrometers in aerodynamic diameter
PSD	Prevention of Significant Deterioration
QA	Quality Assurance
QAAR	Quality Assurance Annual Report
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan
QC	Quality Control
QMP	Quality Management Plan
QMS	Quality Management System
RHR	Regional Haze Rule
RTI	Research Triangle Institute
SIP	State Implementation Plans
SOP	Standard Operating Procedure
SQL	Structured Query Language
TI	Technical Information
TOR	Multiwavelength Thermal Optical Reflectance
TOT	Multiwavelength Thermal Optical Transmittance
TSA	Technical System Audit
UCD	University of California-Davis
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
WESTAR	Western States Air Resources Council
XRF	X-Ray Fluorescence

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1 PROJECT MANAGEMENT AND INFORMATION

1.1 PROJECT PURPOSE

The Interagency Monitoring of Protected Visual Environments (IMPROVE) Program is a speciated aerosol monitoring program designed to support visibility regulations and science in rural environments. Today, IMPROVE's primary objective is to support the Regional Haze Rule in tracking progress towards the national visibility goal of no human caused visibility impairment in Class I areas (CIAs).

Secondary objectives include:

(1) Monitoring the species used to calculate reconstructed extinction at IMPROVE Protocol sites to understand the transport of visibility-impairing species into CIAs,

(2) Establishing the background visibility levels necessary to assess impacts of potential new sources, and

(3) Monitoring trace elements to determine possible sources of the visibility-impairing species.

1.2 PROJECT BACKGROUND

Visibility impairment is an effect of air pollution in the atmosphere caused by the scattering and absorption of light by particles and gases in the air. Under the Clean Air Act (CAA), Congress recognized that good visibility is a resource to be valued and preserved, now and for future generations. In Section 169A of the Act, Congress set forth a national goal that calls for "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory federal CIAs, which impairment results from man-made air pollution." The U.S. Environmental Protection Agency (EPA) is responsible for establishing regulations ensuring that "reasonable progress" toward the national goal is achieved in the 156 mandatory CIAs (primarily national parks and wilderness areas) identified under the Act. In 1999, the EPA promulgated Regional Haze Regulations requiring states to develop state implementation plans (SIPs) that include reasonable progress goals for improving visibility in CIAs, and present strategies to achieve those goals.

Monitoring of visibility-related parameters has been used to document existing conditions and identify trends in ambient visibility. In response to the 1977 Clean Air Act Amendments, the National Park Service (NPS) Visibility Monitoring Program started in 1978 but was without particulate measurements. A program administered by the Las Vegas office of the EPA began monitoring particulate concentrations in 1979 at several NPS CIAs. Using the samplers and protocols from this EPA network, the NPS Visibility Monitoring Program added a particulate monitoring component in 1981. In 1985, the EPA established Federal Implementation Plans for states without approved visibility provisions

in their SIPs. To assist states in meeting Clean Air Act (CAA) objectives, Federal Land Management agencies (FLMs) responsible for CIAs joined the EPA in a collaborative monitoring program called IMPROVE. The EPA's 1990 amendments to the CAA reaffirmed the importance of visibility protection. Section 169B includes provisions for the EPA to conduct visibility research with the National Park Service and other federal agencies. In 1999 the EPA promulgated the Regional Haze Rule (RHR) (40 CFR 51.308(f)) which established the goal of returning visibility in CIAs to natural levels by 2064. IMPROVE became the official network to support the RHR and track progress towards the goal of no human caused impairment. Thus, the IMPROVE network underwent a major expansion from 1999-2002 to include monitoring representative of 155 CIAs. Thus, the IMPROVE network underwent a major expansion from 1999-2002.

Visibility is also protected under Section 109 (relating to the National Ambient Air Quality Standards, or NAAQS) and Section 165 (requirements for new or reconstructed sources) of the Act. Section 109 calls for the EPA to establish primary and secondary NAAQS to protect public health and public welfare, respectively. For many years, visibility has been recognized as a "welfare effect" of particulate matter.

Data from the Aerosol Monitoring Network are used for calculating long-term visibility trends as reported in the IMPROVE Report (https://vista.cira.colostate.edu/Improve/improve-reports/). Data and descriptions of the monitoring activities are available on the IMPROVE and Federal Land Manager Environmental Database (FED) websites (https://vista.cira.colostate.edu/Improve/ and https://views.cira.colostate.edu/fed/).

In 2025, the IMPROVE network consisted of 229 sites (155 current and 74 discontinued sites). Of these sites, 110 "Regional Haze Tracking Sites" represent 155 of the 156 visibility-protected federal CIAs and are used to track progress towards the national visibility goal. The 45 sites not directly representing CIAs are sponsored by FLMs, states, tribes, local, and international agencies. These sites use the same instrumentation, monitoring, and analysis protocols as the IMPROVE sites and are referred to as "IMPROVE Protocol sites."

1.3 PROJECT ORGANIZATION

The overall organizational chart is provided in Figure 1 and highlights the relevant organizations involved in the activities of the IMPROVE Network. Primary funding comes from the U.S. Environmental Protection Agency (EPA), who also provides oversight for the project, including final approval of the quality documents and proposed procedures. Additional funding comes from FLMs, states, tribes and other entities to support IMPROVE Protocol sites.

All organizations involved in the IMPROVE network also have their own internal

organizational structure that includes senior management; operations management; and, for the contracted laboratories, a Quality Assurance Manager (QAM).

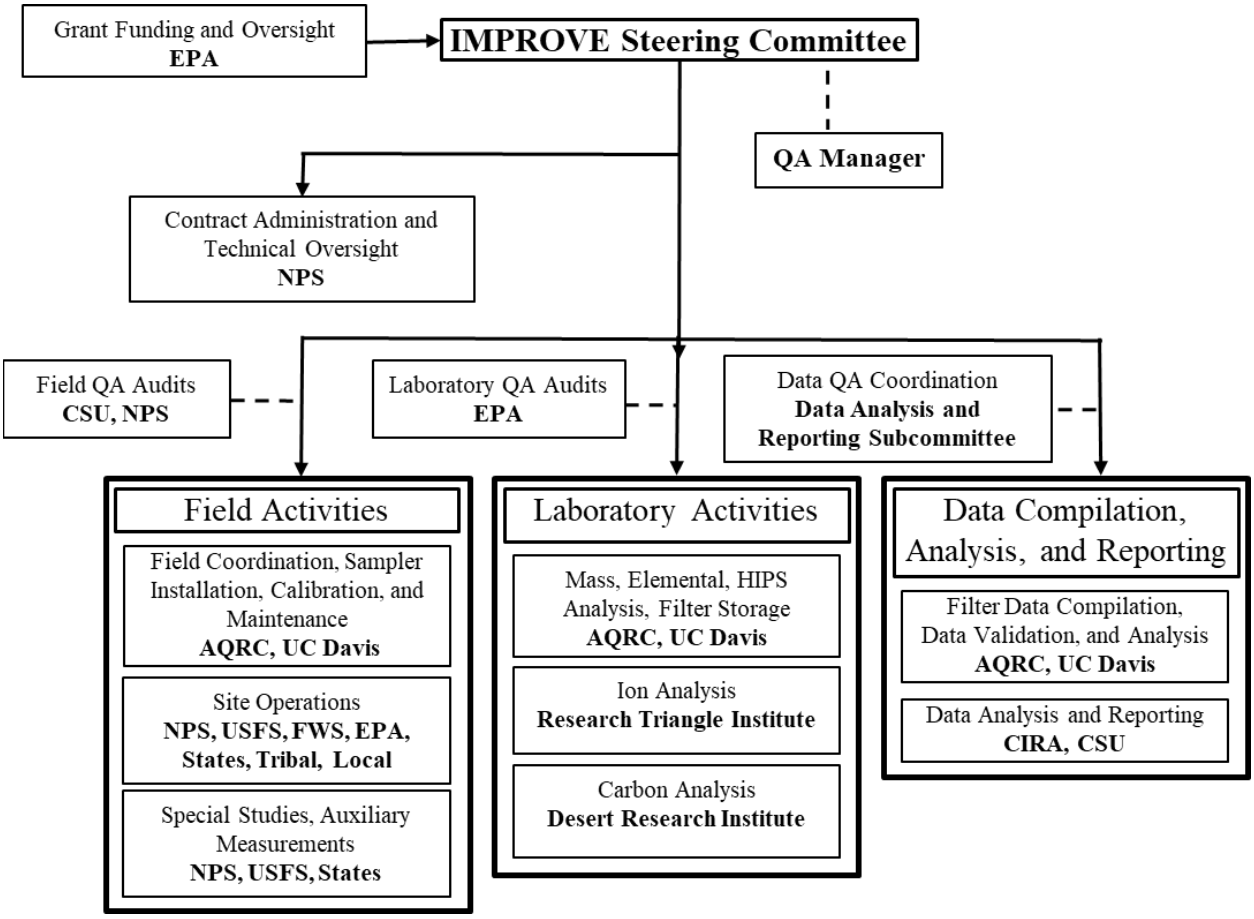


Figure 1. IMPROVE Organizational Chart. The IMPROVE Steering Committee, whose current chair is Bret Schichtel (National Park Service, NPS), serves as the senior management of the IMPROVE organization while the NPS handles most program and contract management. Dashed lines indicate Quality Assurance (QA) activities with Bonne Ford (Cooperative Institute for Research in the Atmosphere, CIRA, CSU) serving as the IMPROVE Quality Assurance Manager (QAM). Major activities of the IMPROVE Network are listed along with the entities currently responsible.

1.3.1 IMPROVE Steering Committee (Senior Management)

The purpose, organization, and governance of the IMPROVE Steering Committee are described in the IMPROVE Steering Committee Charter, available on the IMPROVE website (vista.cira.colostate.edu/Improve/). The IMPROVE Steering Committee oversees all program activities, develops guidance and procedures governing IMPROVE samples and data, and makes recommendations to the EPA and the NPS related to funding, expansion or reduction of the network, and all other technical and non-technical issues. It

coordinates subcommittee activities and provides a forum for the interaction between stakeholders and other interested parties. These activities are conducted with direct interaction with the laboratories conducting analyses.

The IMPROVE Steering Committee consists of representatives from the ten voting member organizations and the non-voting associate members (Table 1). Members of the Steering Committee are appointed by their organizations and serve an indefinite term determined by their organization. Information on how new organizations can be added to the Steering Committee are provided in the IMPROVE charter. These representatives provide oversight to the entire program and meet at least annually (at a Fall Steering Committee Meeting) to discuss any issues that concern the program, necessary improvements, budget constraints, and vote on any major decisions about the network. In addition, they interact with the QAM and the organizations involved in field, laboratory, and data reporting activities. Contracted laboratories participate in steering committee meetings and subcommittees but are not voting members of the IMPROVE Steering Committee.

Table 1. List of IMPROVE Steering Committee member organizations.

Steering Committee Member Organizations
U.S. Environmental Protection Agency (EPA)
National Park Service (NPS)
U.S. Forest Service (USFS)
U.S. Fish and Wildlife Service (FWS)
Bureau of Land Management (BLM)
National Oceanic and Atmospheric Administration (NOAA)
Western States Air Resources Council (WESTAR)
Northeast States for Coordinated Air Use Management (NESCAUM)
Mid-Atlantic Regional Air Management Association (MARAMA)
National Association of Clean Air Agencies (NACAA)
Non-voting Associate Members
State of Arizona
Environment and Climate Change Canada

Steering Committee Member Organizations
Republic of Korea Ministry of Environment

The current chair of the IMPROVE Steering Committee is Bret Schichtel, who represents the NPS. The duties of the chair are outlined in the IMPROVE charter available on the IMPROVE website (https://vista.cira.colostate.edu/Improve/) and include: preparing meeting agendas and presiding over Steering Committee meetings, managing external filter sample requests, organizing and managing subcommittees and workgroups, and keeping the broader IMPROVE community informed of important network changes, events, and data updates through email communication.

1.3.2 IMPROVE Subcommittees

Three subcommittees support the Steering Committee and provide guidance needed to evaluate and advance the IMPROVE monitoring program, help oversee the quality of data and operations of the network and ensure the timely and transparent dissemination of measurement data and analysis results. Each subcommittee is composed of members from the Steering Committee and the broader IMPROVE community (scientists, federal partners, and state partners) and has a specific mission and objectives defined by the subcommittee. Standing subcommittees include (1) network operations; (2) data analysis and reporting; and (3) communication and outreach. Structure of the subcommittees and full details on responsibilities, management practices, and structure are provided in the IMPROVE charter. Subcommittee meetings are held periodically, and activities are communicated to the full committee at IMPROVE Steering Committee meetings.

1.3.3 Quality Assurance Manager (QAM)

The EPA's *Environmental Information Quality Procedure* (CIO 2105-P-01.4) requires organizations to assign a QAM. The current QAM for IMPROVE is Bonne Ford at CIRA at Colorado State University. The QAM reports Quality Assurance (QA) activities and results directly to the IMPROVE Steering Committee who designates the authority of the QAM to manage the overall Quality Program of the network. The QAM is not a member of the Steering Committee but attends and participates in Steering Committee and Subcommittee meetings. The QAM is not directly involved in the management of the network activities, does not perform any laboratory filter analysis, and does not oversee the validation of data products from the laboratories. Instead, the primary role of the QAM is to ensure the quality procedures outlined in this QAPP are followed. The QAM is not a full-time role; thus, the QAM may participate in analysis of IMPROVE data for research studies and conduct other ancillary activities if it is independent of the environmental information operations being overseen. Research activities may be overseen by the QAM's agency/university supervisor, but all QA activities are conducted independently and

directly under the authority of the IMPROVE Steering Committee. The QAM may coordinate quality assurance activities and discuss quality-related issues with the IMPROVE Steering Committee and other QA staff without their direct supervisor.

The QAM is responsible for reviewing the Quality Assurance Project Plan (QAPP) and Quality Management Plan (QMP) annually and determining if updates should be made. The QAM then coordinates with the NPS and contractors to make updates to the QAPP. The QAPP is thoroughly reviewed for re-approval every 5 years from the date approved to determine if the information remains relevant and effective. While the QAM is responsible for updating the QAPP, the approval of the QAPP for implementation requires the IMPROVE Steering Committee, NPS, laboratory contractors, and EPA Office of State Air Partnerships (OSAP). While many of the QAM activities are done in conjunction with other QA staff, the IMPROVE network QAM is ultimately responsible for ensuring that all QA procedures are being followed, and QA documentation is complete and up to date. The QAM is responsible for communicating all QA activities and results to the IMPROVE Steering Committee at annual IMPROVE Steering Committee meetings and through annual reports.

Each laboratory is responsible for internal audits and QA documentation. Laboratory QAMs should alert the IMPROVE QAM, NPS, and IMPROVE Steering Committee of any discrepancies or non-conformance within their own organization. The IMPROVE QAM also coordinates with the laboratories to receive documentation related to quality procedures and ensures that all quality-related documents, such as QAPPs, Standard Operating Procedures (SOPs), and Technical Information documents (TIs), are up to date. The QAM conducts audits of a subset of field sites annually and coordinates with other entities/agencies conducting field site audits (every site is audited at least once in a 10-year period). The QAM creates an annual audit report, maintains records on all site audits, and reports any discrepancies to the NPS and IMPROVE Steering Committee. The QAM also coordinates with the Data Analysis and Reporting subgroup to review quality control assessments as defined in the QAPP.

1.3.4 The U.S. Environmental Protection Agency (EPA)

Funding for the network primarily comes from the U.S. EPA. The EPA reviews and approves QA documentation, such as the QMP and QAPP, and provides oversight for the IMPROVE program by having EPA staff serve on the IMPROVE Steering Committee. The EPA reviews QA reports and aids in the coordination of external audits of laboratories participating in the IMPROVE network.

1.3.5 National Park Service (NPS, Operations Management)

The NPS is the key operational agency of the IMPROVE Program. The agency is responsible for implementing the technical direction of the Steering Committee. The NPS

regularly communicates with the laboratory contractors through emails and virtual meetings. It also operates many of the IMPROVE monitoring sites through cooperating national parks and maintains IMPROVE samplers and sampling structures. NPS oversees program management by issuing and administering IMPROVE contracts and cooperative agreements for the following activities:

(1) IMPROVE Network Operations and Filter Analysis (current contract to University of California-Davis Air Quality Research Center – AQRC for 1/29/2021 – 1/28/2026, currently operating under an extension)
(2) IMPROVE Ion Analysis (current contract to Research Triangle Institute – RTI for 7/1/2021 – 6/30/2026)
(3) IMPROVE Carbon Analysis (current contract to Nevada System of Higher Education; Desert Research Institute – DRI for 7/21/2023 – 7/20/2028)
(4) Data quality assurance, analysis, and data dissemination (through FED database) and reporting (current contract to AQRC for 1/29/2021 – 1/28/2026, currently operating under an extension and cooperative agreements with AQRC for 9/1/2024 – 1/31/2029 and CIRA, Colorado State University for 11/1/2025 – 2/28/2029)

NPS staff also perform detailed data analyses, including the preparation of scientific papers and presentations, and participate in the IMPROVE Steering Committee and Subcommittees. In addition, NPS plans and coordinates special studies, including conducting auxiliary measurements in conjunction with other agencies.

1.3.6 Entities Carrying out the Environmental Information Operations

As stated in section 1.3.5., the NPS has contracted or created cooperative agreements with different institutions/agencies to perform the environmental monitoring activities of the network as set forth by the IMPROVE Steering Committee. Contracted laboratories all have required, regular reporting to the NPS and IMPROVE Steering Committee. In addition, the laboratories should relay (through email or phone call) any issues (instrumentation or personnel) that may interrupt scheduled activities or analysis.

1.3.6.1 University of California-Davis Air Quality Research Center (AQRC)

AQRC is currently contracted to manage the IMPROVE Network operations and conduct gravimetric, elemental, and optical absorption analysis on the collected filters. AQRC also coordinates filter pre-sampling, shipping, sampling, and post-sampling activities. AQRC is responsible for the following field, laboratory, and data activities:

(1) Procuring filters and conducting acceptance testing.
(2) Tracking and recording all samples as they move through the program.
(3) Performing gravimetric, optical absorption, and elemental analysis on IMPROVE Module A filters and gravimetric analysis on Module D filters.
(4) Coordinating the manufacturing of IMPROVE samplers.

(5) Installing instrumentation at new monitoring sites and removing instrumentation from discontinued sites.
(6) Communicating with site operators for shipment, sampling, and troubleshooting instructions.
(7) Receiving filters boxes back from site operators and reviewing flow data and log sheets.
(8) Monitoring performance of sites across the network (including contacting site operators when sites are offline, individual modules are offline, modules are reporting low/high flow, or parts need to be replaced). Conducting biennial visits to each site to update, clean, and calibrate modules.
(9) Data processing and validation (including results sent from RTI and DRI).
(10) Data preparation and delivery to CIRA for FED and to EPA-AQS.
(11) Creating annual data quality reports, annual site reports, and quarterly field status reports which are sent to the Steering Committee, NPS, and IMPROVE QAM.
(12) And under their cooperative agreement, performing scientific analyses of IMPROVE data and other scientific research as directed by the NPS and preparing scientific papers and presentations.

The following table provides a description of the essential roles and authorities at AQRC. Employees should communicate any potential issues to their supervisors.

Table 2. Table of roles and authorities for AQRC

Person/Position	Authority	Supervisor
Nicole Hyslop, IMPROVE PI and Associate Director of Quality Research	Overall supervision of program, ensures procedures are followed and reporting requirements are satisfied, ensures quality and timely delivery of data	Reports to, but is not supervised by Anthony Wexler, the AQRC Director. Works closely with AQRC QAM
Sean Raffuse, Associate Director of Analytical Research	Oversees data management, validation, database, and software development. Oversees technical staff.	Reports to, but is not supervised by Anthony Wexler, the AQRC Director
Ann Dillner, Associate Director of Analytical Research	Oversees laboratory operations, research, and staff	Reports to, but is not supervised by Anthony Wexler, the AQRC Director
Marcus Langston, AQRC QAM	Monitors QA/QC, investigates issues and recommends corrective actions, reviews quality documents and reports, performs in-lab audits and participates in external audits and PE analysis	Reports to, but is not supervised by Anthony Wexler, the AQRC Director; works closely with Associate Directors and Group Managers

Jason Giacomo, Laboratory Manager	Oversees laboratory and laboratory staff. Maintains schedule for sample analysis, tests, and data processing. Reviews quality documentation.	Reports to Director of Analytical Research
Laboratory Supervisors	Oversee technical details and laboratory QA procedures. Supervise assistants	Reports to Laboratory Manager
Laboratory Assistants/Technicians II/III	Oversee and train new assistants, review filter readings, log sheets, and flow data, oversee filter handling procedures, inventory filters	Reports to Laboratory Supervisor
Laboratory Assistants I and Student Assistants	QC and cleaning of sampling cassettes; loading, unloading, weighing, and processing filters	Reports to lead lab technician and Laboratory Supervisor
Data & Reporting Group Manager	Oversees all aspects of data ingestion, processing, validation, and reporting. Reviews all components of measurements and validates final data	Reports to Associate Director of Analytical Research
Data Quality and Validation Associate	Performs validation procedures, maintains database. Devises data management techniques, develops validation criteria, reviews MDL and uncertainty. Receives all analytical data and ingests into database, performs validation checks, communicates issues with laboratories, submits validated data to EPA and CIRA.	Reports to Data & Reporting Group Manager
Yongjing Zhao, Field Team Manager	Oversees Field Team, manages field team schedule	Reports to Associate Director of Quality Research
Field Technicians	Conduct maintenance trips, communicate with site operators	Reports to Field Team Manager

1.3.6.2 Research Triangle Institute (RTI)

RTI is contracted to perform ion chromatography on all IMPROVE Module B nylon filters. Specifically, RTI is responsible for:

(1) Receiving all Module B nylon filters and associated files with sample identification information from AQRC.
(2) Performing ion chromatography on all sample filters and blanks.

(3) Validating Module B ion analysis data (final validation is conducted by the Quality Assurance (QA) Team at AQRC).
(4) Reporting all results to AQRC.

The following table provides a description of the essential roles and authorities at RTI. Employees should communicate any potential issues to their supervisors.

Table 3. Table of roles and authorities for RTI.

Person/Position	Authority	Supervisor
Dr. Reshan Fernando, Senior Director	Provides high-level oversight and serves as the escalation point for critical issues	Reports to RTI Senior Vice President
Tracy Dombek, RTI Program Manager and Ions Laboratory Manager	Supervises the program, coordinates program activities, and is responsible for day-to-day operations of the program, including the Ions Laboratory. Performs secondary reviews of all results and compiles data reports.	Reports to Senior Director and communicates any data quality or performance issues with the QA Manager, the IMPROVE Steering Committee, and the University of California at Davis Team.
Andrea McWilliams, QA Manager	Responsible for monitoring all aspects of QA and QC and has appropriate access to management support, while also maintaining independence and authority with respect to decisions regarding data quality	Reports to but is not supervised by the RTI Senior Director and works closely with technical staff and the RTI Program Manager
RTI Technical Team	Performs technical tasks related to ion analysis of IMPROVE filters in accordance with established QAPPs and SOPs. Responsible for preparing calibration and quality control solutions, performing quality control checks, maintaining instrument performance, and conducting routine instrument maintenance and replacement of consumables. Data generation, documentation in laboratory notebooks and bench sheets.	Technical staff report to the Project Manager and maintain regular communication regarding sample analysis, instrument performance, and quality control results. Any QC failures or instrument issues are promptly communicated to the Project Manager for evaluation and resolution

RTI Admin Support	Supports administrative functions, purchasing, and invoicing.	Reports to the Senior Director. Communicates any unforeseen issues that delay project deliverables with the Project Manager.

1.3.6.3 Desert Research Institute (DRI)

DRI is contracted to analyze all IMPROVE Module C quartz filters for carbon. Specifically, DRI is responsible for:

(1) Procuring and pre-firing all Module C quartz filters, testing for contamination after pre-firing, and sending prepared filters to AQRC.
(2) Receiving all sampled Module C filters and associated files with sample identification information from AQRC.
(3) Performing Multiwavelength Thermal Optical Reflectance/Transmittance analysis for organic carbon, elemental carbon, and thermal fractions on all sample filters and blanks.
(4) Validating Module C carbon analysis data (final validation is conducted by the QA team at AQRC).
(5) Reporting all results to AQRC.
(6) Performing scientific analyses of IMPROVE data as directed by the NPS.

The following table provides a description of the essential roles and authorities for the Environmental Analysis Facility (EAF) at DRI. Employees should communicate any potential issues to their supervisors.

Table 4. Table of roles and authorities for Environmental Analysis Facility at DRI.

Person/Position	**Authority**	**Supervisor**
Dr. Judith Chow, EAF Director	All aspects of EAF organization, personnel, operations, and reporting.	Dr. Naresh Kumar, Exec. Director Division of Atmospheric Sciences
Dr. Xiaoliang Wang, EAF Deputy Director	Day-to-day EAF operations and personnel supervision	Dr. Naresh Kumar, Exec. Director Division of Atmospheric Sciences
Dr. John G. Watson, Quality Assurance Officer	External evaluation of EAF procedures, reporting structures, competence certification, and ethics training.	Dr. Naresh Kumar, Exec. Director Division of Atmospheric Sciences
Mr. Steven D. Kohl, EAF Analytical Laboratory Supervisor	Oversight of all on-site laboratory facilities, technician training and	Dr. Judith C. Chow, EAF Director

	supervision, and procedure modification	
Dr. Mohammadreza Elahifard, Carbon Lab Coordinator	Oversees daily operations, receives and logs filters from UC Davis, schedules and supervises technicians, validates and transmit data to UC Davis, maintains instruments and supplies, revises SOPs as needed	Mr. Steven D. Kohl, EAF Analytical Laboratory Supervisor
Carbon Laboratory Technicians	Perform daily startup and shutdown, analyze samples, maintain logbooks, perform QC checks, apply data flags	Mr. Steven D. Kohl, EAF Analytical Laboratory Supervisor and Dr. Mohammadreza Elahifard, Carbon Lab Coordinator

1.3.6.4 Cooperative Institute for Research in the Atmosphere (CIRA)

Under a cooperative agreement with the NPS, the Colorado State University – Cooperative Institute for Research in the Atmosphere is tasked with database management, analysis, and reporting functions for IMPROVE. Specifically, CIRA is responsible for:

(1) Maintaining all IMPROVE data, reports, and program documentation on the IMPROVE and FED websites.
(2) Performing scientific analyses of IMPROVE data and preparing scientific papers, presentations, and reports.
(3) Performing visibility research and calculating RHR metrics.
(4) Preparing IMPROVE Reports that detail the spatial and temporal variability in haze and its components across the U.S.

1.3.6.5 Site Sponsors and Field Operators

Most sites are sponsored by the NPS, USFS, or FWS. However, some sites are also sponsored by the EPA, tribes, states, or other entity. Site sponsors are responsible for providing funding as well as logistics planning for site installation (including access to electrical power) and maintenance. Site management and logistical decisions are reported to the NPS and Steering Committee, while day-to-day operational issues are handled by the Field Team (AQRC).

The site sponsor must also provide a site operator. Site operators are an integral part of the operation of the IMPROVE network. The site sponsor must provide the Field Team (AQRC) with updated contact information for operators. Site operators must be trained by the Field Team or previous site operator in the proper operations of IMPROVE samplers and provided with the necessary resources to manage the sampling site (e.g., training

videos, scheduling calendars, and AQRC *SOP 201: Sampler Maintenance by Site Operators*, Appendix 5.1.1). Specific duties include:

(1) Operating and maintaining the IMPROVE samplers.
(2) Receiving filters, log sheet, and SD card and sending sampled filters, completed log sheet, and SD card back to AQRC.
(3) Checking module flow and pressure values and filling out log sheets.
(4) Following the filter change schedule (Figure 2).
(5) Submitting to and participating in field audits and reviewing results.

The Field Team (AQRC) keeps records of all current site operators and communicates instrument and sample change issues (such as abnormal flow or offline status) directly back to the operator. The Field Team processes the log sheets when they are returned from the field. The IMPROVE QAM observes the site operators during TSAs to evaluate their knowledge of procedures and available resources and compliance with SOPs.

1.3.7 Communication within the IMPROVE Network

The IMPROVE Steering Committee communicates during the annual committee meetings and between meetings through email. The Steering Committee Chair is responsible for organizing annual meetings. The committee must meet at least once a year, with a preference to hold the meeting in-person. The annual meeting and/or additional meetings may be held virtually to accommodate committee member travel constraints. Presentations and meeting minutes are made publicly available through the IMPROVE website (https://vista.cira.colostate.edu/Improve/steering-committee-meetings/). The IMPROVE Steering Committee annual meeting is the primary opportunity for evaluating the overall effectiveness of the quality program and should include presentations and discussions from all contractors, the QAM, NPS, and all subcommittees. The majority of the IMPROVE annual meeting is open to the public; however, annual meetings may also include a closed-door discussion for committee members to discuss issues without the public and/or contractors. Closed-door sessions are used when voting is required to reach a concurrence and approve modifications to the network and/or procedures.

The IMPROVE Steering Committee also meets virtually with the NPS, EPA, AQRC, and the IMPROVE QAM monthly for updates and discussion about the IMPROVE network operation and data analysis. AQRC reports on current data delivery timelines, site statuses, data completeness, and/or other QA concerns. The IMPROVE Steering Committee, EPA, and NPS may request specific additional information from AQRC to be presented at these meetings. AQRC is in routine communication with RTI and DRI about filter shipments and data delivery through email.

If non-conformance is found at a specific institution/agency, it is the responsibility of the

supervising manager and/or QAM of that specific institution/agency to investigate the root cause of the issue to determine whether the problem is unique or has systemic implications and to propose corrective action or further analysis of the issue. In addition, the supervising manager is required to document the issue, outcomes of the investigation, the proposed corrective action, and expected timeline. If the issue is minor and easily resolved at the institution-level (e.g., staff requiring retraining or incomplete documentation), it is at the discretion of the managing supervisor to inform the IMPROVE QAM and/or Steering Committee (which includes the EPA). This reporting may be done at a monthly meeting or through email communications. If the issue is systemic and has broad implications on data quality, the supervisor must alert the IMPROVE QAM and IMPROVE Steering Committee (which includes the EPA) of the issue in a timely manner and the matter should be discussed at an IMPROVE Steering Committee meeting. The IMPROVE Steering Committee may designate the Data Analysis and Reporting Subcommittee with investigating the impact of issue on the data record and reporting back to full IMPROVE Steering Committee.

1.4 PROJECT TASK DESCRIPTION

1.4.1 Field Activities

The IMPROVE network consists of 155 sampling site locations across the US (as of 2025). Fine particle monitoring at each site is achieved by using the IMPROVE aerosol sampler to collect filter samples on a 1-in-3-day sampling cycle (currently, sampling schedule shown in Figure 2).

Figure 2. IMPROVE calendar created for site operators showing sampling schedule for January 2026. Sampling days are shown in blue. Sample change and alternate sample change days are shown in yellow.

The standard IMPROVE sampler has four sampling modules (A, B, C, D), designed to

obtain the composition of the particles that affect visibility. A photograph of an IMPROVE sampler stand is given in Figure 3a, along with a diagram of a standard IMPROVE aerosol sampler (Figure 3b), and a photograph of an example set of weekly filters for each module (Figure 3c). A full description of the IMPROVE aerosol sampler and its operation is provided in AQRC *SOP 201: Sampler Maintenance* (Appendix 5.1.1).

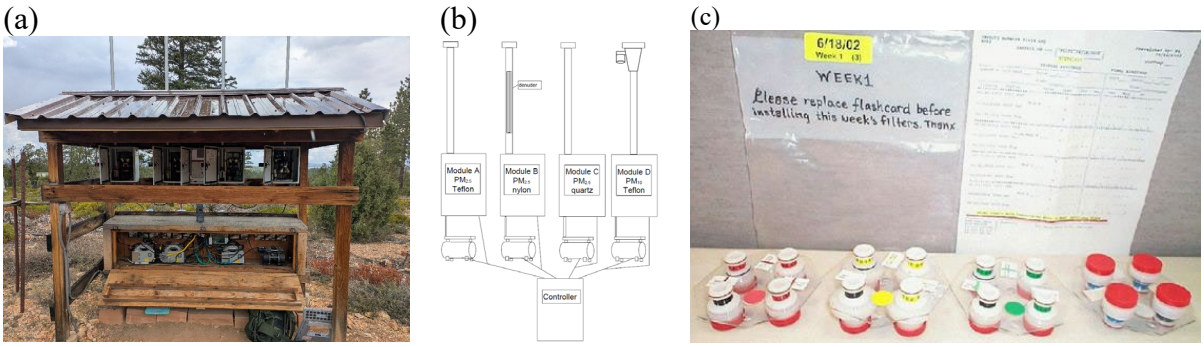


Figure 3. (a) Photograph of IMPROVE sampling stand with standard modules and pumps. (b) Diagram of the IMPROVE sampler. (c) Photograph of the log sheet and weekly filters for all 4 modules for an IMPROVE site.

Coordination of field activities is led by the Field Team (current contract to AQRC). Once sampling sites are installed, field operators conduct routine, weekly sampling, and document site-specific activities. Details on Field Activities are provided in Section 2.2.1.

1.4.2 Laboratory Activities

Contracted laboratories prepare filters for sampling and then analyze exposed filters for aerosol composition. Module A filters are analyzed for $PM_{2.5}$ mass, elemental concentrations, and filter light absorption (current contract to UC-Davis AQRC). Module B filters are analyzed for ions (current contract to RTI). Module C filters are analyzed for organic and elemental carbon (current contract to DRI). Module D filters are analyzed for PM_{10} mass (current contract to UC-Davis AQRC). Laboratories also archive filters. Details on Laboratory Activities are provided in Section 2.2.2.

1.4.3 Data Product Activities

The principal products of the IMPROVE monitoring program are the speciated data and related visibility metrics. Routine and novel data analyses and products are also generated, such as the Regional Haze Rule (RHR) metrics generated for each complete calendar year of data and the IMPROVE Reports (https://vista.cira.colostate.edu/Improve/improve-reports/).

AQRC performs centralized data processing and validation for the IMPROVE network as outlined in AQRC *SOP 351: Data Processing and Validation* and the associated TIs

(Appendix 5.1.1). These activities include ingestion and integration of laboratory analytical results and field sampling data; application of automated quality control checks to evaluate data completeness, internal consistency, and instrument performance; and calculation of standard parameters (e.g., mass concentrations) using established IMPROVE equations. Data processing involves calculating sample volume from field data on flow rates and sampling duration and subsequently calculating ambient concentration, uncertainty, and method detection limit (MDL) for each analyte using the laboratory result plus the sample volume. Data are subjected to systematic screening to identify anomalies, outliers, and potential contamination, followed by technical review to confirm data validity. Validation procedures include verification of sampling metadata, flow rates, and analytical results against established acceptance criteria, as well as assignment of data quality flags to document limitations and usability. Final validated datasets are compiled, documented, and prepared for submission to FED and the EPA Air Quality Systems (AQS) Database, ensuring traceability and adherence to IMPROVE quality assurance requirements. Data processing and validation for IMPROVE are the responsibility of the AQRC Data & Reporting Group, and the AQRC Data & Reporting Manager supervises the project. Data processing and data validation are performed in parallel.

These data and all associated metadata and reports are made available through the IMPROVE (https://vista.cira.colostate.edu/Improve/) and FED (https://views.cira.colostate.edu/fed/) websites. Data are also available from the EPA's AQS database (https://www.epa.gov/aqs). Preliminary data products are delivered as analysis and initial data verification is completed, usually 2-6 months after sample collection. Once a full year of samples have been collected, analyzed, and the data validated; the full year of data is redelivered, approximately 8-9 months after the final samples were collected. RHR metrics are then generated.

1.5 DATA QUALITY OBJECTIVES AND PERFORMANCE AND ACCEPTANCE CRITERIA

1.5.1 Network Mission

Data quality objectives for IMPROVE are based on the central mission of the network: tracking changes in concentrations of key light scattering and absorbing components of particulate matter. The long-term goal of the Clean Air Act is to eliminate "man-made" visibility impairment. EPA's 1999 Regional Haze Rule defines progress towards the CAA goal by setting the goal of a linear reduction in the haze index (in deciviews) on the "most anthropogenically impaired" days, while preventing increases in the haze index on the clearest days. The implications of the goal are (1) that the IMPROVE network needs to be able to quantify changes in concentrations of haze forming species and (2) that it is necessary to understand which portions of haze forming species are anthropogenic.

1.5.2 Data Quality Objectives

The IMPROVE network follows the data specifications established by the EPA Visibility Guidance for the Regional Haze Rule (https://www.epa.gov/visibility/visibility-guidance-documents). As part of these specifications, the IMPROVE network must ensure that the measurement sites are representative of the visibility conditions in CIAs (Section 1.5.3), that the parameters measured are representative of the major constituents of haze in the different regions of the U.S., and that the measurements are suitable for tracking long-term trends in visibility.

The primary Data Quality Objective (DQO) for IMPROVE is to detect changes in haze-forming pollutants sufficient to reject the null hypothesis of "no change" in total light extinction on the most impaired days. Based on a previous analysis, it was determined that this corresponds to detecting a 5% change in calculated light extinction in a 5-year period.

However, an assessment of the implications of trend targets for IMPROVE data quality was presented in *Tracking Progress with Imperfect Measurements: Data Quality and the Regional Haze Rule* (IMPROVE, 2005). Two key findings from that report are:

(1) Natural variability: Weather-related variability in aerosol concentrations can obscure small changes between multi-year periods.

(2) Bias sensitivity: Time-varying bias is the dominant error source affecting long-term trends. Random errors average out across years, so QA efforts should focus on minimizing systematic measurement bias.

1.5.3 Site Selection and CIA Representativeness

The minimum number of monitoring sites in the network is based on the number of visibility-protected CIAs in the United States, currently totaling 156. The CIA, Bering Sea, AK, does not have infrastructure to support monitoring; therefore, only 155 CIAs are considered. Because a single monitoring site may represent multiple CIAs, the network configuration has expanded and contracted over time in response to periodic network assessments. These reviews evaluate the adequacy of site coverage, including relocated or decommissioned sites, and confirm that all CIAs remain appropriately represented.

Monitoring sites are selected to provide regionally representative measurements with minimal influence from local emission sources. Site locations are chosen based on representative meteorological conditions, minimal physical obstructions, and adherence to established spatial parameters, including distance and elevation criteria. Detailed siting procedures are provided in AQRC *SOP 126: Site Selection* (Appendix 5.1.1). The sampling frequency at the site (currently one 24-hour sample every three days) must also be appropriate for monitoring visibility trend assessments for the CIAs represented. Site selection and any subsequent modifications to the network or sampling schedule are determined collaboratively by the FLMs, air quality agencies, and AQRC, under the oversight of the IMPROVE Steering Committee.

1.5.4 Performance/Acceptance Criteria

The parameter of interest for the RHR is reconstructed light extinction, which is calculated following EPA's 2018 *Technical Guidance on Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program* (https://www.epa.gov/visibility/technical-guidance-tracking-visibility-progress-second-implementation-period-regional) from the following $PM_{2.5}$ constituents: sea salt, fine soil, elemental carbon, organic mass, fine particle nitrate, and fine particle sulfate. These constituents are estimated from IMPROVE sampler filter measurements using different analytical methods. There are broad Measurement Quality Objectives (MQOs) for each analytical method, which specify the acceptable levels of random and systematic error to meet the DQO based on laboratory intercomparisons and co-located sampling. MQOs for specific quality control activities are described in Section 2.4.

Table 5. IMPROVE Measurement Quality Objectives

Method	Parameter(s)	Random Error (rms)	Systematic Error (limit)
Gravimetric	Mass	±5 µg/filter	±5 µg/filter
HIPS	Light absorption (Fabs)	±10%	±5%
XRF	Al, Si, S, K, Ca, Ti, Fe	±10%	±5%
IC	NO_3^-, SO_4^{2-}, Cl^-	±10%	±5%
TOR/TOT	OC, EC	±10%	±5%

The measurement methods listed in Table 2 are based on established IMPROVE program standard operating procedures. These methods are not designated as Federal Reference Methods (FRM) or Federal Equivalent Methods (FEM); however, they are widely used and accepted by EPA for visibility monitoring. Where applicable, analytical techniques (e.g., ion chromatography and gravimetric mass determination) are consistent with or comparable to EPA reference methods. For measurements without direct EPA method equivalents (e.g., TOR/TOT carbon analysis and HIPS-derived parameters), IMPROVE-specific methods are used that are well-documented, validated, and supported by established quality assurance protocols.

The following Data Quality Indicators (DQIs) are used to evaluate the performance and reliability of the IMPROVE dataset:

(1) Precision: Variability among independent measurements. Precision is determined from both co-located samplers (Section 2.4.8) and replicate laboratory analyses.
(2) Bias: Systematic deviation from the true or reference value. Bias is quantified using reference standards traceable to the National Institute of Standards and Technology (NIST) or equivalent authorities.

(3) Method Detection Limit (MDL): Lowest value distinguishable from zero with 99% confidence. MDLs are stored with each result in the IMPROVE databases and are based on field or laboratory blanks. During monthly data validation, the current monthly calculated MDLs are compared against the proposed, new monthly MDLs for each parameter to ensure the MDL are stable and reasonable (equations used for calculating MDLs for each parameter and composite variable are given in AQRC *TI 351B: Data Processing*).

(4) Completeness: Proportion of valid samples relative to those scheduled for collection. The recovery rate is determined as the ratio of valid filter samples to total possible samples. The completeness criterion is the ratio of samples with valid measurements for all major species required for reconstructed extinction. The objectives are: ≥90% recovery rate network-wide, ≥75% completeness per year, ≥50% completeness per quarter, and ≤10 consecutive missed samples per quarter. Network-wide averages since 2002 have exceeded these thresholds. Completeness is assessed in the annual QA report.

(5) Representativeness: Degree to which data accurately reflect ambient aerosol conditions and spatial trends. Representativeness is ensured through consistent network design (with specified siting criteria used to evaluate the suitability of potential sites as described in AQRC *SOP 126: Site Selection*, Appendix 5.1.1), standard operating procedures, and adherence to uniform analytical methods.

(6) Comparability: Consistency across sites, laboratories, and over time. Comparability across the network is maintained by using the same sampling methods at all sites and the same laboratories for all filter analyses. Comparability for laboratory analysis is maintained through common reference materials, calibration procedures, and cross-laboratory intercomparisons of filter species. Laboratories also participate in external performance evaluations.

1.6 PERSONNEL TRAINING AND CERTIFICATION

1.6.1 Training

Appropriate training is made available to persons supporting the IMPROVE Program, commensurate with their duties. Training should cover both technical demonstrations and review of pertinent documents. Each contractor is responsible for providing adequate training to all employees working on the IMPROVE project and maintaining a record of training. Program managers at each contracted laboratory identify mandatory training required by staff to comply with program requirements and ensure that the necessary levels of technical proficiency and QA knowledge are maintained. All laboratory QA staff are required to be trained on documentation and record-keeping procedures; it is the responsibility of the laboratory managers to document that laboratory staff have the appropriate training and certifications as required by their institutions. Internal and external

audits are used to identify any new training or retraining needs. .

The individual laboratory managers train their respective lab technicians in sample handling and filter analysis. Other employees are trained in data validation, and reporting by their respective manager. Written, laboratory-specific SOPs and TIs provide detailed guidance for all procedures (Appendix 5.1); staff are required to be familiar with these documents and follow the outlined procedures. Laboratory managers maintain binders of training records for all employees. Staff are assessed on their use and knowledge of SOPs and TIs during any internal or external audit or evaluation. RTI Ions Laboratory staff must pass a Demonstration of Capability (DOC) procedure for each task that the staff member is expected to perform. Passing this DOC procedure documents they can achieve acceptable precision and accuracy when performing a technique according to the respective technical SOP. Laboratory managers, in conjunction with each laboratory's Principal Investigator, are responsible for defining employee responsibilities, determining necessary personnel qualification, providing necessary training to lab technicians and their internal laboratory quality managers, and keeping records on training and job responsibilities. Laboratory managers are responsible for determining and enforcing compliance with all required safety training.

The Field Team Manager (currently at AQRC) and the Principal Investigator of the laboratory contracted to manage field operations (currently AQRC) are responsible for determining the amount of training necessary for site operators. Site operators are given training on routine equipment operations, sample collection, log recording, preventive maintenance, and troubleshooting by Field Team technicians and/or previous site operators. A training session is conducted during new site installations and is repeated as needed during biennial maintenance visits. The Field Team manager maintains records of all trained site operators and backup operators. The Field Team also provides ongoing telephone and email support to site operators. Written SOPs provide detailed guidance for all procedures (Appendix 5.1) and operator instruction videos are available online at https://aqrc.ucdavis.edu/resources-for-operators. The IMPROVE QAM assesses the training of site operators during a Technical Systems Audit (TSA) and determines if additional training is necessary. Any update to a procedure, which requires an update to an SOP or TI, is communicated to the site operator; new documents and the option for additional training are also provided.

The IMPROVE Steering Committee is responsible for determining the necessary knowledge and training required for the QAM. The QAM is trained on field audits by the previous QAM and by the Field Team manager. The QAM should report these trainings to the IMPROVE Steering Committee and the NPS. Training on quality documentation is conducted through meetings with the IMPROVE Steering Committee, the Operations Manager (NPS), EPA, and the contracted laboratories.

The Field Team manager trains the field technicians on all instrument calibration, maintenance, and site operator training procedures at the time of employment. SOPs and TIs provide guidance for all procedures, and field technicians should be familiar with these documents before conducting any field work. The Field Team manager and the Principal Investigator at the laboratory contractor for Field Operations are responsible for documenting and assessing field technician training (binders with all employee training records are maintained by the Field Team manager).

CIRA staff working on the IMPROVE Program are trained in their respective data validation, analysis, reporting, documentation, and web management duties by senior CIRA staff and by NPS scientists. The Principal Investigator at CIRA is responsible for defining job responsibilities, outlining necessary training, and assessing performance of CIRA employees.

Field staff for various organizations that perform TSAs receive training from the IMPROVE QAM. This training includes the calibration and use of flow audit devices, sampler design, and IMPROVE siting requirements. Additionally, the IMPROVE QAM explains the TSA form and requirements as well as discusses record keeping and reporting of results. The QAM provides a certificate to trainees and documents all trainings. Any update to a procedure which requires an update to an SOP or TI is communicated to the partner auditor and requires new documents and the option for additional training to be provided.

1.6.2 Certifications

UC Davis regulations require that AQRC staff who operate EDXRF instrumentation are certified in radiation safety by the UC Davis Environmental Health and Safety Department. Records are maintained by UC Davis Environmental Health and Safety. No certifications are required by RTI or DRI to receive samples or perform analysis.

Laboratory accreditation is included in Section 2.3.2.

1.7 DOCUMENTS AND RECORDS

1.7.1 IMPROVE Network Management

The IMPROVE Steering Committee, Subcommittees, and NPS assess the need for planning documents in accordance with the EPA. The IMPROVE Steering Committee is responsible for ensuring that there is a QAPP and QMP, which are annually reviewed by the IMPROVE QAM and updated at least every 5 years. SOPs are required for any complex task proposed by contractors to perform environmental measurements and must be updated whenever equipment or procedures change. The QMP, QAPP, and SOPs are controlled documents and must have the appropriate approval as determined for each document before being implemented. The IMPROVE Network QMP is reviewed by the contracted laboratories and is approved by the IMPROVE QAM, the IMPROVE Steering Committee,

the NPS, and the EPA OAPS Project Officer and QAM. The QAPP is approved by the IMPROVE QAM, the laboratory QAMs and Project Managers/PIs, the IMPROVE Steering Committee, NPS, and the EPA OAPS Project Officer and QAM. At AQRC, SOPs and TIs are drafted by staff; reviewed by the Laboratory Group, Field Team, or Data and Reporting Group Manager/Supervisor; and approved by the AQRC QAM (Table 2). At RTI, the SOPs are drafted and updated by staff, reviewed by the RTI QAM, and approved by the RTI Project Manager (Table 3). At DRI, the Carbon Lab Coordinator initiates SOP drafts and revisions which are reviewed and corrected by the Analytical Laboratory Supervisor and approved by the Quality Assurance Officer or the EAF Deputy Director, depending on the nature of the revisions (Table 4).

When reviewing planning documents, the QAM must ensure that all documents are in conformance with any requirements or EPA policy, regulation, or standard and with all terms and conditions of any extramural agreements. Any revisions to planning documents must be documented. When revised versions have been approved, previous versions of documents should be archived. All planning documents (IMPROVE Charter, QMP, QAPP, and SOPs) are electronically stored and publicly available on the IMPROVE website (https://vista.cira.colostate.edu/Improve/). Planning documents (SOPs and TIs) written by contractors (AQRC, RTI, DRI, ARS) are also available on the IMPROVE website and are listed in the Appendix (Section 5) of this document (https://vista.cira.colostate.edu/Improve/sops/).

The IMPROVE network is committed to making and preserving records containing proper documentation of the network organization, functions, procedures, and transactions in compliance with the EPA Records Management Policy (Directive No: 2155.5). Records are treated as an asset and managed throughout their life cycle (creation, maintenance, and disposition). The IMPROVE Steering Committee, and in particular the Steering Committee Chair, is responsible for managing the custody and confidentiality of evidentiary quality-related documents and records as pertains to the IMPROVE Steering Committee and the network as a whole. Program managers at the NPS and each contracted laboratory are also responsible for managing their own evidentiary records that pertain to the project. The IMPROVE Steering Committee may request these records from the NPS or a contracted laboratory as part of their oversight of the project.

Quality documents for the IMPROVE network each have a “sponsor” that is ultimately responsible for management of the document. The QAPP and QMP are “sponsored” by the IMPROVE QAM who must review these documents annually and coordinate with the contracted laboratories for maintenance. The QAPP and QMP must be thoroughly reviewed for re-approval every 5 years to determine if the information remains relevant and effective. SOPs and TIs all laboratory and/or field operations are “sponsored” by the QAMs at each contracted laboratory. The laboratory sponsor is listed with each SOP/TI

referenced in this document, and all SOPs/TIs are listed in the Appendix. The NPS is responsible for ensuring that the contracted laboratories are fulfilling their record-keeping responsibilities; thus, while the contracted laboratories create and maintain SOPs, the NPS can specify which SOPs need to be created and their maintenance schedule and must be informed when SOPs are disposed or replaced. NPS reviews all SOPs at the beginning of each contract period and reviews all updated SOPs from laboratories. The IMPROVE QAM reviews all quality documents annually and discusses updates or necessary updates with the NPS and contracted laboratories. SOPs have been periodically updated throughout the time period of the project to reflect changes to methods, procedures, or instrumentation. The IMPROVE QAM is responsible for coordinating with the contracted laboratories to maintain the list of current SOPs and revision status and to ensure that these are publicly available through the IMPROVE website (https://vista.cira.colostate.edu/Improve/sops/).

The NPS retains all contract documentation for a minimum of 6 years after the end of the contract period. All contractors for the IMPROVE network are required to keep documents for the duration of their contract period (listed in Section 1.3.5). All environmental measurement documentation (written or electronic) is retained for at least five years from the date that it was generated. All environmental measurement data are kept indefinitely and are publicly available through the FED and the EPA-AQS databases.

QA documents such as SOPs, QAPPs, QMPs, and TSAs are held electronically for the duration of the project and made available through the IMPROVE website. Quality-related documents are archived on the IMPROVE website when new versions are generated or, in the case of SOPs, the document no longer applies. The IMPROVE Steering Committee, in conjunction with the NPS, determines when QA documents should be updated.

1.7.2 Laboratory Contractors

1.7.2.1 AQRC

AQRC maintains documentation in accordance with contract requirements. The project QMP, QAPP, SOPs, and TIs are stored in a shared network location accessible to all employees. These PDF versions represent the reviewed and approved releases. Previous versions are retained in restricted folders. Draft documents are stored separately, clearly watermarked as “DRAFT,” until they are approved for release. Each document type follows a defined approval process, with digital signatures used whenever possible. Physical copies of SOPs are kept near the workstation for the relevant processes, and outdated physical copies are destroyed upon release of a new revision. Process supervisors periodically review and update SOPs and TIs. Quality documents have the following approval process: first the primary writer, then the process/area manager, then the AQRC QAM. All three are required to approve with the AQRC QAM completing review before release. Updated SOPs and TIs are sent to the NPS and IMPROVE QAM and made available on the IMPROVE website.

Nonconformances, Corrective Actions, Planned Process Deviations, Investigations, and other quality reports are stored on a secure server. Each report is reviewed and signed prior to issue closure. While these reports may be made available for external review upon request, they are primarily intended for internal documentation and are not published. If an issue requires discussion or approval from the sponsoring agency, the agency is contacted to review the matter, determine next steps, agree on closure actions, and provide signatures as needed.

Paper log sheets from the field sites are stored for a minimum of two years until data validation is complete. Any comments or necessary information from the log sheets are transferred to databases upon receival. Logbooks are kept for instruments where required, such as EDXRF safety logs. A digital log is kept for lab-related activities such as maintenance or lot changes.

Vendor certifications are kept for as long as the equipment is in the possession of AQRC.

1.7.2.2 RTI

RTI maintains documentation in accordance with contract requirements. Project records are retained for the contract period, following sample analysis. Records are archived within the records retention facility at RTI. RTI logs the records into the RTI tracking system and stores them in a secure location until expiration. The RTI Program Manager oversees the review and revision of quality documents, while the RTI QAM maintains the document control system and ensures access for project staff.

The QAPP, SOPs, and other project documents are reviewed annually and revised as needed. The QAPP and SOPs are controlled documents. Revision history and distribution of SOPs are maintained in accordance with RTI *SOP-100-ADM-001: Preparation and Maintenance of Standard Operating Procedures Within Discovery Sciences* (Appendix 5.1.2). The RTI QAM is responsible for ensuring document control for project documents under their oversight. To align with QT9™ Quality Management System (QMS) procedures, all electronic SOPs in PDF format now display the footer 'UNCONTROLLED WHEN PRINTED.' This designation clarifies that printed copies are not considered controlled documents and may not reflect the most current approved version. Staff must always refer to the electronic version within QT9 QMS as the official source to consistent use pf the most current SOP versions.

1.7.2.3 DRI

DRI maintains documentation in accordance with contract requirements. Project records (including logbooks and sample analysis lists) are retained for the contract period. The SOPs and other project documents are reviewed periodically and revised as needed. It is the responsibility of DRI's Environmental Analysis Facility's Quality Assurance Officer to review and approve updated versions.

2 ENVIRONMENTAL INFORMATION OPERATIONS

2.1 PROJECT ENVIRONMENTAL INFORMATION OPERATIONS (NETWORK DESIGN)

The IMPROVE network is designed to provide data for the Regional Haze Rule (as discussed in Section 1.1) and to show baseline, temporal, and spatial trends in ambient air quality for all CIAs in the United States. To accomplish these goals, locations are selected for IMPROVE sites to provide long-term, regionally representative samples to estimate concentrations of the major constituents of haze (Section 2.2.1.1). Each IMPROVE site has an identical IMPROVE aerosol sampler installed (Section 2.2.1.2) which collects aerosol mass on filters. AQRC acts as the coordinating laboratory to prepare and ship filters to the sites for sampling. The IMPROVE aerosol sampler collects ambient $PM_{2.5}$ and PM_{10} aerosol samples every third day beginning at midnight local standard time and sampling for 24 hours, with an identical sampling schedule maintained across the network. Filters are returned to the laboratories for analysis, each different filter type (Table 3) undergoes the same analysis at the lab contracted for the analysis (Section 2.2.2). The Data Quality Team at AQRC compiles and validates the data for release (section 4).

2.2 METHODS FOR ENVIRONMENTAL INFORMATION ACQUISITION

2.2.1 Field Activities for Environmental Measurements

2.2.1.1 Site Selection

Sites are selected to provide regionally representative samples for CIAs. The addition or removal of IMPROVE sites is ultimately the decision of the IMPROVE Steering Committee who are tasked with deciding on the number and location of sites to provide representative measurements for all visibility-protected CIAs. Original planning used distance and elevation criteria (e.g., all CIAs should be within 100 km of a monitoring site, whose elevation lies between the highest and lowest elevations of each area represented by the site, with a permitted variance of 100 feet or 10%).

Once potential sites are determined, NPS and the AQRC field team coordinate with the FLM to select a site location which will meet the specific guidelines detailed in AQRC *SOP 126: Site Selection* (Appendix 5.1.1). This is kept up to date by the AQRC field group in coordination with the AQRC QAM. The most critical criteria are related to distances from local emission sources. The SOP also documents necessary power, inlet height, and distance from obstructions. The local FLM/agency completes the necessary paperwork required to use the site (e.g., permission requests, environmental impact reports, electrical power installation or use authorization), installs power, and builds or installs a suitable structure.

2.2.1.2 IMPROVE Sampler

The IMPROVE aerosol sampler collects ambient aerosols on a variety of substrates for the analysis of elemental, ion, and carbon species involved in visibility impairment. The IMPROVE Sampler was developed by UC Davis and was designed to withstand ambient field conditions and to make operation and maintenance easy. The IMPROVE aerosol sampler collects ambient $PM_{2.5}$ and PM_{10} aerosol samples every third day, beginning at midnight local standard time and sampling for 24 hours. A description of the sampler is provided in AQRC *SOP 201: Sampler Maintenance* (Appendix 5.1.1). This is kept up to date by the AQRC field group in coordination with the AQRC QAM.

Most sites contain four sampling modules, labeled A, B, C, and D. Some sites contain an extra module, which is used for quality assurance. Each module collects a single filter for each sample date. Module A samples $PM_{2.5}$ on 25 mm PTFE filters. Module B samples $PM_{2.5}$ on 37 mm nylon filters. Module C samples $PM_{2.5}$ on 25 mm quartz filters. Module D samples PM_{10} on 25 mm PTFE filters. The analyses performed and parameters measured are provided in Table 3. Module D uses a fixed orifice for flow. Modules A, B, and C are being upgraded with active flow-control; these upgrades to active flow control started in 2023 and are expected to be completed across the network in 2026. Upgrades, which require both hardware changes and firmware updates, take place with biennial routine maintenance and calibration visits by the AQRC Field Team.

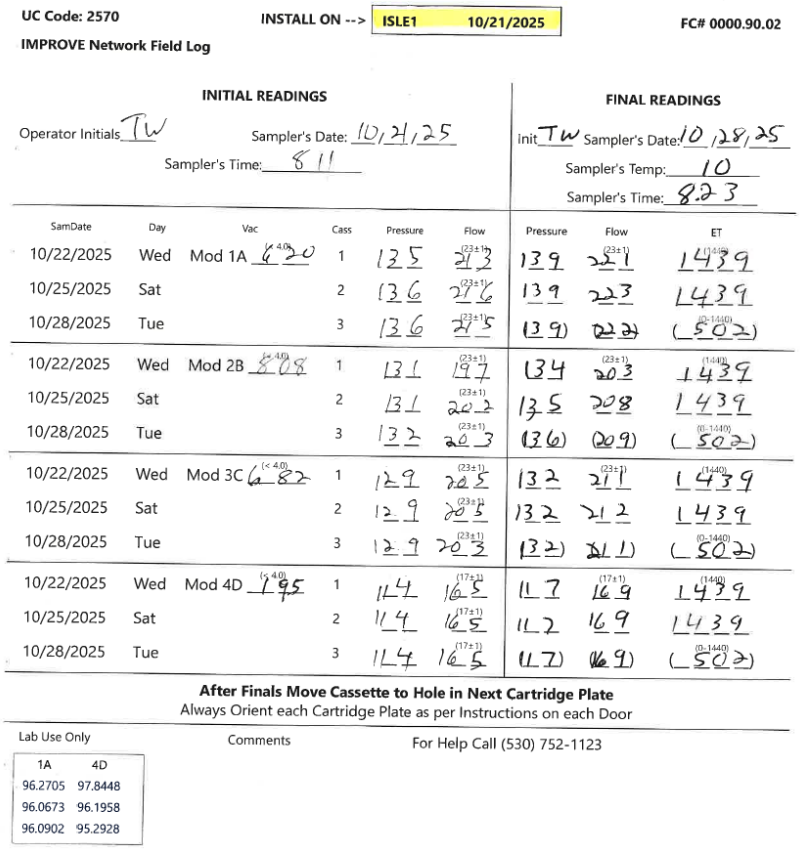
Table 6. IMPROVE Sampler Modules with filter media, the analysis performed on the filter, and the parameters measured from the filter sample.

Module	Nominal Flow Rate	Filter	Analysis Performed on Filter	Parameters Measured
A	23 lpm	PTFE	Gravimetric, Hybrid Integrating Plate/Sphere (HIPS), Energy Dispersive X-Ray Fluorescence (EDXRF)	$PM_{2.5}$ mass, coefficient of absorption (fabs) Na, Mg, Al, Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Zr, Pb
B	23 lpm	Nylon	Ion Chromatography (IC)	Nitrate, Nitrite, Sulfate, Chloride
C	23 lpm	Quartz	Multiwavelength Thermal Optical Reflectance/Transmittance (TOR/TOT)	OC, EC, OC1, OC2, OC3, OC4, EC1, EC2, EC3
D	16.9 lpm	PTFE	Gravimetric	PM_{10} mass

Each filter is considered a sample, and the sample volume is the product of the flow rate and the sampling duration. The sampling duration is determined from the elapsed time recorded by the sample controller. Methods for calculating sample volume and flow rates are discussed in AQRC *TI 351B: Data Processing* (Appendix 5.1.1).

2.2.1.3 Sampling Operations

Routine operation of the IMPROVE sampler at each site is handled by a site operator, who is local to the site location. The site operator performs routine weekly filter sample changes and basic maintenance as outlined in AQRC *SOP 201: Sampler Maintenance by Site Operators* (Appendix 5.1.1). Larger maintenance tasks are performed by UC Davis Field Team personnel during biennial maintenance and calibration visits as outlined in AQRC *SOP 226: Site Maintenance* (Appendix 5.1.1). Filter boxe are received by the operator with multi-week sampling increments (currently three weeks per shipment), used in the sampling procedures, and then shipped back to the UC Davis sample-handling lab (SHL) for distribution to the other laboratories. Sampling filter change schedules are provided by UC Davis SHL (Figure 3 shows a monthly sample schedule). If sample days are missed (either due to a malfunctioning module or an operator missing a filter change day), filters are returned unsampled. Site updates and issues are reported to the UC Davis Field Team through email or a phone helpline. Site operators change filters weekly and fill out log sheets. Sample filters are only used for the designated sample date. If a sample date is missed due to late sample change, the filter is returned unused. An example field log sheet is given in Figure 4.



UC Code: 2570 INSTALL ON --> ISLE1 10/21/2025 FC# 0000.90.02

IMPROVE Network Field Log

INITIAL READINGS

Operator Initials: TW Sampler's Date: 10/21/25

Sampler's Time: 811

FINAL READINGS

Init TW Sampler's Date: 10/28/25

Sampler's Temp: 10

Sampler's Time: 823

SamDate	Day	Vac	Cass	Pressure	Flow	Pressure	Flow	ET
10/22/2025	Wed	Mod 1A 620 (<40)	1	135	212 (23±1)	139	221 (23±1)	1439 (1440)
10/25/2025	Sat		2	136	216 (23±1)	139	223	1439
10/28/2025	Tue		3	136	215 (23±1)	(139)	(222)	(502) (0–1440)
10/22/2025	Wed	Mod 2B 808 (<40)	1	131	197 (23±1)	134	203 (23±1)	1439 (1440)
10/25/2025	Sat		2	131	202 (23±1)	135	208	1439
10/28/2025	Tue		3	132	203 (23±1)	(136)	(209)	(502) (0–1440)
10/22/2025	Wed	Mod 3C 682 (<40)	1	129	205 (23±1)	132	211 (23±1)	1439 (1440)
10/25/2025	Sat		2	129	205 (23±1)	132	212	1439
10/28/2025	Tue		3	129	203 (23±1)	(132)	(211)	(502) (0–1440)
10/22/2025	Wed	Mod 4D 795 (<40)	1	114	165 (17±1)	117	169 (17±1)	1439 (1440)
10/25/2025	Sat		2	114	165 (17±1)	112	169	1439
10/28/2025	Tue		3	114	165 (17±1)	(117)	(169)	(502) (0–1440)

After Finals Move Cassette to Hole in Next Cartridge Plate

Always Orient each Cartridge Plate as per Instructions on each Door

Lab Use Only

1A	4D
96.2705	97.8448
96.0673	96.1958
96.0902	95.2928

Comments

For Help Call (530) 752-1123

Figure 4. Example of completed field log sheet for sample cartridge with three cassettes (i.e., three sampling days).

2.2.2 Laboratory Analyses

2.2.2.1 Gravimetric Analysis

Filters for module A and module D undergo gravimetric analysis. AQRC uses two MTL AH500 automated weighing chambers, each with a Mettler Toledo XPR6UD5 ultrabalance. Each IMPROVE PTFE filter scheduled for gravimetric analysis undergoes a pre-weigh and a post-weigh step. The same balance is used for the pre- and post-weigh of a filter, unless one balance is inoperable for an extended period.

Each PTFE filter has a unique ID number and matrix code embedded on its outer support ring. These identifiers are used throughout handling for data traceability. For gravimetric mass measurements, filters are placed into carriers and loaded into the MTL silos. Within the MTL chamber, filters are automatically transferred to the balance for weighing and then returned to their silos through a series of robotic movements. This process applies to both pre- and post-weigh operations. The difference between pre- and post-weights is used to calculate mass gain, and flow data are used to determine average concentrations.

Temperature and humidity within the MTL chambers are monitored and controlled.

Antistatic polonium units are utilized to minimize static buildup on the filters.

The procedures for the pre-weigh are given in AQRC *TI 251J: Pre-Sample Weigh-In* and the procedures for the post-weigh are given in AQRC *TI 251H: Post-Sample Weigh In* (Appendix 5.1.1).

2.2.2.2 HIPS

The HIPS instrument measures light absorption on PTFE filters. A laser beam is directed at the filter, and an integrating plate and sphere collect the light transmitted through the filter (plate) and the light reflected from its surface (sphere). The portion of light not collected represents the amount absorbed by the sample material. The instrument currently operates at a wavelength of 633 nm, with a new version under development to incorporate additional wavelengths. HIPS records transmittance (T) and reflectance ® and calculates absorption (b). Two parameters are derived from the HIPS measurement: Tau (τ)**,** the unitless optical absorption depth, and fAbs**,** the optical absorption factor, expressed in inverse megameters (Mm^{-1}). The "spot size" of the laser is used to calculate the average values of the parameters. Full description of the measurement and methods are provided in AQRC *SOP 276: Optical Absorption Analysis of $PM_{2.5}$ Samples*.

2.2.2.3 X-Ray Fluorescence

After gravimetric and HIPS analysis, filters used in the IMPROVE sampler module A are analyzed for elements using energy-dispersive X-ray fluorescence (EDXRF) with PANalytical E5 analyzers operating under vacuum. The method measures characteristic X-rays emitted when atoms in the filter deposit are excited by photons from a 100-kV Scandium/Tungsten (Sc/W) X-ray tube. Emitted X-rays are detected by a solid-state Germanium (Ge) detector, and spectra are processed using E5 software with non-linear least squares fitting based on the AXIL algorithm.

The E5 system provides —gh-sensitivity, multi-element analysis with low detection limits and stable calibration performance. Although the EDXRF technique is non-destructive, some volatile species (e.g., ammonium, nitrate, chlorine, bromine) may be lost under vacuum conditions.

For IMPROVE samples, six analytical conditions are used in each run to optimize detection for the 24 reported elements. Each condition applies a specific combination of secondary target, tube voltage and current, energy range, and exposure time. Detailed parameters are provided in AQRC *SOP 301: XRF Analysis of Aerosol Deposits on PTFE Filters* (Appendix 5.1.1).

2.2.2.4 Ion Chromatography (IC)

Nylon filters from the IMPROVE sampler B module are analyzed for anions using ion chromatography. Quantitative determination of chloride (Cl^-), nitrite (NO_2^-), nitrate

(NO_3^-), and sulfate (SO_4^{2-}) in air quality samples is performed following RTI *SOP Ion2: Determination of Anions and/or Cations Extracted from Nylon® Filters by Ion Chromatography (IC)* (Appendix 5.1.2).

Filters are extracted with deionized water using the SimPRep autodilutor, according to RTI *SOP Ion3: Filter Extraction via SimPRep Autodilution System.* Following extraction, staff sonicate the samples for 30 minutes, allow the extracts to sit at room temperature overnight, and then refrigerate for at least 24 hours prior to analysis. Samples are removed from the refrigerator before analysis, IC is used to analyze the extracts for anions (chloride [Cl^-], nitrite [NO_2^-], nitrate [NO_3^-], and sulfate [SO_4^{2-}]). Internal RTI SOPs govern the verification of measuring and dispensing devices, storage and maintenance operations, and use of balances. These supporting SOPs are referenced in RTI SOP #Ion2 but are not publicly distributed.

2.2.2.5 Multiwavelength Thermal/Optical Carbon Analysis (TOR/TOT)

Quartz filters for the IMPROVE sampler module C undergo multiwavelength Thermal Optical Reflectance/Transmittance analysis for the components for organic carbon, elemental carbon, thermal carbon fractions, and reflectance/transmittance at seven wavelengths following DRI *SOP 2-226: DRI Model 2015 Multiwavelength Carbon Analysis (TOR/TOT) of Aerosol Filter Samples – Method IMPROVE_A* (Appendix 5.1.3).

2.2.3 Data Activities

Procedures for data handling, processing, and validation are described in AQRC *SOP 351: Data Processing and Validation* (Appendix 5.1.1) and in the related TIs. The steps in the data processing and validation are listed below:

(1) Data ingest (described in AQRC *TI 351A: Data Ingest*): Gravimetric mass, EDXRF, and HIPS analysis results are transferred into the UCD database through an automated service. IC analysis results files from RTI and TOA analysis results files from DRI are received via email, and results are ingested to the database at AQRC.

(2) Data processing (described in AQRC *TI 351B: Data Processing*): Operational information from field sampling and laboratory analysis results are combined to calculate concentrations, uncertainties, and method detection limits. The following equation (Equation 1) is used to determine the concentration:

$$C = \frac{A-B}{V} \qquad \text{(Equation 1)}$$

where C is the ambient concentration (ng/m3) determined from the mass measured on sample (A, ng/filter or ng/cm^2) minus the artifact mass (B, in ng/filter or ng/cm^2, which is either the filter pre-weight or the monthly median of ion or carbon field blank mass loading, divided by the ample air volume (V, in m^3).

The sample air volume (V) is determined by the following equation, from the volumetric flow rate (Q, in liters per minute) and the Elapsed Time:

$$V = Q \times Elapsed\ Time \qquad \text{(Equation 2)}$$

The volumetric flow rate is determined by the following equation (Equation 3) using site-specific temperature and pressure (not STP) for modules A, B, and C:

$$Q = 10^{a} M^{b} \times F(elev) \times \sqrt{\frac{T+273.15}{293.15}} \qquad \text{(Equation 3)}$$

Where a and b are calibration coefficients, M is the cyclone transducer reading, F(elev) is an elevation factor to account for the pressure difference between sea level and the site, and T is the ambient temperature in degrees Celsius at the time of sampling. For module D, the flow is determined from the measurement of absolute pressure downstream of the filters near the critical orifice using a pressure transducer (referred to as the ORI value). Since the pressure is measured after the filter, a decrease in measured flow rate could be indicative of a heavily loaded filter or filter clogging that is restricting the flow. The sampler flow rate is calculated using Equation 4 below:

$$Q = (c + d \times G) \times F(elev)^{2} \times \sqrt{\frac{T+273.15}{293.15}} \qquad \text{(Equation 4)}$$

Where c and d are calibration coefficients, G is the critical orifice transducer reading, F(elev) is the elevation factor, and T is the ambient temperature in degrees Celsius at the time of sampling. All the calibration coefficients were previously site-specific, but universal constants have been used for all samples collected after 2017. The constants are reviewed and updated as needed. Current constants are available in *AQRC TI 351B: Data Processing*.

The uncertainty and method detection limits (MDLs) are reported with each concentration. Methods for calculating uncertainties and MDLs and the values determined from the equations for ions, carbon and elements are given in AQRC *TI 351B: Data Processing*. The document also provides all equations for determining composite variables. Appendix 5.2 gives the recent average MDLs and percentage of reported data above the MDLs for 2020-2023 data.

(3) Validation (described in AQRC *TI* 351C: Data Validation): Data and metadata are reviewed through a variety of visualizations and summary data tables. Several statistical and visual checks are applied and examined. Reanalyses are requested as needed. Data are flagged with informational and/or flags (status) as appropriate.

(4) Data delivery (described in AQRC *TI 351D: Data Delivery*): Data are formatted into formats for delivery to the CIRA/FED database and another format for delivery to the AQS database. Data are reported for local times and local conditions. Parameters and

units are given in Table 7. For mass, ions, carbon, elements, and light absorption; the units listed are also used for uncertainty and MDL.

Table 7. Parameters and units of parameters for data delivered to CIRA and the EPA for uploading into corresponding databases. NA indicates that the data type is not reported to the corresponding database.

Data Type	**Parameter**	**CIRA/FED Unit**	**AQS Unit**
Flow Rate	Flow	L/min	
Elapsed Time	ET	Min	
Gravimetric mass	$PM_{2.5}$, PM_{10}	ng/m^3	$\mu g/m^3$
Ions	Cl^-, NO_2^-, NO_3^-, SO_4^{2-}	ng/m^3	$\mu g/m^3$
Carbon	OC1, OC2, OC3, OC4, OC, OPTR, EC1, EC2, EC3, EC TC, OPTT, OPTR at other wavelengths, OPTT at other wavelengths	ng/m^3	NA
Carbon_laser	RefF_wavelength, Refl_wavelength, RefM_wavelength, TransF_wavelength, Transl_wavelength, TransM_wavelength	reading	NA
Elements	Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Pb, Se, Br, Rb, Sr, Zr	ng/m^3	$\mu g/m^3$
Light Absorption	fAbs	Mm^{-1}	Mm^{-1}
Composite species	OMC, NH_4NO_3, $(NH_4)_2SO_4$, PM_{10}-$PM_{2.5}$, Soil	NA	$\mu g/m^3$

(5) Flow validation (described in *AQRC TI 351E: Flow validation*): Flow data from the network are reviewed and validated using various tools including a flow plotter website. The flow criteria and flags used are listed in Appendix. 5.3.

(6) Data Preparation and Reporting (described in *AQRC TI 351F: Data Preparation and Reporting*): Box information is created or modified in the UCD database. New sampling site metadata is also added to the UCD database and AQS database. Quarterly site sampling information is compiled into a report and delivered to IMPROVE related personnel.

2.3 Integrity of Environmental Information

2.3.1 Sample Handling and Chain of Custody

A flow diagram of the sample-handling process is shown in Figure 5, and the sample-handling procedures are described in detail in AQRC *SOP 251: Sample Handling* (Appendix 5.1.1). AQRC has a specific process in place for the filters used in each module, due to the different analysis paths. The general processes for filters are purchase and acceptance testing (described in section 2.3.1.1), pre-analysis, loading filters into cartridges, shipping to site operator, sampling, shipping back to the lab, analysis, and finally archiving.

The IMPROVE database at AQRC is used to track the filter information, and several apps and web-based pages are used to review and track data through the different processes. The A and D PTFE filters have a laser-engraved matrix code on the support ring. The code is scanned at each stage of handling and prior to each analysis to ensure that data are correctly associated with the corresponding filter. The matrix codes include built-in error correction and safeguards to prevent duplication or misreads. If a matrix code cannot be scanned, an alphanumeric code printed on the filter ring may be entered manually. AQRC is also implementing camera-based text recognition systems to assist in cases where matrix codes fail to scan. Trays and cartridges are also labeled to aid in organization, but the matrix codes are the primary tracking method.

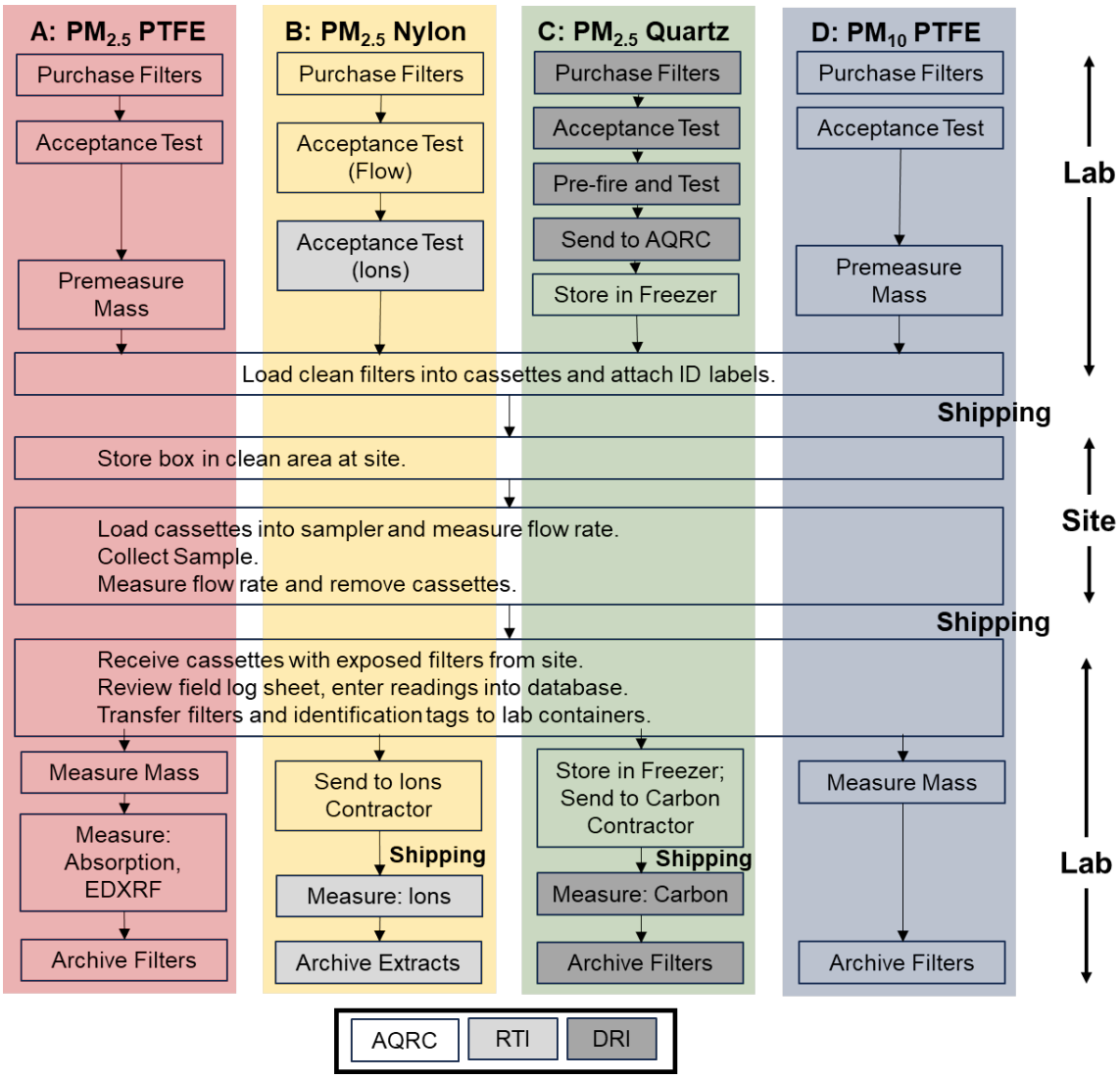


Figure 5. Flow diagram of the sample-handling process. Each colored column represents the filters used in an IMPROVE sampler module (red: A, yellow: B, green: C, blue: D). Shade of text box represents the contracting laboratory responsible for the process (clear: AQRC, light grey: RTI, dark grey: DRI).

2.3.1.1 Purchasing Filters and Acceptance Testing

The PTFE and nylon filters are purchased by AQRC, while quartz filters are procured by DRI. Approximately 20,000 filters per year (including blanks) are required for each of the four different sampling modules for network operations. Filters are purchased annually to ensure that each year's supply originates from a single manufacturing lot.

All filters undergo acceptance testing before being shipped out for sampling to verify minimal contamination and physical consistency. About a dozen filters of each type are selected for testing. For each new PTFE filter lot, AQRC measures flow resistance and

conducts EDXRF and HIPS analyses to assess contamination. Nylon filter flow resistance is measured at AQRC, and RTI performs ion chromatography analysis to check for contamination. Additional details on filter procurement and testing are provided in AQRC Technical Information document *TI 251C: Filter Inventory and Acceptance* (Appendix 5.1.1).

DRI analyzes quartz filters from each lot—both before and after pre-firing—to check for contamination. Acceptance testing procedures at DRI are described in DRI *SOP #2-106: Pre-firing and Acceptance Testing of Quartz Fiber Filters for Aerosol and Carbonaceous Material Sampling* (Appendix 5.1.3), and carbon acceptance testing is performed as described in DRI *SOP #2-226: DRI Model 2015 Multiwavelength Carbon Analysis (TOR/TOT) of Aerosol Filter Samples – Method IMPROVE_A* (Appendix 5.1.3). Boxes containing quartz filters which pass acceptance testing are placed in zip-lock bags, and stored in the freezer until they are shipped to AQRC.

2.3.1.2 Preparing Clean Filters for Shipping to Sites

The AQRC sample-handling computer system is used to maintain detailed records of cassette loading requirements. It is also used to log every action performed, along with the time, and the name of the technician. Following on-screen instructions, clean filters are loaded into the appropriate cassettes within the sampling cartridge (a cartridge holds 4 cassettes, for sampling or blanks). Each cassette is labeled with a unique identifier consisting of a five-character alphanumeric site code, sample date, and module type. Labels are generated by the computer and affixed to the cartridge adjacent to the corresponding cassette, ensuring proper filter/sample identification. Each cartridge is further labeled with a color-coded tag indicating the module type (red for A, yellow for B, green for C, or blue for D). Details on labels are given in AQRC *TI 251R: General Laboratory Procedures* (Appendix 5.1.1).

Cartridges for a given sampling periodare placed in a resealable bag labeled with the site code, installation date (currently, on Tuesdays), and sampling period (currently, weeks 1-3). The field log sheet (Figure 4) is included in the same bag. Currently, three such bags, each representing one sampling cycle, are then packed into a shipping box (currently, this represents 7 total sampling days). A custom-designed shipping container is used to transport a the multi-week supply of sampling materials between AQRC and the field sites.

2.3.1.3 Transport and On-Site Storage

Each shipping box is labeled with the site identification code and the installation date as described in AQRC *TI251L: Box Shipping* (Appendix 5.1.1). Most shipments are sent via United Parcel Service (UPS); however, a few remote locations without UPS service use First-Class U.S. Mail or alternative carriers as needed. Cold packs are not included in the shipments. Site operators typically receive the containers one to two weeks before the first

scheduled installation.

A box contains one sampling cycle, currently three sets of cartridges with 7 sampling filters and 5 blanks. Typical durations for the filter samples before and after sampling—including time spent in shipment, onsite storage, and within the sampler—are provided in Table 3.

Table 8. Current number of days each of the filters in a sampling cycle is in shipment, in storage at the site, or in the sampler before sampling ("Clean Filter") and after sampling ("Exposed Filter").

Filter in Cycle	Clean Filter	Exposed Filter
Filter 1	15 Days	22 Days
Filter 2	18 Days	19 Days
Filter 3	21 Days	16 Days
Filter 4	24 Days	13 Days
Filter 5	27 Days	10 Days
Filter 6	30 Days	7 Days
Filter 7	33 Days	4 Days

2.3.1.4 Handling Onsite

Upon receipt, site operators store the shipping boxes in a clean, secure location—either in an indoor office area or in onsite sampler housing units. Each shipping box currently contains the three labeled, sealed bags for the sampling cycle, one for each sample change/installation date. In each bag are four cartridges (each with four filter cassettes), one for each module, and one field log sheet (example in Figure 4). Filter cartridges are stored in the sealed bag before and after sampling. A detailed description of the onsite sample changing procedure can be found in AQRC *SOP 201: Sampler Maintenance by Site Operators* (Appendix 5.1.1). After the completion of the sampling cycle, the operator ships the box with all completed samples, log sheets, and memory card back to AQRC using an enclosed return shipping label.

2.3.1.5 Receiving Boxes and Log Sheet Information

When shipping boxes with exposed cassettes are delivered from the site to AQRC, a lab technician checks the filters and log sheets and then transports the cartridges to the sample handling laboratory. Details on opening boxes from sites are provided in AQRC *TI 251D: Box Receiving* (Appendix 5.1.1).

The memory cards are used if the data were not automatically uploaded from the site. The log sheet inputs from the field may also be used if the memory card is damaged or missing. Details on these processes are given in AQRC *TI 251E: Entering Log Sheets and Simple Problem Diagnosis* (Appendix 5.1.1). The data validation team contacts the analyzing

laboratory for the specific filter type if any data are missing or corrupt. Errors or problems are noted in a comment field or documented in the ticketing system. If necessary, the site operator is called.

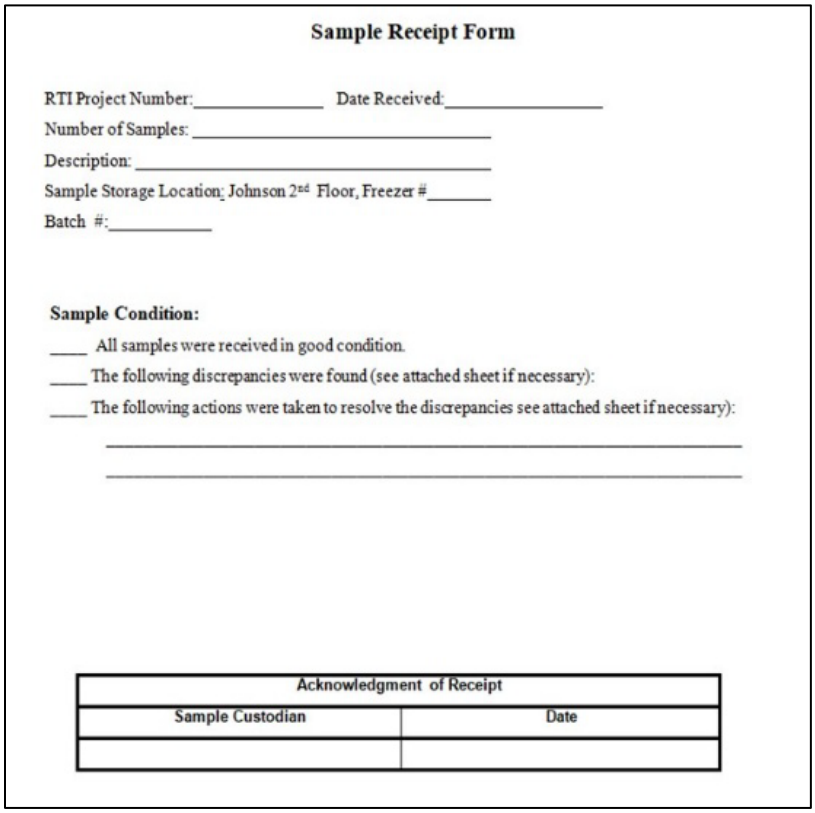
2.3.1.6 Unloading Filters

Nylon and quartz filters are removed from their cassettes and are shipped for analysis to RTI and DRI, respectively. Each filter is placed in its own Petri dish and the Sample Identification label is transferred from the cassette to the Petri dish. The Petri dishes are placed into a white Petri shipping tray that contains fifty Petri dishes. Each tray is labeled with the site and sample date of the first and last filters in the box and the filter type: B (Nylon) or C (Quartz). Details of these procedures are given in AQRC *TI 251F: Post Sample Processing* (Appendix 5.1.1). The A and D module (PTFE) filters are weighed and placed in lab dishes, as described in AQRC *TI 251H: Post-Sample Weigh-In* (Appendix 5.1.1). Module A filters undergo subsequent non-destructive analysis by EDXRF, HIPS, and other analysis, if scheduled.

2.3.1.7 IC Analysis

The sampled nylon filters are shipped to the ion contractor (RTI) approximately once a week, in batches of approximately 400 filters. Sample lists with the site and date of each filter in the tray are printed and included with the filters. Electronic sample lists are emailed.

At RTI, the set number and date received are recorded on a Sample Tracking and Extraction log. A Sample Receipt Form (Figure 6) is filled out when samples are received by the laboratory. Samples arrive at room temperature but are then stored at $<0^{o}$ C in a freezer until extraction. They are moved into refrigerated storage and remain overnight prior to analysis. Samples are extracted at room temperature and allowed to sit overnight immediately following extraction and sonication. Unused sample portions are refrigerated for up to 2 years beginning from the sampled date. Analysts use gloves rinsed in deionized water when handling filters, extracts, calibration standards and QC standards. Following DI water addition during extraction, samples remain capped throughout storage to minimize exposure to the laboratory environment. Sample vials are uncapped briefly during aliquoting for analysis and are recapped immediately afterward. Details of the analysis are given in RTI *SOP Ion2: Determination of Anions and/or Cations Extracted from Nylon® Filters by Ion Chromatography (IC)* (Appendix 5.1.2).



Sample Receipt Form

RTI Project Number:_____ Date Received:_____
Number of Samples: _____
Description: _____
Sample Storage Location: Johnson 2nd Floor, Freezer #_____
Batch #:_____

Sample Condition:

____ All samples were received in good condition.
____ The following discrepancies were found (see attached sheet if necessary):
____ The following actions were taken to resolve the discrepancies see attached sheet if necessary):
_____
_____

Acknowledgment of Receipt	
Sample Custodian	Date

Figure 6. Example Sample Receipt Form used by RTI upon receipt of filters from AQRC.

2.3.1.8 Multiwavelength TOR/TOT Analysis

The sampled quartz filters are shipped from AQRC to the carbon contractor (DRI) approximately once a week, in batches of approximately 400 filters. Sample lists with the site and date of each filter in the tray are printed and included with the filters. Electronic sample lists are emailed.

After receiving filters from AQRC, Module C (quartz) samples are stored in a freezer until analysis. On the day of analysis, samples are retrieved from the freezer and stored in a cooler or in the analysis room refrigerator. Details are provided in DRI *SOP 2-111: Sample Shipping, Receiving, and Chain-of-Custody* (Appendix 5.1.3).

2.3.1.9 EDXRF and HIPS

Module A (PTFE) filters in their lab dishes are placed in trays and are taken for analysis to the XRF lab and HIPS lab. Filter preparation and tracking procedures for these analysis steps are discussed in AQRC *TI276A: Preparation of Filters for HIPS Analysis* and AQRC *TI301B: Sample Changes for 8-Position Trays* (Appendix 5.1.1). Each PTFE filter has a matrix code and numerical ID that is used for tracking progress of the filters through each analysis procedure. These are scanned via handheld or automatic scanners before being loaded into the instruments for analysis.

2.3.1.10 Archiving

After all analyses of the A filters are completed, the A and D filters are archived indefinitely in a clean, but not climate-controlled, environment at AQRC. At the archiving step, filters are organized, stored, and logged in groups in a database so the physical filters can be found later.

RTI stores nylon extracts after analysis in a refrigerator at ~ 4°C for a minimum of six months following analysis.

After analysis of quartz filters, samples are returned to the refrigerator and stored in industrial-sized coolers at <4°C indefinitely. Temperature is continuously monitored, and emergency backup power is supplied during outages.

2.3.2 Laboratory Accreditation/Certification and Compliance with EPA Competency Policy

RTI is accredited by the American Industrial Hygiene Association Laboratory Accreditation Programs, LLC (AIHA LAP, LLC) for the analysis of anions and cations extracted from filters and sorbent media by ion chromatography (laboratory ID 100600).

DRI's Environmental Analysis Facility is accredited with the National Environmental Laboratory Accreditation Program (NELAP, http://www.nelac-institute.org/), which conducts biennial systems and performance to verify analytical capabilities and quality systems.

RTI and AQRC also participate in interlaboratory performance evaluations such as MegaPE for CSN (https://www.epa.gov/amtic/chemical-speciation-network-interlaboratory-performance-evaluation-comparison-results) and Environment and Climate Change Canada Proficiency Testing Program (RTI).

These accreditations and evaluations demonstrate that participating laboratories operate under established quality systems, employ validated analytical methods, and undergo regular independent assessments. In accordance with EPA's Competency Policy for assistance agreements, these elements provide objective evidence of organizational competence for the generation and analysis of environmental data used in this project.

Laboratory activities are further governed by this QAPP and associated SOPs, ensuring that data collection and analysis meet project DQOs. Personnel qualifications and training requirements supporting these laboratory activities are described in Section 1.6.

2.4 QUALITY CONTROL

2.4.1 IMPROVE Sampler Quality Control

2.4.1.1 Field Team Personnel

AQRC Field Team maintenance personnel perform routine maintenance on each site and IMPROVE sampler every other year. Quality control activities conducted during site visits include flow checks with a Magnehelic gauge, temperature checks with a NIST-certified thermometer calibrations, leak checks, and denuder replacements. Field personnel also inspect for airflow obstructions such as spiderwebs or debris. When repairs are required due to environmental damage or weather, the team completes the necessary work to restore the site to normal operating condition. All procedures are documented in AQRC *SOP 226*: *Site Maintenance* and the associated TIs. If needed, the field team make additional trips between routine visits to address urgent issues. Two magnehelic devices are brought on all Field Team maintenance trips and consistency between the devices is checked using a BIOS Definer 220 calibrator (measured flow rates must be within 2%) prior to the trip. Magnehelic devices are also audited after every maintenance trip.

The magnehelic devices are calibrated every year in house using a standard flow meter and the standard flow meter is certified by the manufacture annually. The NIST-certified thermometers are used during maintenance trips before their expiration dates and replaced with new NIST-certified thermometers after the expiration dates. The field group's shop manager controls calibration records.

Any issue discovered on site during a site maintenance trip that has the potential of affecting sampling will be written up in a JIRA issue (a web-based ticket tracking system used by AQRC). The field technician should also notify the AQRC Data QA team directly of these issues, so they can start the process of flagging all relevant samples.

2.4.1.2 Site Audits

Audits of IMPROVE sites and samplers are conducted routinely by an IMPROVE auditor and by state partners. Each site must have a full TSA conducted a minimum of once every 10-year cycle; sites that are replaced, moved, or were noted to have significant issues may be audited more frequently. A description of the site audit procedures is given in Section 3.1.1 and an example audit form is given in Appendix 5.2. This QC check covers both the hardware state of the sampler as well as the procedures that the site operator is performing. Descriptions of TSA procedures and results are provided in annual TSA reports prepared by the IMPROVE QAM (https://vista.cira.colostate.edu/Improve/technical-system-audits/). The NIST-traceable flow meters used for TSAs are calibrated and re-certified annually, and the IMPROVE QAM is responsible for maintaining the certification records.

2.4.1.3 Data Validation

Routine data validation at AQRC may detect an issue with a sampler or a site if one of several automated checks is unusual or fails. For example, during data validation there are checks of the historical record, the field blanks, operational settings, and between the

measurements taken from different modules (for example, $PM_{2.5}$ from Module A is compared to PM_{10} mass from Module D and sulfur from Module A is compared to sulfate from Module B). These data investigations may indicate an issue with the site or sampler that needs to be addressed for future samples. A more detailed description of the data validation process is given in AQRC *SOP 351: Data Processing and Validation* and associated TIs (Appendix 5.1.1). These activities include ingestion and integration of laboratory analytical results and field sampling data; application of automated quality control checks to evaluate data completeness, internal consistency, and instrument performance; and calculation of standard parameters (e.g., mass concentrations) using established IMPROVE equations. Data processing involves calculating sample volume from field data on flow rates and sampling duration and subsequently calculating ambient concentration, uncertainty, and method detection limit (MDL) for each analyte using the laboratory result plus the sample volume. Data are subjected to systematic screening to identify anomalies, outliers, and potential contamination, followed by technical review to confirm data validity. Validation procedures include verification of sampling metadata, flow rates, and analytical results against established acceptance criteria, as well as assignment of data quality flags to document limitations and usability. Final validated datasets are compiled, documented, and prepared for submission to FED and the EPA Air Quality Systems (AQS) Database, ensuring traceability and adherence to IMPROVE quality assurance requirements. Data processing and data validation are performed in parallel. Equations for calculating the uncertainties and MDLs are given in AQRC *TI 351B: Data Processing* (Appendix 5.1.1).

Field blanks are used for calculation of method detection limits (MDLs) reported for each species. Prior to 2018, MDLs for ions and carbon species were calculated as 2× the standard deviation of the field blank loadings, using a minimum of three field blanks collected in the sampling month for each filter type. Beginning with samples collected January 2018, AQRC harmonized the MDL calculation for ions and carbon species to be 95th percentile minus median of the field blank loadings, using 50 field blanks collected in and closest to the sampling month for each filter type. The MDL calculation for elements was not changed and is calculated as 95th percentile minus the median of field blank loadings, using 35 field blanks (AQRC *SOP 351: Data Processing and Validation*, Appendix 5.1.1). This calculation change for ions and carbon species was done to stabilize the MDLs and make them less susceptible to influence from field blank outliers. Appendix 5.3 provides a table summarizes calculated MDLs for IMPROVE data for 2020-2023.

All data flags used by each of the contracted laboratories is given in Appendix 5.4.

2.4.2 Gravimetric Quality Control

Gravimetric quality control is performed on a daily and weekly basis. All QC activities are summarized in Table 5, and full details are given in AQRC *SOP 251: Sample Handling*

Lab and accompanying TIs (Appendix 5.1.1) found on the IMPROVE website (https://vista.cira.colostate.edu/Improve/sops/).

Before analysis, filters are conditioned in the chamber for a minimum of 4 hours. The analysis procedure begins with certified test weights, and the MTL weigh chambers are programmed to take a QC measurement of these test weights every 4 hours until the cycle is complete. The test weights used are nominal 50 mg, 100 mg (matches weight of MTL 25 mm PTFE filters), and 200 mg. The tolerance for each test weight is ± 0.004 mg, as determined by capability analysis of the scale, test weight certification, and typical mass gain values. At a minimum, 2 of 3 test weights must pass to pass the daily QC check. If there are failures, the filters that are not bracketed by two passing QC measurements will be re-measured. If there are multiple failures in a short time, AQRC investigates the root cause (typically a balance must be recalibrated, or test weights need to be cleaned and recertified).

While test weights are measured, temperature and humidity levels are also recorded. Temperature tolerance is set for 21.5 °C ± 1.5 °C. Relative humidity is set for 39% ± 2%. These tolerances were chosen based on equipment capability, the PTFE filter characteristics, and previous research.

On a weekly basis, an automatic replicate analysis of the filters loaded in the MTL weigh chamber is conducted. Typically, this is the set of filters loaded on Friday and repeated over the weekend. Also on a weekly basis, an intercomparison of the same certified test weights on all active automatic balances routinely used for IMPROVE filters is run.

Table 9. Quality Control procedures for gravimetric analysis at AQRC.

QC Activity	Frequency	Reference Standards / Materials	Acceptance Criteria (MQO)	Corrective Action
Balance Performance Verification (Test Weights)	Daily and as needed	Certified test weights (50 mg, 100 mg, 200 mg, 400 mg)	Weight checks within ± 0.004 mg	Clean with air puffer and recheck; if still out of tolerance, investigate (may use other test weights) and recalibrate, then retest. If all repeat tests fail, designate instrument as out of service until technician repairs.
Temperature and Humidity Check	Daily	VAISALA HMT333	Temperature: 21.5 °C ± 1.5 °C RH: 39% ± 2%.	Check conditioning circuits for issues. Replace or service parts as needed.
Inter-Instrument Test Weight Comparison	Weekly	Certified test weights (50 mg, 100 mg, 200 mg, 400 mg)	New criteria under development	New corrective action is under development

Routine Replicate Analysis	Weekly	Field filters	New criteria under development	New corrective action is under development

2.4.3 HIPS Quality Control

Routine quality control procedures for the HIPS instruments ensure the stability, precision, and consistency of light absorption measurements in the absence of certified reference standards. Since no external standards exist for particulate light absorption on filter media, all HIPS quality control checks rely on internally established reference filters. Reference values for these filters are determined through multiple replicate measurements over several days to capture instrument and procedural variability. The system undergoes regular checks using neutral density materials and defined filter sets to verify detector performance, assess drift, and ensure consistent calibration response. Table 6 summarizes the routine quality control checks, acceptance criteria, and corresponding corrective actions for the HIPS instruments.

Table 10. Routine quality control checks for HIPS instruments.

QC Activity	Frequency	QC Materials / Filters	Acceptance Criteria (MQO)	Corrective Action
Registration Filter (Verification Set filter #3)	Before analysis and every 200 samples (≈5 trays)	Filter from Verification Set	Measured intensity within ±1% of reference value	Visually inspect filter for damage or contamination. If no damage found, rotate filter. Ensure sample was loaded correctly. Re-register detectors. Reanalysis required.
Verification Set Check	Daily (prior to analysis)	Set of 14 reference filters representing a range of absorbances	Raw detector response within ±3% of established reference values	Investigate deviation; verify detector stability; repeat verification until criteria met
Reanalysis Set (Drift Check)	Daily (once at the beginning of the analysis and once at the end of analysis)	Set of reference filters analyzed and reanalyzed in same day	Calibrated results within acceptance limits; no drift beyond control limits	Investigate instrument drift; reanalyze affected samples; verify stability before next batch
Routine Replicate Analyses	Once per batch (~80 filters, two trays)	Field or test filters	Criteria under development; replicate data currently collected for trend and precision evaluation	Continue data collection for control limit development; implement future criteria as defined in TI-HIPS-QC procedure

2.4.4 EDXRF Quality Control

The Epsilon 5 EDXRF instruments are subject to a structured quality control (QC) program consisting of daily, weekly, and monthly checks to verify analytical accuracy, precision, and instrument stability. Detailed procedures and acceptance criteria are documented in AQRC *TI 301C: Quality Assurance/Quality Checks (QA/QC) of XRF Performance* (Appendix 5.1.1) and all QA activities listed below are summarized in Table 7.

Daily: Each instrument contains a dedicated blank PTFE filter that is analyzed at the start of each operating day prior to sample analysis. Measured values must fall within established acceptance limits. If the blank exceeds control limits, corrective actions may include cleaning the filter with compressed air, replacing the blank, cleaning the diaphragm, or reanalyzing affected samples as necessary. Each instrument also contains a dedicated multi-element QC filter analyzed daily. QC elements include Al, Si, S, K, Ca, Cr, Fe, Zn, As, Se, Rb, Sr, Cd, Sn, and Pb. All QC elements must fall within the greater of ±10 percent or three standard deviations of their reference mass loading values.

Weekly: A single multi-element filter is analyzed on all operational instruments each week to assess instrument comparability. The same QC elements and acceptance criteria (±10 percent or 3 SD) apply. Replicate network samples are analyzed weekly, typically over weekends. Trays are programmed to automatically re-run upon completion of the first analytical cycle. Replicate results are evaluated for all elements except Br and Cl. Replicate uncertainty must not exceed three (3) times the analytical uncertainty for each element.

Monthly: A designated reanalysis set of multi-element QC filters with a range of loadings is analyzed monthly on each operational instrument. QC elements include Al, Si, S, K, Ca, Cr, Fe, Zn, As, Se, Rb, Sr, Cd, Sn, and Pb. A z-score is calculated for each element, which must fall within ±1.0. A NIST-certified SRM 2783 filter (air particulate on PTFE) is also analyzed monthly on all operational instruments. QC elements include Al, Si, S, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, and Pb. Elemental bias must be within defined acceptance limits.

If any QC check fails to meet acceptance criteria, the affected instrument is investigated in accordance with procedures in TI 301C. Appropriate corrective actions may include instrument cleaning, recalibration, component replacement, or reanalysis of affected samples. Network samples analyzed after a failing QC test are reanalyzed unless the investigation determines that data impact is negligible.

AQRC documents all QC failures, investigations, and corrective actions in the instrument log. Data flags, comments, reports, and advisories are applied when warranted to ensure transparency in data reporting.

Any staff member may report concerns regarding data quality to the AQRC Laboratory Manager or AQRC Laboratory QAM. Reported issues are formally investigated to

determine root cause, scope, and data impact. Corrective and preventive actions are identified and implemented as appropriate, and all activities are documented in accordance with the QA program requirements.

Table 11. Routine quality control checks for XRF instruments.

QC Activity	Frequency	QC Materials / Elements	Acceptance Criteria (MQO)	Corrective Action
Blank Filter Check	Daily	Dedicated blank PTFE filter	All measured elements within established blank acceptance limits	Clean or replace blank filter; clean diaphragm if contamination suspected; reanalyze affected samples
Multi-Element Filter Check (Instrument-Specific)	Daily	Al, Si, S, K, Ca, Cr, Fe, Zn, As, Se, Rb, Sr, Cd, Sn, Pb	Each element within ±10% or 3 SD of reference value (whichever is larger)	Investigate deviation; rerun QC; recalibrate instrument if required
Inter-Instrument Multi-Element Comparison	Weekly	Same multi-element filter analyzed on all instruments; same QC elements as above	Each element within ±10% or 3 SD across instruments	Investigate instrument alignment; recalibrate or service if bias identified
Network Sample Replicate Analysis	Weekly	Field samples (excluding Br, Cl)	For each element, z-score ≤ 3	Identify source of variation; verify analytical setup; reanalyze if limits exceeded
Reanalysis Filter Set	Monthly	Al, Si, S, K, Ca, Cr, Fe, Zn, As, Se, Rb, Sr, Cd, Sn, Pb	z-score within ±1.0 for all QC elements	Investigate outliers; review calibration stability; recalibrate if trend persists
NIST SRM 2783 Calibration Verification	Monthly	Al, Si, S, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Pb	Elemental bias within defined acceptance limits per TI 301C	Perform troubleshooting per TI 301C; rerun SRM; recalibrate instrument if necessary
Data Review and Flagging	Continuous	All sample and QC results	All QC results within acceptance limits prior to data release	Apply data flags or advisories as needed; document findings and resolutions in instrument log

2.4.5 IC Quality Control

Calibration and QC standards are prepared through serial dilutions of concentrated NIST traceable standards purchased from outside vendors. QC samples are analyzed at the beginning and end of each analytical sequence and after every ten samples to verify instrument stability and calibration integrity.

Matrix spikes are prepared by fortifying separate aliquots of representative samples with known concentrations of target analytes. Each analytical batch of 50 samples includes three duplicate analyses and two matrix spikes to assess precision and accuracy.

If any QC standard exceeds acceptance limits, all samples bracketed by the failed QC standards are reanalyzed. QC failures are infrequent, occurring in approximately 1% of analytical batches.

Concentrations of all analytes are determined from the measured mass, corrected for the median artifact determined from designated field blanks, and normalized to the sampled volume. Reported uncertainty incorporates contributions from volume measurement error, instrument calibration uncertainty, and the standard deviation of field blank values.

Overall analytical precision is characterized by the standard deviation of the difference between the measured values of the QA standards and the predicted values, recoveries of spiked samples, and differences between duplicate samples. A summary of QC sample types, frequency, acceptance limits, and corrective actions is provided in Table 8.

Table 12. QC Samples and Acceptance Criteria for Ion Analysis at RTI.

QC Activity	Frequency	Acceptance Criteria (MQO)	Corrective Action
Calibration regression	Daily	R^2 >0.999	Investigate, and then repeat calibration
Continuing calibration verification check standard (RTI dilution of a commercially prepared, NIST-traceable QC sample)	Daily, immediately after calibration and at every 10th sample	Measured concentrations <0.050 milligrams per liter (mg/L) within 35% of known values Measured concentrations >0.050 mg/L within 10% of known values	Investigate, and then reanalyze the samples
Replicate	3 per batch of 50 samples	RPD = 10% at 10 times MDL	Replicate
Spiked sample extract	2 per batch of 50 samples	Recoveries between 90% to 110% of the target values	Investigate, and then reanalyze
Reanalysis	5% per batch reanalyzed on a different day and as requested	MDL – 10 times MDL percent differences up to 200% 10–100 times MDL percent differences <20% >100 times MDL differences within 10%	Investigate from batch; if needed, reanalyze samples

2.4.6 Multiwavelength Thermal Optical Reflectance/Thermal Optical Reflectance/Transmittance Quality Control

Routine quality assurance and quality control (QA/QC) activities are conducted to ensure the accuracy, precision, and stability of multiwavelength thermal–optical carbon analyzer measurements as outlined in DRI *SOP 2-226: DRI Model 2015 Multiwavelength Carbon Analysis (TOR/TOT) of Aerosol Filter Samples - Method IMPROVE_A* (Appendix 5.1.3). These checks are designed to verify instrument performance, calibration integrity, and analytical consistency across all operational periods. The QA/QC program incorporates a combination of daily, weekly, and periodic procedures, including system and laboratory blanks, gas and liquid standard calibrations, replicate analyses, and temperature verifications. NIST-traceable standards and certified reference materials are used wherever applicable to maintain traceability and comparability of results. Table 9 summarizes the QA/QC activities, frequencies, materials, acceptance criteria, and corrective actions implemented to maintain data quality and instrument reliability for carbon analysis.

Table 13. Summary of Quality Assurance/Quality Control Activities for TOR/TOT Analysis at DRI.

QA/QC Activity	Frequency	QC Materials and Range	Acceptance Criteria (MQO)	Corrective Action
System Blank Check	Once per week	NA[a]	<0.2 µg C	Check instrument.
Laboratory Blank Check	Beginning of analysis day	NA[a]	<0.2 µg C	Check instrument and filter punch and re-bake
End-of-Run Internal Calibration Peak Area Check	Every analysis	NIST-traceable 5% CH_4/He gas standard; 20 µg C (6-port valve injection loop, 1000 µl)	Typical counts 14,000-25,000 and 90-110% of average calibration peak area of the previous day.[b]	Void analysis result; check flowrates, leak, and 6-port valve temperature; conduct an auto-calibration; and repeat analysis with second filter punch.
Auto-Calibration Check[e]	Alternating beginning or end of each analysis day[e]	NIST-traceable 5% CH_4/He gas standard; 20 µg C (Carle valve injection loop, 1000 µl)	Relative standard deviation of the three injection peaks <10%.[b]	Troubleshoot and correct system before analyzing samples.
Manual Gas Injection Calibration[e]	Maximum of four times a week[d,e]	NIST-traceable 5% CO_2/He gas standards; 20 µg C (Certified gas-tight syringe, 1000 µl)	<±5% of calculated standards based on individual tank specifications	Troubleshoot and correct system before analyzing samples.

Sucrose Calibration Check	Alternating days	10µL of 1200 ppm C sucrose standard; 12 µg C	11-13 µg C	Troubleshoot and correct system before analyzing samples.
Potassium Hydrogen Phthalate (KHP) Calibration Check	Alternating days	10µL of 1200 ppm C KHP standard; 12 µg C	11-13 µg C	Troubleshoot and correct system before analyzing samples.
Semiannual Performance Verification	Every six months	10 µl of 150 ppm and 1200 ppm KHP or sucrose solution; 20 µl of 150 ppm and 1200 ppm KHP or sucrose solution	The calibration slope is within ± 10% of previous slope.	Troubleshoot and conduct full carbon calibration if necessary.
Multiple Point Calibrations	Every 12 months or after major instrument repair	150 ppm C Potassium Hydrogen Phthalate (KHP) and Sucrose; 1200 ppm C Potassium Hydrogen Phthalate (KHP) and Sucrose; NIST-traceable 5% CH4/He, and NIST-traceable 5% CO2/He gas standards; 1.5-24 µg C for KHP and Sucrose; 4-20 µg C for CH4 and CO2	The carbon/signal ratio (slope) for each calibration point is within ± 10% of average ratio for all calibration points in the set.	Redo calibration for individual points with slopes differing by > ±10% from the average slope. If the overall slope differs from previous slope of the analyzer by >± 10%, verify if major maintenance has occurred. Troubleshoot instrument and repeat calibration if necessary.
Sample Replicates (second filter punches on the same or a different analyzer)	Every 10 analyses	NA	±10% of avg. of two values when avg of OC or TC ≥10 µg C/cm^2 ±20% of avg. of two values when avg of EC ≥ 10µg C/cm^2 ±1 µg/cm^2 when avg of OC or TC <10 µg C/cm^2 <±2 µg/cm2 when avg of EC <10µg C/cm^2.	Investigate instrument and sample anomalies and rerun replicate.

Temperature Calibrations	Every six months, or whenever the thermocouple is replaced	NIST-traceable thermocouple	Linear relationship between analyzer and NIST-traceable thermocouple values with R^2>0.99.	Troubleshoot instrument and repeat calibration until results are within stated tolerances.
Oxygen Level in Helium Atmosphere (using LD8000[c])	Every 12 months	25 ppm, 50 ppm, 75 ppm and 100 ppm certified gas standards	< 100 ppm O_2	Replace the He cylinder and/or O_2 scrubber.

[a] NA: Not Applicable.
[b] Typical, but not required by the calibration guidelines
[c] Trace impurity analyzer (Model LD8000, Rotronic Instruments Corporation, Inc, Hauppauge, NY, USA)
[d] Assuming operation on a 24 hour/7 day per week schedule
[e] Only applicable following periods of non-operation in laboratory

2.4.7 Field Blanks

Field blanks are used to estimate the background contamination on sample filters, for blank correction, and for minimum detection limit (MDL) determination. The field blank cassette is identical to the normal cassette and placed in the same cartridge. The controller does not allow any air to pass through the field blank. The field blanks go through normal sample handling and analysis, and no special treatment for field blanks is needed at the site. Field blanks for all four modules are prepared at a rate of ~40 per month for modules A and B, ~30 per month for module C, and ~20 per month for module D.

With the introduction of the PANalytical XRF instruments in 2011, the median monthly PTFE field blank loading for each element is subtracted from the sample loadings to correct for background contamination. Prior to that only spectral background subtraction was performed by the XRF software. The nylon field blanks are used to estimate the artifacts of the ionic species, and the quartz field blanks are used to estimate the artifacts of the carbonaceous aerosol. The blank values are generally small compared to those on ambient filters but are not negligible.

Field blanks may be invalidated for similar reasons to a sample. Field blank weights can be in a range of ±0.005 mg. If outside this range, a message in AQRC's Improve Filter Processing balance application will pop-up and an automated analysis comment is added to the IMPROVE filter's gravimetric measurement analysis record. AQRC's data validation team investigates to determine if the field blank filter received a sample and if the filter may need to be re-weighed or invalidated.

2.4.8 Site Co-locations

In 2003, IMPROVE began co-located measurements at select IMPROVE sites. At most of

these selected sites, a fifth sampling module (which is an identical sampler to one of the A, B, C, or D modules) is added to the aerosol sampler. At a few sites, a complete set of samplers has been installed. Comparing sample data from the duplicate module allows for an estimate of the overall precision and uncertainty in the measurements across the network from all sources.

2.5 Instrument Calibration, Testing, Inspection, and Maintenance

2.5.1 IMPROVE Sampler Testing and Maintenance

The Field Team remotely monitors all sites to determine if the sites are online and operating normally. When a sampler malfunction occurs (either as noted by the field team or by the site operator), AQRC Field Team staff first work with the site operator via phone or email to diagnose and resolve the issue. If the problem involves a removable component, a replacement part is shipped to the site operator. The Field Team maintains a significant storage of spare parts (controllers, stacks, pumps, etc.) and replacement modules to allow for immediate shipment. If necessary, a complete replacement module is sent. As a last resort, AQRC staff travel to the site to perform repairs.

During biennial site visits, field technicians inspect and verify sampler operation, including solenoid function, vacuum pressure, and electronic controls. They clean the inlet head, inlet stack, and internal cyclone; replace worn components; and calibrate or adjust flow rates as needed. If a problem that affects flow rate or system vacuum is identified, the technician will have to perform two flow checks: one with the existing problem and a second check once the problem is corrected. Technicians also review sampling procedures with operators and provide refresher or new-operator training.

All equipment modifications are tested at the AQRC Field Test Station prior to deployment in the network.

During installation and any routine site visits, the field technician performs a flow check using a digital magnehelic and probe and a site-specific flow check/flow adjustment spreadsheet. The flow check tests current flow rates and equations to determine whether there has been any drift since the last maintenance visit and if adjustment is necessary. Further details on the procedure are described in AQRC *TI 226B: Flow Check* (Appendix 5.1.1). Before cleaning the modules, the field technician also performs a leak check of the sampling modules. The field technician checks the vacuum gauge reading from each pump and module to find possible existing leaks in vacuum system and weak pumps. If a difference between pump and module is greater than 2.0” Hg, the field technician pays close attention when cleaning the modules to identify where the leak is located and corrects it. If a pump vacuum is greater than -20” Hg, the pump is considered “weak” and should be flagged for replacement. Instructions on the leak check procedure are given in AQRC *TI 226E: Leak Check* (Appendix 5.1.1).

After finishing all maintenance procedures, the field technician checks the zero flow values for all modules. Pressure/Orifice readings should be 14.7 psi, and lower as elevation increases. Flow/Cyclone readings will be around 3.3. The field technician then verifies the flow rate on all $PM_{2.5}$ modules (1A, 2B, and 3C) run at a nominal rate of 23 lpm, and the PM10 module (4D) to run at a rate of 16.9 lpm. The techniques used to set nominal flow rate and check it against a standard are explained in AQRC *TI 226C: Flow Adjustments*.

Any issue discovered on site that has the potential of effecting sampling is written up in a JIRA issue (a web-based ticket tracking system used by AQRC) by the field technician, who also directly notifies the QA team of the team, so they can start the process of flagging all relevant samples.

After maintenance visits, the flow data is scrutinized to ensure that the final flow rate check was performed properly and that the resulting flow data are valid, as well as to confirm that any replaced equipment is working appropriately. Action is taken immediately if any equipment appears to be malfunctioning or if any of the flow data differs significantly from what was expected.

2.5.2 Gravimetric Laboratory

Two Mettler Toledo (MTL) AH500 automated weighing chambers, two Mettler Toledo XPR6UD ultrabalances, and one Mettler Toledo XPR6 microbalance are employed for gravimetric analysis of IMPROVE samples. The MTL weighing chambers are maintained under the supervision of AQRC staff. Routine maintenance, troubleshooting, and minor repairs are performed by staff unless an issue requires service by a qualified external technician. Routine maintenance activities focus on mechanical and environmental control systems. Each weighing chamber undergoes a comprehensive annual preventative maintenance inspection, typically requiring approximately two days to complete. During this process, chamber operations are suspended, and all critical mechanical and electronic components are inspected for wear or misalignment. Components are repaired, replaced, or realigned and system fluids are drained and replenished as needed. Upon completion of maintenance activities, chamber functionality is verified using certified test weights prior to returning the chamber to routine operation.

Software maintenance is performed as necessary to ensure secure and reliable operation. AQRC currently operates the weighing chambers using the MTL-provided Windows-based control system. Firmware, driver, and software updates are applied as required for cybersecurity compliance and operational stability. AQRC staff coordinate with MTL technical support to resolve software or firmware-related issues. When permissible under network security policies, software configurations are stabilized to maintain consistency in data acquisition and processing.

The Mettler Toledo analytical balances used for filter weighing are calibrated annually in

accordance with manufacturer specifications and standard laboratory practice. Calibration services are performed on-site by a qualified technician. Following calibration, a certification label indicating the expiration date is affixed to each balance. Calibration verification is performed using certified test weights to confirm that balance performance is within tolerance across the working mass range. If a malfunction or deviation is detected during operation, or if a balance is damaged, corrective service and recalibration are performed prior to resuming use, regardless of the scheduled calibration interval.

AQRC maintains multiple sets of certified test weights (nominal 50 mg, 100 mg, 200 mg, and 400 mg) for routine balance verification before and during each weighing session. The 50 mg, 100 mg, and 200 mg weights are used for daily QC checks; the 400 mg weight is used only as needed for higher-mass samples. Test weights are calibrated annually by an accredited external vendor. During calibration of one set, a second certified set is rotated into use to ensure continuity of operations. If particulate contamination (e.g., dust) is suspected on a test weight, it is gently cleaned with an air puffer and rechecked. If a test weight fails verification after cleaning, it is removed from service, investigated, and recalibrated or replaced as necessary.

Each weigh chamber is equipped with a VAISALA HMT333 temperature and humidity probe for continuous environmental monitoring. These sensors are calibrated annually by an accredited external vendor. While one sensor is out for calibration, an identical calibrated backup unit is rotated in to maintain uninterrupted monitoring.

2.5.3 HIPS

The HIPS measurement is a novel analytical process, and no established standards exist for the light absorption of particulate matter on filter media. Thus, AQRC does not conduct routine calibration or maintenance beyond the criteria specified in the Quality Control procedures. Instead, measurement consistency is verified over time using the same reference filters described in Section 2.4.3.

The instrument requires minimal routine maintenance, as it contains few moving parts and has demonstrated long-term mechanical reliability. Repairs are performed on an as-needed basis, though such instances are infrequent. The primary criterion for determining the need for maintenance, repair, refurbishment, or upgrade is the laser intensity measured at the detector. Laser alignment is conducted manually, with incremental adjustments made until the maximum detector response is achieved, indicating proper alignment.

Following any hardware modification, the Registration Filter, Verification Set, and Reanalysis Set are re-evaluated to confirm that all results remain within established tolerances.

2.5.4 EDXRF

Each week, the liquid nitrogen (LN_2) dewar associated with each PANalytical Epsilon 5

X-ray fluorescence (XRF) analyzer is refilled with LN_2 to ensure proper cooling of the detector. Approximately two hours after refilling, an automatic detector calibration is initiated in the Epsilon 5 software. Upon completion of the calibration, detector Q-values are compared to previous results to ensure no large drift has occurred in the detector.

Twice a year, manufacturer-certified service personnel perform on-site preventative maintenance of all Epsilon 5 instruments. Preventative maintenance activities include inspection, functional testing, and servicing of all systems and components. Repairs, component replacements, and realignments are performed as required. Between scheduled semi-annual services, AQRC staff perform limited maintenance or component checks as necessary to diagnose and correct performance issues.

The Epsilon 5 instruments undergo full calibration annually using certified reference materials and internal standards in accordance with *TI301C: Quality Assurance/Quality Checks (QA/QC) of XRF Performance*. The calibration process requires approximately one week to complete and includes standard analysis, calibration curve development, and verification. Each instrument maintains an independent calibration application tailored to its detector characteristics, though all are developed using the same suite of calibration materials. A mid-year calibration may be performed if performance checks indicate drift or deviation from established control limits.

In the calibration process, NIST Standard Reference Material (SRM) 2783, *Air Particulate on Filter Media*, are analyzed. Calibration elements include Al, Si, S, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, and Pb. Each element's calibration curve must achieve a correlation coefficient (R^2) ≥ 0.98 and fall within established acceptance limits. If calibration results fail to meet required performance criteria, troubleshooting steps defined in *TI 301C* are executed under the supervision of the Laboratory Manager or Spectroscopist.

In addition, blank PTFE filters from the current production lot are analyzed during calibration verification. Results must fall within established acceptance limits; however, up to two (2) elements may exceed these limits under justified conditions as defined in *TI 301C*. Internal AQRC multi-element QC samples are also analyzed to verify analytical accuracy. The QC elements include Al, Si, S, K, Ca, Cr, Fe, Zn, As, Se, Rb, Sr, Cd, Sn, and Pb. Each element must fall within the greater of ±10% or three (3) standard deviations of its reference mass loading value. Finally, a designated set of multi-element QC reanalysis filters is analyzed on each Epsilon 5 instrument to assess reproducibility and long-term stability. The QC elements are identical to those in the multi-element sample check. For each QC element, a z-score is computed; acceptable results are defined as z-scores within ±1.0.

2.5.5 Ion Chromatography

RTI staff use the following analytical instruments to perform the required anion extraction

and analysis, a Thermo Fisher Scientific ICS-6000 Dual Anion Channel Instrument, three Thermo Fisher Scientific Dionex Aquion IC instruments, two SimPrep Autodilution Systems (SimPrep), and an ultrasonic bath using Polymer test tube racks.

RTI maintains a service contract for all instruments used for IMPROVE analysis. Manufacturer-recommended preventative maintenance is performed annually by qualified vendor service technicians. IC laboratory personnel are responsible for routine maintenance and replacement of consumable components, including guard columns, analytical columns, and suppressors. Repairs involving major instrument components are performed by the instrument manufacturer or authorized service provider. Records of all maintenance activities, repairs, and consumable replacements are maintained in the instrument laboratory notebooks maintained for each instrument. . The RTI Laboratory Manager is responsible for ensuring that all pieces of equipment are tested, inspected, and maintained prior to and during use.

Calibrations are performed at a frequency stated in the applicable analytical method or respective instrument SOP. Multipoint calibrations (0.05 to 25.0 parts per million [ppm] for NO_2^-, NO_3^- and SO_4^{2-}; 0.01 to 5.0 ppm for Cl^-) are performed daily. Calibration is followed by analysis of QA and QC samples, which include the following: (1) QC samples spiked with anions which target the upper, mid, mid-high and high level of the calibration curve and (2) QC samples spiked with anions that target the 25^{th}, 50^{th} and 75^{th} percentile concentrations measured in routine samples. Calibrations are quadratic fits for all ions with a continuous curve and no midpoint standards excluded. If needed, the lowest standard can be excluded if the required reporting limit is still met. If the highest standard is excluded, then the chemist must ensure that all samples are bracketed by the remaining standards.

2.5.6 Thermal Optical Reflectance/Thermal Optical Transmittance Maintenance

Routine maintenance procedures for carbon analyzers are specified in DRI *SOP 2-226: DRI Model 2015 Multiwavelength Carbon Analysis (TOR/TOT) of Aerosol Filter Samples – Method IMPROVE_A* (Appendix 5.1.3), which includes checks of thermocouples, system leaks, and MnO_2 oxidizing capacities. Daily maintenance activities include verifying compressed gas supplies, cleaning punches used for filter subsampling, cleaning forceps between samples, performing calibrations in accordance with the SOP schedule (twice daily), conducting leak and flow checks, and backing up data files. Laser and CO_2 detector responses (both physical and electrical) are also checked daily.

Calibration and performance test standards and their maintenance are also described in DRI *SOP 2-226: DRI Model 2015 Multiwavelength Carbon Analysis (TOR/TOT) of Aerosol Filter Samples - Method IMPROVE_A* (Appendix 5.1.3). Calibration standards consist of 5% nominal CH_4 in He, 5% nominal CO_2 in He, KHP (potassium hydrogen phthalate), and sucrose. Calibration gases are used daily as analyzer performance monitors. KHP and sucrose are used in conjunction with CH_4 and CO_2 semiannually to establish the calibration

curve of each analyzer.

Calibrations include an end-of-run calibration peak, beginning and end-of-day injections of He/CH_4 and He/CO_2 (or the auto calibration check), full instrument calibration, performed every six months (using KHP, sucrose, and the two calibration gases), and temperature calibrations performed every six months using a traceable temperature probe. Full instrument calibration, performed every 6 months or after major maintenance or repairs, establishes the calibration slope used in converting detector outputs to microgram equivalents. Instrument calibration involves spiking pre-fired quartz punches with 5.0 to 20.0 µl of the 1800 ppm KHP and sucrose solutions and injecting 200 to 1000 µl of the CH4 and CO2 gases. All calibrations, maintenance activities, and repairs are recorded in the individual analyzer logbook and documented in the online maintenance tracking system. These calibration procedures are included in the list of quality control activities in Table 8 in Section 2.4.6.

2.6 INSPECTION/ACCEPTANCE OF SUPPLIES AND SERVICES

PTFE filters are ordered, received, and inspected by the primary contractor, AQRC. Before receipt of the total order, a pre-delivery quantity of filters is requested from the supplier so that acceptance testing can be performed before the final production run is complete. These are tested for elements contamination by XRF and flow by loading into an IMPROVE sampler. Upon receipt, the inventory of boxes is compared to the shipping invoice for accuracy and the lot is noted. Then acceptance testing is repeated again on randomly selected filters from the delivered lot. More details can be found in Section 2.3.1.1 for pre-deployment acceptance testing and in AQRC *TI 251C: Filter Inventory and Acceptance* (Appendix 5.1.1 for list of SOPs and TIs).

Nylon filters are also ordered, received, and inspected by the primary contractor, AQRC. Before receipt of the total order, a pre-delivery quantity of filters is requested from the supplier so that acceptance testing can be performed before the final run is complete. Flow testing is performed by AQRC by placing the filters into an IMPROVE sampler. Approximately 10 filters from the pre-delivery boxes are sent to the RTI for acceptance testing. These acceptance tests are repeated when the final delivery is made from randomly selected filters.

Quartz filters are ordered, received, and inspected by DRI. After acceptance-testing and pre-firing, filters are shipped to AQRC. Acceptance testing is outlined in DRI *SOP 2-106: Pre-firing and Acceptance Testing of Quartz-Fiber Filters for Aerosol and Carbonaceous Material Sampling* (Appendix 5.1.3).

2.7 ENVIRONMENTAL INFORMATION MANAGEMENT

2.7.1 Project Process

AQRC is contracted as the coordinating laboratory for all field operations and speciation laboratory work. AQRC coordinates filter pre-sampling, shipping, sampling, and post-sampling activities. Figure 7 outlines the flow of filter samples and data through the different entities (as described in detail in Section 2.3.1). Filters are pre-weighed and Module C filters are pre-fired. Filter samples are organized and packaged and sent to field operators at all sites. Field operators install/change filters and then return the filters after sampling. AQRC analyzes Module A and D filters and sends Module B filters to RTI for ion analysis and Module C filters to DRI for carbon analysis. RTI and DRI have internal data verification and validation procedures for samples, and after completion of these quality checks, return results to AQRC. AQRC completes a full validation of all filter mass and composition results and adds quality flags to the data. The data are then sent to both AQS and to CIRA (for distribution on the FED website). After analysis, sampled filters are archived by the respective laboratories (Section 2.3.1.10).

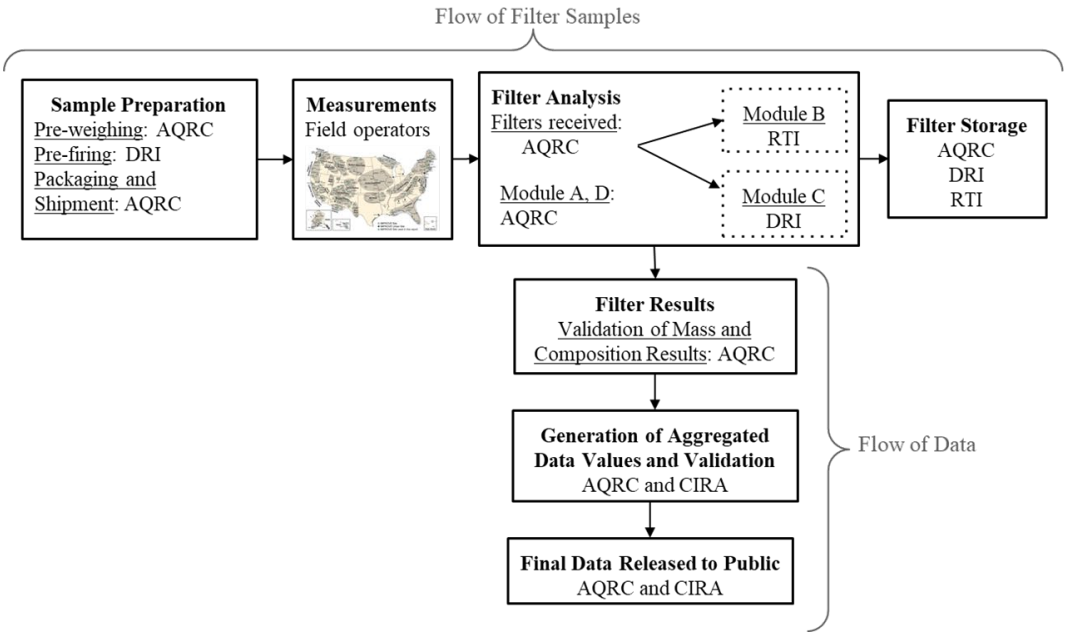


Figure 7. Flow chart of environmental measurement procedures depicting both the flow of filter samples and the flow of data after analysis of filter samples. Flow chart also notes the party responsible for each process.

2.7.2 Record-keeping Procedures

All AQRC SOPs and TIs are maintained on a secure shared server and reviewed periodically. The current approved versions are stored in a read-only folder accessible to staff, while draft documents are kept in a separate workspace and clearly watermarked as drafts. Superseded SOP versions are archived in restricted-access folders, with only authorized personnel, such as the Quality Manager, permitted to retrieve them. Hard copies of obsolete revisions are destroyed and replaced with current versions.

AQRC maintains nonconformance reports, corrective actions, planned process deviations, and related documentation on the shared drive. These records are reviewed, signed, and retained for future reference.

Field operator log sheets (example in Figure 4) are retained for a minimum of two years. During that time, flow data and field comments are electronically ingested from digital sources or manually entered as needed. After data validation and delivery, physical log sheets are discarded, as all information is preserved on the AQRC IMPROVE server.

Calibration records are retained for the life of each instrument and are available for review upon request (an example of calibration records is shown in Figure 6). Logbooks are kept for instruments where required. An example logbook for the EDXRF instruments is given in Figure 7. A digital log is also kept for lab-related activities such as maintenance or lot changes. Staff training records are stored electronically for the duration of employment. Current training and SOP revision records are readily available, while older records are archived for long-term retention. The laboratory and field managers maintain the binders of training records for each employee.

Improve Management Site | Home | Samplers | XRF | Analysis Data | Operations | Reports | Admin | Hello Jason | Log off

Analysis Data | Mass | Carbons | Ions | HIPS | FTIR | Analysis Paths

HIPS Calibrations

Add

CalibrationEffectiveDate	QcCode	Intercept / Uncertainty	Slope / Uncertainty	CalibrationDate	Wavelength	CalibrationSet	Comments	
8/7/2025 1:58:25 AM	1 (Valid)	1374.70 / 8.70	-2.60 / 0.05	8/13/2025 1:58:25 AM	633.00	MTL Lot 259 Lab Blanks Lot '259'	Initial calibration of MTL Lot 259.	Edit Delete
6/5/2025 12:00:00 AM	1 (Valid)	1447.60 / 6.40	-3.03 / 0.04	11/26/2025 1:30:04 AM	633.00	initial_264 Lot '264'		Edit Delete
10/29/2024 12:00:00 AM	1 (Valid)	1362.80 / 7.90	-2.51 / 0.04	11/26/2024 12:09:42 PM	633.00	Apr-2024 FB Lot '255'	Initial calibration for IMPROVE Lot 255.	Edit Delete
9/25/2024 12:00:00 AM	0 (Invalid)	1093.20 / 5.10	-1.42 / 0.02	9/25/2024 11:49:21 AM	633.00	PALL Lot 64247558 Lab Blanks - new set Lot '64247558'	Accidentally applied this calibration to the wrong Calibration set, so I'm invalidating it.	Edit Delete
9/25/2024 12:00:00 AM	1 (Valid)	1093.20 / 5.10	-1.42 / 0.02	9/25/2024 12:16:58 PM	633.00	QC_RA-001 Lot ''	Recalibration for the reanalysis set filters as they are showing some signs of a slight drift since the last calibration more than a year ago.	Edit Delete
8/21/2024 12:00:00 AM	1 (Valid)	802.30 / 3.50	-0.69 / 0.01	6/16/2025 12:39:27 PM	633.00	MTL 2um 25mm Lot 252 calibration for special projects Lot '252'	MTL 2 um pore size filter testing (August batch).	Edit Delete
6/26/2024 12:00:00 AM	1 (Valid)	828.70 / 3.70	-0.73 / 0.01	4/18/2025 12:44:50 PM	633.00	MTL 2um 25mm Lot 249 calibration for special projects Lot '249'	MTL 2 um pore size filter testing (June batch).	Edit Delete
6/1/2024 12:00:00 AM	1 (Valid)	1284.10 / 9.80	-2.12 / 0.05	6/28/2024 8:58:59 AM	633.00	PALL Lot 64247558 Lab	This is the second calibration of this Pall filter lot. It is being performed	Edit

Figure 8. Example of records keeping system at AQRC. Figure specifically shows the calibration records for the HIPS instrument.

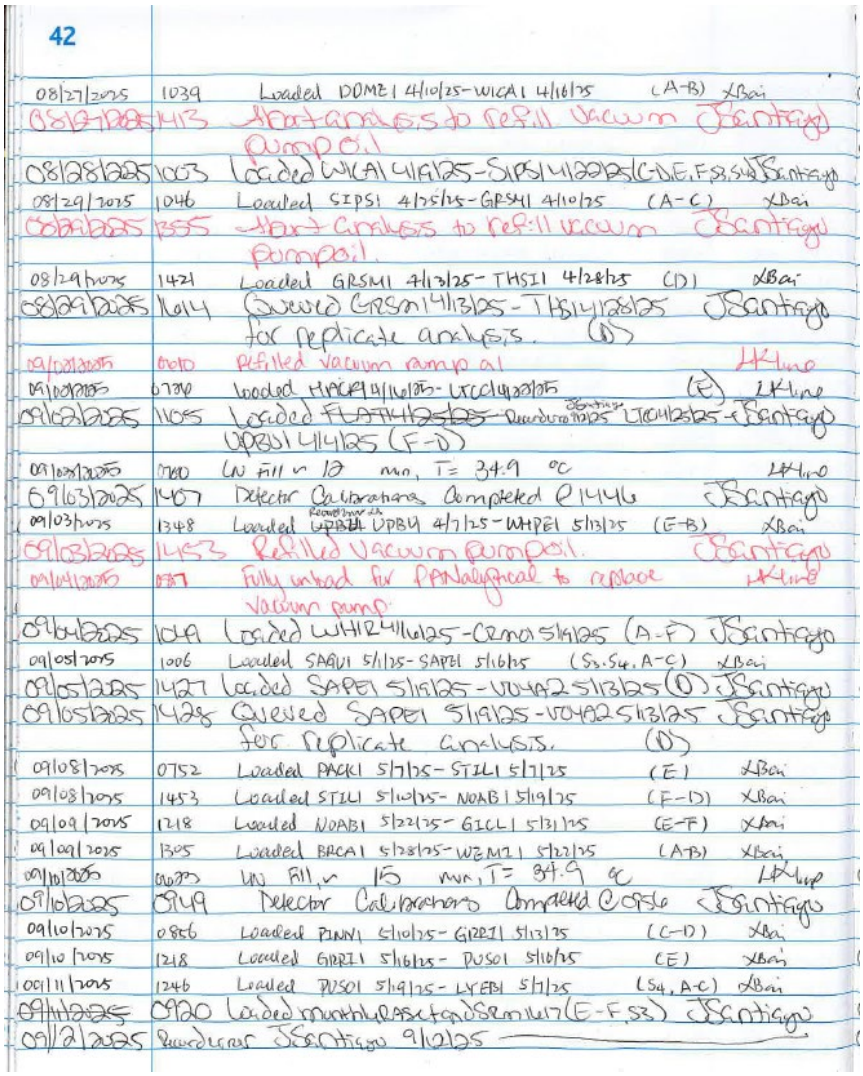


Figure 9. Example of an instrument logbook at AQRC. The specific example is for the EDXRF instrument.

AT RTI, current training and SOP revision records are readily available, while older records are archived for long-term retention. SOP revisions are tracked through the QMS with revisions histories, and older records are deemed obsolete with access restricted to the QAM. Training records are maintained as a continuous running history in each employee's training log.

At DRI, SOPs are reviewed during annual internal audits to determine where changes are needed. New revision numbers are issued for major changes, while minor changes (e.g., job titles, grammatical corrections) are made and documented within an addendum to the procedure.

2.7.2.1 AQRC Data Management

All IMPROVE data are stored and managed in a Microsoft SQL Server database maintained by AQRC. The production database operates on a dedicated Windows Server with RAID storage and offsite backups; differential backups are performed daily and full backups weekly. Development and test environments are virtual machines routinely restored from production backups to verify recovery procedures.

Custom AQRC software, developed on the .NET platform, manages data ingest, processing, and reporting. Data processing and calculations are implemented in R, with R Shiny applications supporting data validation and network oversight. Analytical data from laboratory instruments—including the PANalytical Epsilon 5 EDXRF, MTL Automated Weighing System, and Hybrid Integrating Plate and Sphere (HIPS)—are automatically transferred to the central database after each analysis. Field flow data are transmitted nightly from samplers to a secure server, with backup copies delivered on SD cards.

The relational SQL database serves as the central repository for all primary IMPROVE data, including filter weights, sampler flow rates, analytical results, and operator comments. Data from partner laboratories (ions from RTI and carbon from DRI) are integrated upon receipt. Database edits occur only through controlled software interfaces, with all transactions time-stamped to maintain a complete audit trail.

Access to databases and computers associated with the IMPROVE project is limited to authorized project personnel by use of access control lists for files, programs, and database access. Access to laboratory and office space is controlled by keycards. Unique passwords are issued to each employee by the UC Davis campus system administrator. Password integrity is monitored by the UC Davis campus system administrator, and system access is revoked for terminated personnel. The IT Administrator disables domain accounts and passwords upon termination of employment.

2.7.2.2 RTI Data Management

All raw data acquired by the instruments are stored on the computer hard drive, along with the processed data. At the completion of the study, or at least quarterly, data are transferred from the instrument hard drive to a secondary storage device used solely for this project. Data are transferred to a database from the instrument in an Excel format by use of a report template in the Chromatography software. A database file is prepared with all results from the appropriate standard curve. This file is imported into the Ion Lab Data Review Application for review. A QC report for each analytical batch is printed and maintained with hard copy files of the analytical queues, the chain-of-custody (COC) cover letter received from AQRC, the sample receipt form, extraction records, and a sample extraction log. After all data verification and validation, data are exported as a .csv file and sent to AQRC.

The servers on which the data management system applications are stored and maintained are backed up daily on a high-performance disk subsystem and redundant server hardware.

2.7.2.3 DRI Data Management

Specialized programs were created in LABview™, R, and Python languages to generate analysis logs, record analyzer inputs, document calibrations and quality control, review data, and prepare spreadsheets for transfer to the UC Davis data base. These programs provide dashboard noting the status of each analyzer, its maintenance activities, calibrations, and quality control tests.

2.7.3 Hardware/Software

AQRC maintains and upgrades the IMPROVE samplers, including hardware, firmware, and software components. All new hardware is tested in-house before limited field deployment at pilot sites. Following successful evaluation, upgrades are implemented across the network. Design files (e.g., 2D drawings, 3D models) and related documentation are stored on secure servers for reference and future use.

Software and firmware updates follow a similar process, including controlled testing, approval, and network-wide deployment. All versions are archived for traceability. AQRC-developed software supports instrument QC, data validation, reporting, scheduling, and network oversight, and is routinely verified prior to release.

Analytical instruments are maintained by AQRC personnel, manufacturers, and approved third-party vendors. Calibration records are maintained for all instruments and associated equipment requiring calibration.

DRI and RTI provide the laboratory facilities, instrumentation, computer systems, and consumables necessary to perform analytical tasks in accordance with contractual and quality specifications. Ion analyses are processed using Chromeleon™ instrument software.

3 ASSESSMENT, RESPONSE ACTIONS, AND OVERSIGHT

3.1 ASSESSMENTS

Regular assessments of the IMPROVE program are implemented to ensure that the data meet the primary objective of the IMPROVE program; namely, making high quality measurements of the concentrations and compositions of particles affecting visibility in CIAs.

3.1.1 Technical System Audits of Field Operations

Field sites must be audited periodically, with the goal of auditing each site at least once in every ten-year cycle. The QAM organizes field site audits annually and either performs the audit or coordinates with a trained designee. Field site audit forms are used for each

individual site audit (Appendix 5.2). The auditor verifies that equipment is working properly, and the site operator is following procedures in the SOPs. They also verify that the site includes current information (phone numbers, QA documents). Based on the results of these audits, the IMPROVE Operations contractor should address any minor problems found. Major problems are addressed by a joint committee including the PI of the IMPROVE Operations contractor (currently AQRC), the Steering Committee Chair, and the NPS Contracting Officer Representative on a timescale agreed upon by the joint committee.

A list of the elements assessed during a site audit, how they are evaluated, the acceptance criteria and required follow-up activity are given in Table 10.

Table 14. Summary of IMPROVE site field audit procedures.

Audit Category	Assessment Element	Evaluation Method	Acceptance Criteria	Corrective Action / Follow-Up
Personnel	Operator knowledge of IMPROVE protocols	Interview operator; observe procedures	Operator demonstrates familiarity with site operations, sampling schedule, and documentation requirements	Auditor and/or Field Team provides targeted retraining
Documentation	SOP availability and use	Verify current SOPs are accessible; operator walkthrough of procedures	Current SOPs available and followed	Auditor sends updated SOPs, operator acknowledges receipt
Sampling Modules	Flow rate verification (all modules)	Measure flow rates with certified flow meter and compare to specified setpoints	≤10% from nominal and recorded	Field Team recalibrates flow; repairs or replaces components; document adjustments; AQRC Data Analysis Team investigates data impact
Sampling Modules	Clock	Compare sampler clock to cell phone time	< 5 minutes difference	Auditor resets clock; verifies correct programming
Sampling Modules	Temperature	Certified temperature instrument	<10°F	Field Team sends replacement temperature probe
Siting	Coordinates	Compare recorded coordinates to GPS coordinates	<0.01°	Report to Field Team for database update

Siting	Inlet height and placement	Measure inlet height and distance, check level, compare to siting criteria	Inlets 24 inches apart; height between 1.5 and 3 m AGL	Field Team may adjust inlet configuration if feasible; document limitation if not
Siting	Proximity of obstructions (trees, structures)	Visual inspection of inlet surroundings, measurement of required distance	Area free of obstructions that affect airflow. ≤10 m distance, barriers should be > 1 m below inlet. ≥10 meters, barriers < 30° above horizontal with respect for the inlet	Site operator should remove/trim obstruction where possible; document impact
Infrastructure	Electrical supply and grounding	Inspect power stability, grounding, and outages	Stable power with no recurring disruptions	Site sponsor repairs electrical issues and sends follow-up documentation
Housekeeping	Cleanliness of shelter and equipment	Visual inspection	Clean, organized, and free of contamination sources	Site operator cleans site (auditor ask for follow-up photographs); auditor reinforces maintenance procedures
Filter Handling	Sample handling and storage practices	Observe handling; inspect storage conditions	Consistent with IMPROVE SOPs; no contamination risk	Auditor and/or site sponsor retrains operator; report to Field Team
Data Records	Field logs and documentation	Review log sheets	Complete, accurate, and timely entries	Site operator corrects deficiencies; auditor and field team reinforce documentation practices
Equipment Condition	General condition of sampler and components	Visual inspection; check for wear or damage	Equipment in good working condition	Auditor documents necessary maintenance; refer to Field Team for part replacement

The QAM summarizes all Field Audit results in an Annual Report which is presented to the Steering Committee and provided to NPS and the Field Team manager.

3.1.2 Technical System Audits of Laboratory Operations

External audits of the laboratories are performed by an auditor who is not affiliated with

the laboratory being audited and who is designated by the EPA OSAP Project Officer. These audits may be done specifically for the IMPROVE network or in conjunction with an audit of the Chemical Speciation Network (CSN) (which uses similar laboratory procedures). The external assessments include an on-site quality systems audit and TSA. The contracted auditor must be qualified to review quality systems both in terms of documentation and laboratory procedures. The auditors examine all aspects of operations to determine if processes and quality assurance programs being implemented are aligned with the QMP, QAPP, laboratory SOPs, TI documents, and with program and contractual requirements. The audit process should include the auditors, all necessary laboratory personnel including the project manager and QAM, representatives from the EPA and NPS, and the IMPROVE QAM. All results should also be reported to the IMPROVE Steering Committee.

After each audit has been completed, the post-audit activities are conducted to document the audit findings and corrective actions following details documented in Section 15.3.3 and Section 15.3.4 of the *EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II*. The audit report should be prepared and delivered for review within 30 days.

The organization being audited then has 30 days (or a shorter time period if agreed upon at the time of the audit) to respond to the audit report with comments and/or questions, following which the audit team lead finalizes the audit report. After receiving the final audit report, the organization being audited must respond to the findings documented within 30 days, providing a corrective action report that documents actions taken, timeline, responsibility, and status. Laboratory QAMs should keep records of the area of activity audited, the findings, and the corrective actions that arose from the audit and ensure that follow-up audit activities are conducted to verify and record the implementation and effectiveness of the corrective actions taken.

3.1.3 Internal Laboratory Assessments

Laboratory staff are responsible for performing internal audits of project activities that affect achievement and maintenance of the project DQOs. The internal assessments are performed to ensure that the QAPP is correctly implemented, that the data collected meet the measurement criteria for project DQOs, and that corrective actions are implemented in a timely manner. If data usability issues arise (e.g., deviations from SOPs or DQOs not met), then the laboratory QAM communicates with appropriate management staff and administer corrective actions, if necessary. Findings are documented in the reports described in Section 3.2.1.

At RTI, the laboratory QAM is responsible for scheduling, managing, and performing internal audits annually. Internal audits are conducted on a pre-determined schedule and address all elements of the management system. The laboratory QAM summarizes the

results in a report that is submitted to the program and laboratory managers for review.

AT AQRC, internal assessments are conducted as needed, or at least once every five years, by the Quality Assurance team. These assessments may take the form of audits or procedural reviews with spot checks for compliance.

At DRI internal audits are conducted during December of each year for carbon analysis as well as other analysis procedures. These include review and dating of primary and transfer standards, documentation and other paperwork, annual certificates of training and audits of data quality.

3.1.4 Audits of Data Quality

Audits of Data Quality (ADQs) involve post-collection examinations of data to verify that reporting, transcription, and processing have been performed correctly. These audits include tracing data through all processing steps and reproducing intermediate calculations to confirm accuracy. For IMPROVE, ADQs for the program were performed during the program's implementation phase by the contractors, EPA, and IMPROVE Steering Committee but are no longer conducted as an independent procedure. Specifically, ADQs were conducted to ensure that Level 1 and Level 2 validation were completed prior to data release, thereby confirming that reported concentrations met the quality specifications outlined in the QAPP. The laboratories perform internal assessments of data quality, and the Data Analysis and Reporting Subcommittee occasionally undertakes special data quality studies. The Technical System Audits of the individual laboratories also include audits of data quality (Section 3.1.2).

Instead of formal ADQs, AQRC conducts multiple checks to assess data validity and consistency across the IMPROVE network as outlined in AQRC *SOP351: Data Processing and Validation* and *TI351C: Data Validation*. Routine parameter comparisons between analytical modules—such as sulfur (A module, PTFE by XRF) and sulfate (B module, nylon by ion chromatography)—are used to confirm expected historical ratios. Regularly reviewed comparisons include S/SO_4, Cl/Cl^-, $PM_{2.5}/PM_{10}$, fAbs/Carbon, and EC/OC, with new comparisons added as needed to enhance data evaluation.

Co-located IMPROVE samplers are deployed at select sites to assess measurement uncertainty and support method detection limit (MDL) determinations. In addition, replicate analyses are performed for several methods, including XRF and HIPS, with approximately 2–5% of network filters reanalyzed to evaluate repeatability; results are plotted and reviewed weekly.

During data validation, the AQRC Data & Reporting Group Air Quality Management Team also considers information from nearby sites, satellite data, other monitoring networks, news sources, and communications with site operators to investigate outliers and confirm whether anomalies reflect true atmospheric events or contamination. Findings

from these evaluations are summarized and reported semiannually to the IMPROVE Steering Committee as part of AQMT's comprehensive quality report on network performance.

At RTI, the Program Manager and the QAM or designated staff for the project conduct a data quality audit for each set of samples processed through the laboratory.

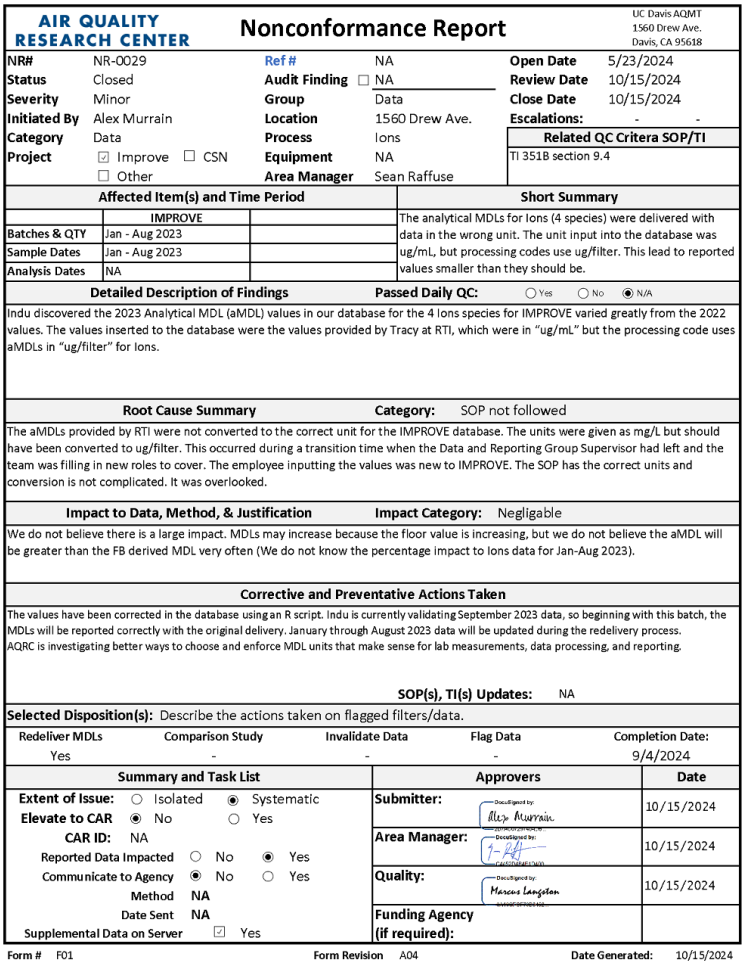
At DRI the Carbon Laboratory Supervisor examines results from standards, replicates, and blanks to assure that they are within tolerance levels. Re-analysis of samples is directed when the quality control samples exceed tolerances for the batch of samples and reasons for discrepancies are sought and corrected. An annual traceability audit by the Quality Assurance Officer determines that data have been faithfully transferred from the instrument outputs to the delivered data files.

3.2 RESPONSE ACTIONS

3.2.1 Internal Response Actions by Laboratory Contractors

3.2.1.1 AQRC

AQRC uses several forms to document and track quality issues. Nonconformance Reports (NCRs) are completed when a known quality issue is identified. The Quality Manager, with input from relevant personnel, prepares the report, which is then distributed to appropriate stakeholders for review and closure. When necessary, NPS may be updated through meetings, emails, or calls. Final reports are archived for future reference. An example AQRC nonconformance report is given in Figure 10.



AIR QUALITY RESEARCH CENTER

Nonconformance Report

UC Davis AQMT
1560 Drew Ave.
Davis, CA 95618

NR#	NR-0029	**Ref #**	NA	**Open Date**	5/23/2024
Status	Closed	**Audit Finding**	☐ NA	**Review Date**	10/15/2024
Severity	Minor	**Group**	Data	**Close Date**	10/15/2024
Initiated By	Alex Murrain	**Location**	1560 Drew Ave.	**Escalations:**	- -
Category	Data	**Process**	Ions	**Related QC Critera SOP/TI**	
Project	☑ Improve ☐ CSN ☐ Other	**Equipment**	NA	TI 351B section 9.4	
		Area Manager	Sean Raffuse		

Affected Item(s) and Time Period			Short Summary
	IMPROVE		The analytical MDLs for Ions (4 species) were delivered with data in the wrong unit. The unit input into the database was ug/mL, but processing codes use ug/filter. This lead to reported values smaller than they should be.
Batches & QTY	Jan - Aug 2023		
Sample Dates	Jan - Aug 2023		
Analysis Dates	NA		

Detailed Description of Findings — **Passed Daily QC:** ○ Yes ○ No ◉ N/A

Indu discovered the 2023 Analytical MDL (aMDL) values in our database for the 4 Ions species for IMPROVE varied greatly from the 2022 values. The values inserted to the database were the values provided by Tracy at RTI, which were in "ug/mL" but the processing code uses aMDLs in "ug/filter" for Ions.

Root Cause Summary — **Category:** SOP not followed

The aMDLs provided by RTI were not converted to the correct unit for the IMPROVE database. The units were given as mg/L but should have been converted to ug/filter. This occurred during a transition time when the Data and Reporting Group Supervisor had left and the team was filling in new roles to cover. The employee inputting the values was new to IMPROVE. The SOP has the correct units and conversion is not complicated. It was overlooked.

Impact to Data, Method, & Justification — **Impact Category:** Negligable

We do not believe there is a large impact. MDLs may increase because the floor value is increasing, but we do not believe the aMDL will be greater than the FB derived MDL very often (We do not know the percentage impact to Ions data for Jan-Aug 2023).

Corrective and Preventative Actions Taken

The values have been corrected in the database using an R script. Indu is currently validating September 2023 data, so beginning with this batch, the MDLs will be reported correctly with the original delivery. January through August 2023 data will be updated during the redelivery process.
AQRC is investigating better ways to choose and enforce MDL units that make sense for lab measurements, data processing, and reporting.

SOP(s), TI(s) Updates: NA

Selected Disposition(s): Describe the actions taken on flagged filters/data.

Redeliver MDLs	Comparison Study	Invalidate Data	Flag Data	Completion Date:
Yes	-	-	-	9/4/2024

Summary and Task List			Approvers	Date
Extent of Issue:	○ Isolated	◉ Systematic	**Submitter:** DocuSigned by: Alex Murrain	10/15/2024
Elevate to CAR	◉ No	○ Yes		
CAR ID:	NA		**Area Manager:** DocuSigned by:	10/15/2024
Reported Data Impacted	○ No	◉ Yes		
Communicate to Agency	◉ No	○ Yes	**Quality:** DocuSigned by: Marcus Langston	10/15/2024
Method	NA			
Date Sent	NA		**Funding Agency (if required):**	
Supplemental Data on Server	☑ Yes			

Form # F01 **Form Revision** A04 **Date Generated:** 10/15/2024

Figure 10. Example AQRC Nonconformance Report.

Corrective Action Reports (CARs) are initiated as an escalation of NCRs when an effectiveness check is required. Each CAR is evaluated upon completion and submitted to the relevant project sponsor or auditor for approval before closure.

Investigation Reports are opened when data indicate outliers or trends for which a root cause has not yet been determined. These reports document the investigative steps, findings, and any resulting updates to procedures, data impacts, or corrective actions. Additional reports may be initiated as needed, depending on the nature of the issue.

3.2.1.2 RTI

A corrective action is initiated whenever a program QC failure is identified. Routine examples include exceeding control limits or contamination issues. Deviations identified before preliminary data are reported to data validation do not require a formal corrective action report. These deviations are documented on the Level 0 and Level 1 reviewer sheets, and analyses are repeated (thus, no impact on data). If modifications or deviations are

discovered after data have been finalized, a formal corrective action report is required. The report is initiated by the laboratory manager or project manager and provided to the RTI QAM for approval. Impacts on data are then reported to AQRC, NPS, and the IMPROVE Steering Committee.

Non-routine failures include Performance Evaluations (PE), Certified Reference Materials (CRMs), and audit samples. The Laboratory Manager and Laboratory QAM reviews the PE, CRMs, or audit sample results for possible discrepancies. If a failure occurs, the Laboratory Manager investigates the analytical run with chemists and determines which corrective action is appropriate. This information is reported back to the Laboratory QAM for approval of the corrective action.

3.2.1.3 DRI

All DRI Environmental Analysis Facility employees are responsible for being aware of the potential for operational and data quality issues and to report any problems to their supervisors, including those that may initiate a corrective action. As noted, carbon analyzer status is monitored daily, and instruments are taken offline and remedied when operating parameters are out of specification. As previously noted, control charts of quality control standards, replicates, and blanks are examined each day with analysis being suspended until the causes of exceedances are identified and corrected.

Corrective actions are initiated by internal audits, external audits, and observations of staff and technicians. Corrective actions procedures and forms are described in DRI *SOP 6-017: Corrective Action* (Appendix 5.1.3). Typical circumstances in which the CAR process may be used include major bugs in software, developing new training materials to remedy staff performance issues, investigating and correction systematic data quality or quality system deficiencies, addressing nonconforming work or departures from the policies and procedures identified during audits, implementing new equipment or software, and major changes to procedures in SOPs or other quality documents. An example corrective action form used at DRI is provided in Figure 11. As noted on the example form, the appropriate manuals and SOPs may be revised as part of the corrective action procedure. Copies of each corrective action form are archived on the laboratory server for future reference.

CAR No.: 24-004
To: Steve Kohl **From: Xiaoliang Wang**
How Identified: TNI Assessment
Reported (Nonconformance) Conditions: The laboratory had not conducted internal audits in accordance with a predetermined schedule. Laboratory management stated a predetermined schedule had not been established. Records of a predetermined schedule could not be retrieved.
Answer Due Date: July 31, 2024
Root Cause We have been conducting internal audits annually, and typically in November and December in the last three years. However, we were not aware that we need to specify a predetermined internal audit schedule. Our Quality Manual states: "The internal audit program involves periodic audits generally conducted over a year. This program is defined on an annual basis..."
Corrective Action (Give Steps & Expected Completion Dates) 1. Add a predetermined internal audit schedule to Section 4.14.1 of the Quality Manual: "The internal audits are typically conducted in the fourth calendar quarter of each year, and the cycle for internal auditing is normally completed in one year. " **2.** Add an item to the EAF QA Calendar to remind the EAF management team that the internal QA audits will need to be completed in the fourth quarter of every year.
Preventive Action The completion of internal audits in the fourth quarter will be reviewed in the EAF management review meeting in December every year.
Completed by: Steve Kohl
Accepted by: Xiaoliang Wang
Follow-up Results: QA revies
Performed by: John G. Watson
Closed Out (Y/N): Y Yes
New CAR No.:

Figure 11. Example of Corrective Action Request form used at DRI.

3.3 OVERSIGHT AND REPORTS TO MANAGEMENT

3.3.1 Internal Oversight at Contracted Laboratories

Contracted laboratories maintain internal quality oversight procedures, with laboratory QAMs responsible for facilitating quality checks at each stage of analysis. The laboratory QAMs oversees quality checks across all operations. Routine field and laboratory processes are documented in Standard Operating Procedures (SOPs), which the laboratory QAMs review and approve before implementation.

Routine QC failures may be resolved by the responsible team using established procedures and documentation. Non-routine or recurring issues are reported to the laboratory QAM for documentation, investigation, and corrective action. These reports may be initiated through verbal communication, email, formal reports, or meetings, and should include supporting evidence such as photographs, raw data, or plots.

At AQRC, quality issues are reviewed weekly in field and laboratory meetings. Every other month, AQRC management meets to discuss ongoing investigations, improvement projects, and SOP updates, led by the AQRC QAM. The AQRC QAM also meets regularly with the AQRC Director for Quality Assurance to review reports and determine if escalation is needed. Internal assessments are conducted as needed or at least every five years by the Quality Assurance team through audits and/or procedural reviews. Findings are documented in the reports described in Section 3.2.1.

Internal assessments are conducted at each laboratory as described in Section 3.1.3. These assessments may take the form of audits or procedural reviews with spot checks for compliance. Findings are documented in the reports described in Section 3.2.1.

3.3.2 Oversight of Network Activities by NPS and IMPROVE Steering Committee

It is the responsibility of the IMPROVE Steering Committee and the NPS to ensure that contractors are following the procedures outlined in the QAPP and to review all reports and assessment results. Results from assessments are primarily documented through presentations, which are presented to the IMPROVE Steering Committee, NPS, and EPA at the annual IMPROVE Steering Committee Meetings. All contractors present results of work completed along with QC/QA activities. Presentations are reviewed and made available on the IMPROVE website. Field and laboratory TSAs are written reports and are submitted to NPS and the IMPROVE Steering Committee by the auditor (IMPROVE QAM and external auditors).

3.3.3 Reports

3.3.3.1 IMPROVE Report

IMPROVE reports describe the monitoring methods and changes to instrumentation over time, as well as reports on measured aerosol concentrations and aerosol-derived visibility estimates. These reports are drafted every 5 to 10 years and summarize the trends and patterns in the measurement data. These reports are presented to the IMPROVE Steering Committee and made available to the public through the IMPROVE website (https://vista.cira.colostate.edu/Improve/improve-reports/). These reports are led by the IMPROVE Data and Reporting Subcommittee and CIRA (under the cooperative agreement with the NPS).

3.3.3.2 Annual Data Quality Reports

Data quality reports are produced by the contracted laboratories annually for the IMPROVE network to summarize findings and provide recommendations for changes that could improve data quality. Reports are sent to the IMPROVE Steering Committee, NPS, EPA, and IMPROVE QAM. Data quality reports are then posted on the IMPROVE website: http://vista.cira.colostate.edu/Improve/quality-assurance/. Contracted laboratories also present data quality activities and results at IMPROVE Steering Committee meetings, after which presentation are made publicly available on the IMPROVE website (https://vista.cira.colostate.edu/Improve/steering-committee-meetings/),

3.3.3.3 Annual Site Update Presentation

An IMPROVE site status/update presentation is produced by the primary field contractor (AQRC) and presented annually at the IMPROVE Steering Committee Meeting. This presentation summarizes general site and equipment problems, maintenance visits and audits, and other changes at a site. The presentation is then made publicly available on the IMPROVE website (https://vista.cira.colostate.edu/Improve/steering-committee-meetings/).

3.3.3.4 Quarterly Field Status Reports

A summary of IMPROVE site status relative to the Federal Regional Haze Rule criteria is assembled and reported quarterly (through email) to the IMPROVE Steering Committee, NPS, the IMPROVE QAM, and other stakeholders. Quarterly field status reports are created as excel workbooks by the primary field contractor (AQRC) and are available on the IMPROVE website: http://vista.cira.colostate.edu/Improve/quality-assurance/.

3.3.3.5 External Laboratory Audit Reports

External laboratory audits are described in 3.1.2. These audits are organized by the U.S. EPA OSAP Project Officer, laboratory program managers, and laboratory QAMs and then conducted by an assigned audit contractor approved by the EPA OSAP Project Officer. An audit report is produced by the assigned auditor following each audit and transmitted via email to the EPA, NPS, IMPROVE Steering Committee chair, and IMPROVE QAM. Laboratory staff and the laboratory QAM review and comment on a draft of the audit report before it is finalized by OSAP. After the audit, the laboratory works with the OSAP Project Officer to implement any corrective action plans.

3.3.3.6 TSA of Field Activity Reports

The IMPROVE QAM provides an annual field site audit report (also referred to as a "Technical System Audit (TSA)") detailing the sites that have been audited and the results. A preliminary presentation is given at IMPROVE Steering Committee meeting, and a finalized written report is emailed to the IMPROVE Steering Committee and provided to

NPS, Field Team Lead, and stakeholders. The report is also made publicly available on the IMPROVE website (https://vista.cira.colostate.edu/Improve/technical-system-audits/).

4 ENVIRONMENTAL INFORMATION REVIEW AND USABILITY DETERMINATION

4.1 ENVIRONMENTAL INFORMATION REVIEW

4.1.1 Data Verification

4.1.1.1 AQRC

Data verification procedures are implemented at multiple stages to ensure measurement accuracy and consistency across all analytical processes. For gravimetric mass**,** discrepancies between pre- and post-weigh values can indicate issues such as filter swaps in the field, sample misassignments in the handling lab, or weighing errors from mishandling or contamination. These anomalies are investigated by the data validation team, which determines whether corrective action or invalidation is required. For HIPS**,** data verification includes confirming proper calibration and registration to the reference filter when unusual values are observed. For XRF**,** instrument performance is verified through daily QC checks, and results are further reviewed during data validation. In all cases, the data validation team may request reanalysis to compare results and determines the final reportable value. The data validation team then determine which result to deliver and which to invalidate.

4.1.1.2 RTI

During data verification, results are transferred from the instrument to Excel using a standardized report template, which provides sample injection IDs and ion concentrations. These files are stored on a secure, backed-up server. Two versions of the report are generated to ensure proper use of calibration standards. Data are then imported into a database where batch and individual sample results can be reviewed, including sample details, extraction volumes, and QC summaries. Reviewers check that database entries match the original instrument output, that calibration standards are applied correctly, and that notes from sample queues and extraction logs are accurately recorded. After the data reviewer completes review of the dataset for an entire batch, the packet of data is passed to an independent data reviewer before export. The independent reviewer verifies all notes listed on the queues and sample extraction log are noted in the database. The reviewer confirms that level 0 and level 1 reviews (Figures 11 and 12) have been completed. The independent data reviewer also compares a subset of results (5%) between the database and the original Excel files to ensure accuracy.

ION CHROMATOGRAPH LEVEL 0 REVIEW

IC Analysis Date	
Review Date/Initials	
System	
Batch Number	

	Reading	Consistent w/previous? (yes/no)	Analyst Initials
Background Conductivity			
Pump Pressure			

	Analyst Initials
Confirm that the correct queue has been loaded into the system.	
Double check Autosampler rack positions match the queue on the system and the paper version of the queue	
After analysis check of Autosampler rack position & sample order	

	Yes/No	Analyst Initials
Are DI blanks clean? "Clean" is defined as ≤ MDL for each anion or cation.		
Are peaks identified correctly on chromatograms?		
All calibration curves acceptable (≥ 0.999 w/o std 8)?		
Duplicates ± 10% 10 x MDL Duplicates ±100% MDL-10x MDL Anion MDL's Cl = 0.006 NO2 = 0.010, NO3 = 0.008, SO4 = 0.011 Cation MDL's Na, NH4 0.005 & K = 0.006		
Spike recovery 90-110%		
QC Samples ± 10% standards > 0.050 ppm, ± 35% standards ≤ 0.050 ppm[1]		
Data reviewed using CSN Lab tool to review QC DUP SPK data at bench level version 1 validated		
Data reviewed using NPS BENCH TOOL QC Spike Duplicate recoveries v1 validated		

Revision 4 Revised 4/23/2025

Figure 12. Form for Level 0 data review at RTI.

ION CHROMATOGRAPH LEVEL 1 REVIEW

Date: _____ Analyst: _____

System: _____ Batch #: _____

	Yes/No	Analyst Initials
Are DI blanks clean? "Clean" is defined as ≤ MDL ppb for each anion and cation.		
Are peaks identified correctly on chromatograms?		
All calibration curves acceptable (≥ 0.999 w/o std 8)?		
Duplicates ± 10% 10 x MDL Duplicates +- 100% MDL-10x MDL MDL Anions Cl = 0.006 NO2 = 0.010, NO3 = 0.008, SO4 = 0.011 MDL Cations = 0.005 for Na, NH4 and 0.006 for K		
Spike recovery 90-110%		
QC Samples ± 10% for standards > 0.050 ppm and +- 35% for standards ≤ 0.050 ppm[1]		
Comments entered from extraction record		
Comments entered from queue		
Results needing high standard in curve replaced		
Reanalysis results selected as non-report in the database		

Figure 13. Form for Level 1 data review at RTI.

4.1.1.3 DRI

Data verification ensures completeness and accuracy of carbon analysis results prior to data export. Raw data from each analysis run are uploaded to the SQL Server database and accessed by laboratory staff through a Microsoft Access interface. This interface displays data, performs automated validation checks, and generates the Excel reporting file containing concentrations, uncertainties, and supporting metadata.

Verification begins by confirming that all filters listed on the analysis run sheet have corresponding entries in the database. Missing samples are investigated using built-in database queries to identify upload errors or labeling discrepancies. Corrections are made using the *Edit Sample Info* and *Find Project ID* functions, ensuring all project and sample identifiers are accurate.

Replicates, field blanks, and punches are verified for completeness and proper flagging. Any missing or aborted samples are documented and, if necessary, reuploaded from the analyzer's local database. Deposit and punch areas are confirmed against the run list, as errors directly affect calculated concentrations. Calibration peak values are reviewed to identify outliers, and operator comments or analysis flags are evaluated and resolved. Samples requiring reruns are documented accordingly. A list of carbon analysis flags is given in DRI *SOP 2-226: DRI Model 2015 Multiwavelength Carbon Analysis (TOR/TOT) of Aerosol Filter Samples - Method IMPROVE_A* (Appendix 5.1.3) and reproduced in

Appendix 5.4.

After all data checks are complete, an *Initial Analysis Report* and, when applicable, a *Collocated Sites Report* are generated to finalize the Level I validation process. A final verification step is completed after data validation to ensure that the number of completed samples matches the number of analysis filters.

4.1.2 Data Validation

Following data verification at RTI, the independent reviewer evaluates whether all QC results meet acceptance criteria, confirms that reanalyzed samples satisfy data quality objectives, and ensures that any issues identified during initial reviews have been resolved. The reviewer also confirms that samples requiring extended calibration ranges have been properly processed and that the complete dataset is ready for reporting. Once the dataset passes review, it is exported in CSV format and transmitted to AQRC for inclusion in the project database.

At DRI, after data verification, a reviewer examines the *Validation Report* and *Initial Analysis Report* to identify outliers, abnormal OC/EC or OC/TC ratios, blank anomalies, and other irregularities. Replicates are compared against originals, and primary versus secondary filter results are checked for expected relationships. Samples with questionable results are flagged for further investigation, which may include thermogram review or rerun. All reruns, flags, and comments are documented in the database at DRI. Operator-generated flags are standardized to approved codes, and rerun data are reviewed to ensure issues have been resolved and prior results properly invalidated. Once all data pass validation review; completeness is confirmed, and the final reporting file is generated for submission to AQRC.

AQRC conducts comprehensive data review and validation using results from all participating laboratories to identify analytical issues, trends, and potential anomalies. Following analysis, data are processed to ambient concentrations using validated flow values. Data from individual monitoring sites, analytical modules, and inter-method comparisons are examined to assess consistency, detect outliers, and evaluate atmospheric patterns. These evaluations are typically performed in monthly batches after all analyses are complete, although some checks—such as flow validation and review of field operator comments—occur prior to or during analysis.

During each analytical process, laboratory staff may assign preliminary status flags and comments for review. The data validation team reviews all flags, adds additional information as needed, and applies final determinations. Flags may be informational or terminal and are converted to corresponding AQS codes, when applicable, before data submission (Appendix 5.4). Flag definitions and application procedures are detailed in AQRC *TI 351C: Data Validation*.

Data validation also utilizes module comparisons, including S/SO_4^{2-}, Cl^-/Chloride, $PM_{2.5}/PM_{10}$, fAbs/BC, fAbs/EC, and reconstructed mass. Expected relationships between modules and analytical processes have been established over time, allowing these ratios to serve as diagnostic indicators for identifying outliers, procedural issues, or systematic changes. Parameter-specific checks are al_{so} performed to identify individual anomalies and long-term trends, as described in AQRC *SOP 351: Data Processing and Validation* and the associated TIs. Upon completion of validation, verified data are transmitted to AQS and CIRA/FED for final reporting. Table 7 lists the data types, parameters, and units for all data delivered to CIRA and the EPA for databases (see also *AQRC TI #351D: Data Delivery*, Appendix 5.1.1).

4.2 USEABILITY DETERMINATION

Final validated IMPROVE data are delivered to AQS and the Federal Land Manager Environmental Database (FED; http://views.cira.colostate.edu/fed/), which serves as public access portals. The IMPROVE data have a wide user base, including analysts working under Regional Haze Rule (RHR). Each data point includes an associated quality flag identifying it as fully valid or noting any known irregularities (e.g., deviations from standard sampling schedules). AQRC also issues data advisories to alert users to potential systematic errors or biases. Community-submitted data advisories are hosted on the IMPROVE website (https://vista.cira.colostate.edu/Improve/data-advisories/) for transparency; these are reviewed but not validated or endorsed by the Steering Committee or NPS.

Final data are evaluated against the Data Quality Objectives (DQOs) outlined in Section 1.5.4 to confirm that precision, accuracy, completeness, representativeness, and comparability meet program requirements. The IMPROVE Steering Committee oversees this analysis as carried out by the contractors and Data Subcommittee. Data not meeting acceptance criteria may still be retained with appropriate qualification flags or exclusion notes, depending on the issue's scope and impact. Usability determinations and associated flags are documented within the IMPROVE database and reflected in all data products distributed to AQS and FED.

Based on the validation procedures and IMPROVE Steering Committee review, the final IMPROVE data are determined to be suitable for their intended use—assessing trends in aerosol composition and visibility in CIAs. It is the responsibility of the IMPROVE Steering Committee to ensure that the network and data collected are of continued use for this purpose.

5 APPENDICES

5.1 List of IMPROVE SOPs and TIs

5.1.1 AQRC

The following SOPs from AQRC are available on the IMPROVE website (https://vista.cira.colostate.edu/Improve/particulate-monitoring-network/).

Number	Title	Revision and Revision Date
SOP 126	Site Selection	2.6, 15 July 2022
SOP 151	Installation of Samplers	2.7, 14 March 2024
SOP 201	Sampler Maintenance by Site Operators	3.7, 14 March 2024
SOP 226	Site Maintenance	2.6, 15 June 2022
TI 226A	Site Maintenance for Field Technicians	2.6, 14 March 2024 2022
TI 226B	Flow Check	2.6, 14 March 2024
TI 226C	Flow Adjustments	2.6, 14 March 2024
TI 226D	Denuders	2.5, 15 July 2022
TI 226E	Leak Check	2.5, 15 July 2022
TI 226F	Controller Repair	2.5, 15 July 2022
TI 226G	Field Safety Plan	2.5, 15 July 2022
TI 226H	Calibration of Flow Check Devices Using Positive Displacement Flow Meter	2.5, 15 July 2022
SOP 251	Sample Handling	3.6, 9 February 2024
TI 251A	Reference Weights	3.1, 9 February 2024
TI 251C	Filter Inventory and Acceptance	3.1, 31 January 2024
TI 251D	Box Receiving	3.0, 15 July 2022
TI 251E	Entering Log Sheets and Simple Problem Diagnosis	3.0, 15 July 2022
TI 251F	Post Sample Processing	3.1, 31 January 2024
TI 251G	Post-Weigh Chamber Prep	3.1, 31 January 2024
TI 251H	Post-Sample Weigh In	3.1, 9 February 2024 15 July 2022
TI 251I	Cartridge Preparation Station	3.0, 15 July 2022
TI 251J	Pre-Sample Weigh In	3.0, 15 July 2022
TI 251K	Quality Check Station	3.0, 15 July 2022
TI 251L	Box Shipping	3.0, 15 July 2022
TI 251M	Filter Shipping	3.2, 6 August 2024
TI 251N	Tray Checking	3.1, 9 February 2024
TI 251O	Cleaning Loose Screens	3.0, 15 July 2022
TI 251P	Labeling and Organizing D-Slides	3.0, 15 July 2022
TI 251Q	Cleaning Petri Dishes	3.0, 15 July 2022
TI 251R	General Laboratory Procedures	3.0, 15 July 2022
TI 251S	Box Cycles and Cartridge Orientation	3.0, 15 July 2022
TI 251T	Data and Records Management	3.0, 15 July 2022

TI 251U	Mass Data Validation of Reweigh Request	3.0, 15 July 2022
TI 251V	Replacement Filters and Swaps	3.0, 15 July 2022
SOP 276	Optical Absorption Analysis of PM2.5 Samples	5.6, 19 April 2023
TI 276A	Preparation of Filters for HIPS Analysis	5.6, 3 February 2023
TI 276B	Performing HIPS Analysis	5.6, 19 April 2023
TI 276C	QA/QC of Analysis of Loaded Filters Using HIPS	5.6, 19 April 2023
SOP 301	XRF Analysis of Aerosol Deposits on PTFE Filters	2.5, 30 September 2022
TI 301A	LN2 Fills and Detector Calibration	2.5, 30 September 2022
TI 301B	Sample Changes for 8-Position Trays	2.5, 30 September 2022
TI 301C	Quality Assurance/Quality Checks (QA/QC) of XRF Performance	2.5, 30 September 2022
SOP 351	Data Processing and Validation	6.0, 30 September 2022
TI 351A	Data Ingest	1.2, 17 December 2024
TI 351B	Data Processing	1.4, 7 January 2025
TI 351C	Data Validation	1.1, 14 November 2022
TI 351D	Data Delivery	1.0, 4 October 2022
TI 351E	Flow Validation	1.2, 7 January 2025
TI 351F	Data Preparation and Reporting	1.3, 7 January 2025

5.1.2 RTI

The following SOPs from RTI are available on the IMPROVE website (https://vista.cira.colostate.edu/Improve/ion-chromatography-analysis-of-module-b/).

Number	Title	Latest Revision and Revision Date
Ion2	Determination of Anions and/or Cations Extracted from Nylon® Filters by Ion Chromatography (IC)	Revision 11, 5 March 2025 QT9 Document #: MAP-IONS-SOP-085
Ions3	Filter Extraction via SimPRep Autodilution System	Revision 3, 19 December 2025 QT9 Document #: MAP-IONS-SOP-086

The below SOPs are internal documents held by RTI.

Number	Title	Note

100-EQP-020	Gravimetric Calibration Verification and Maintenance of Liquid Dispensing Devices	Internal Document
100-EQP-007	Refrigerator and Freezer Monitoring, Maintenance and Operation with Storage Condition Definitions	Internal Document
100-EQP-009	Calibration of Temperature Measuring Devices	Internal Document
100-EQP-004	Calibration, Use, and Maintenance of Balances	Internal Document
100-ADM-001	Preparation and Maintenance of Standard Operating Procedures Within Discovery Sciences	Internal Document

5.1.3 DRI

The following SOPs from DRI are available on the IMPROVE website (https://vista.cira.colostate.edu/Improve/carbon-analysis/).

Number	Title	Revision and Revision Date
2-106r11	Pre-firing and Acceptance Testing of Quartz-Fiber Filters for Aerosol and Carbonaceous Material Sampling	Revision 11, 20 May 2024
2-111r6	Sample Shipping, Receiving, and Chain-of-Custody	Revision 6, 5 December 2025
2-226r8	DRI Model 2015 Multiwavelength Carbon Analysis (TOR/TOT) of Aerosol Filter Samples - Method IMPROVE_A	Revision 8, 15 July 2025
4-119r0	Trace Oxygen Level Measurement in Helium Atmospheres of DRI Model 2015 Thermal/Optical Carbon Analyzers by LD8000 Trace Impurity Analyzer	Revision 0, 22 September 2021
4-005-r0	Pipette Calibration Verification	Revision 0, 7 February 2018
6-013r5	Creation, Revision, Distribution, and Archiving of SOPs	Revision 5, 28 January 2020

5.2 IMPROVE Site Technical System Audit Form

Part 1 - Technical System Audit Form

Monitoring Site Location:					
IMPROVE Site ID:					
Latitude/Longitude from IMPROVE Website	Lat.:		Long:	Elevation:	
Assessor Name:		Affiliation			
Observer(s) Name:		Affiliation			
Assessment Date:					

Section 1. Organization and Responsibilities

1. UCDavis Field Operations Manager

Name: Affiliatio
Phone:
Address:
E-mail:

2. Monitoring Site Operator(s)

Name: Affiliatio
Phone:
Address:
Cell Phor
E-mail:

Name: Affiliatio
Phone:
Address:
Cell Phor
E-mail:

3. Date UC Davis field service technicians last visited the site for maintenace/calibratic

(O = Other)

	RESPONSE		
	Y	N	O
4. Were site operators able to meet with UCDavis technicians during the site visit?			
5. Are site operators familiar with SOP 201 "IMPROVE Standard Operating Procedure for Sampler Maintenance by site operators"?			
6. Are site operators aware of resoucres intended to inform them about sampler operation?			
http://vista.cira.colostate.edu/Improve/ General Information			
http://vista.cira.colostate.edu/Improve/particulate-monitoring-network/ SOPs			
https://aqrc.ucdavis.edu/resources-for-operators helpful videos			

7. Do operators have any issues they would like to address or concerns about local activities which might affect sampling?

8. How long have you served as the IMPROVE sampler operator?

IMPROVE
Interagency Monitoring of Protected Visual Environments
Performance Audit Worksheet VER 2.10; 2/20/2017

US Environmental Protection Agency
Office of Air and Radiation

		E Website	GPS Reading	Difference
DATE:	01/00/00			
LOCATION:	0			
SITE ID:	0			
	LAT:			
	LONG:			
	ELEV:			

GENERAL INFORMATION

AUDITOR INFO	
PRIMARY:	
AFFILIATION:	
SECONDARY:	
AFFILIATION:	
OBSERVER:	
AFFILIATION:	

SITE OPERATOR INFO	
PRIMARY:	
AFFILIATION:	
SECONDARY:	
AFFILIATION:	

AUDIT FILTER	
DATE:	
POS:	

**FIRST REFERENCE DEVICE	
MAKE/MODEL:	
S/N:	
Certif. Due Date:	
BACK-UP REFERENCE DEVICE	
MAKE/MODEL:	
S/N:	
Certif. Due Date:	
ALTERNATE FIRST REFERENCE DEVICE	
MAKE/MODEL:	
S/N:	
Certif. Due Date:	
ALTERNATE REFERENCE DEVICE	
MAKE/MODEL:	
S/N:	
Certif. Due Date:	

FINDINGS

INFORMATION

SITE CALIBRATION COEFFICIENTS (ELEV and NOM will be updated after audit pressure is replaced)

MODULE	TYPE	ELEV (f)	CALIB DATE	MAG COEFFICIENTS A	MAG COEFFICIENTS B	NOM (in WC)	VAC COEFFICIENTS C	VAC COEFFICIENTS D	NOM (PSI)
A	PM2.5	0.964		1.489	0.380	0.508			
B	PM2.5	0.964		1.489	0.380	0.508			
C	PM2.5	0.964		1.489	0.380	0.508			
D	PM10	0.964					1.320	1.325	12.23
X (A-B-C)	PM2.5	0.964		1.489	0.380	0.508			
X (D)	PM10	0.964					1.320	1.325	12.23

CONTROLLER

PRESSURE	AUDIT (mm Hg)
First Ref Std:	788
Back-up Ref Std:	

(The initial value is a standard pressure which will be replaced by the audit value from the site and all NOMs/ELEVs will be updated accordingly

TEMPERATURE	AUDIT (Celsius)		IMPROVE (Celsius)
First Ref Std:			
Back-up Ref Std:			
RECALIBRATION:			

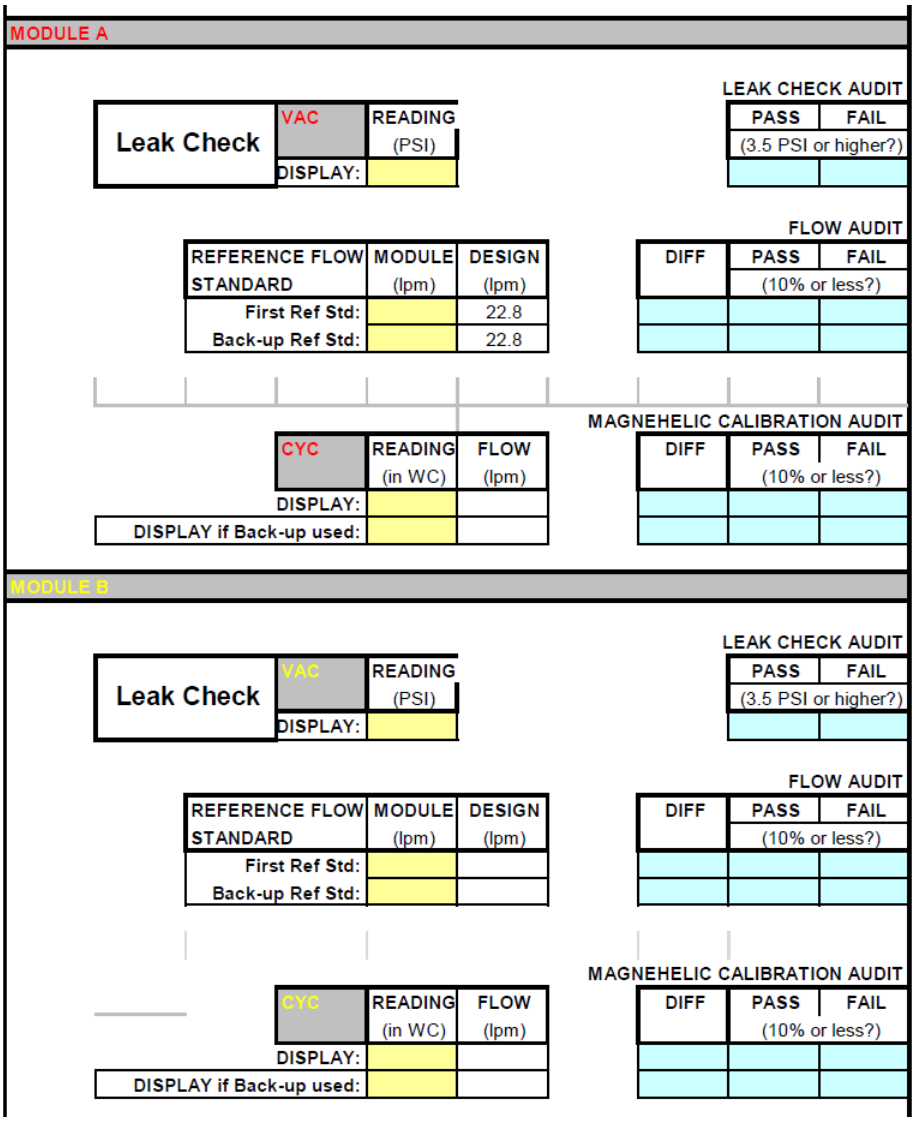
TEMPERATURE AUDIT

DIFF (Celsius)	PASS (10 degrees or less?)	FAIL

TIME	AUDIT (hh:mm)	IMPROVE (hh:mm)
CELL PHONE:		
RECALIBRATION:		

CLOCK AUDIT

DIFF (min)	PASS (5 minutes or less?)	FAIL



MODULE A

Leak Check	VAC	READING (PSI)
	DISPLAY:	

LEAK CHECK AUDIT

PASS	FAIL
(3.5 PSI or higher?)	

REFERENCE FLOW STANDARD	MODULE (lpm)	DESIGN (lpm)
First Ref Std:		22.8
Back-up Ref Std:		22.8

FLOW AUDIT

DIFF	PASS	FAIL
	(10% or less?)	

	CYC	READING (in WC)	FLOW (lpm)
	DISPLAY:		
DISPLAY if Back-up used:			

MAGNEHELIC CALIBRATION AUDIT

DIFF	PASS	FAIL
	(10% or less?)	

MODULE B

Leak Check	VAC	READING (PSI)
	DISPLAY:	

LEAK CHECK AUDIT

PASS	FAIL
(3.5 PSI or higher?)	

REFERENCE FLOW STANDARD	MODULE (lpm)	DESIGN (lpm)
First Ref Std:		
Back-up Ref Std:		

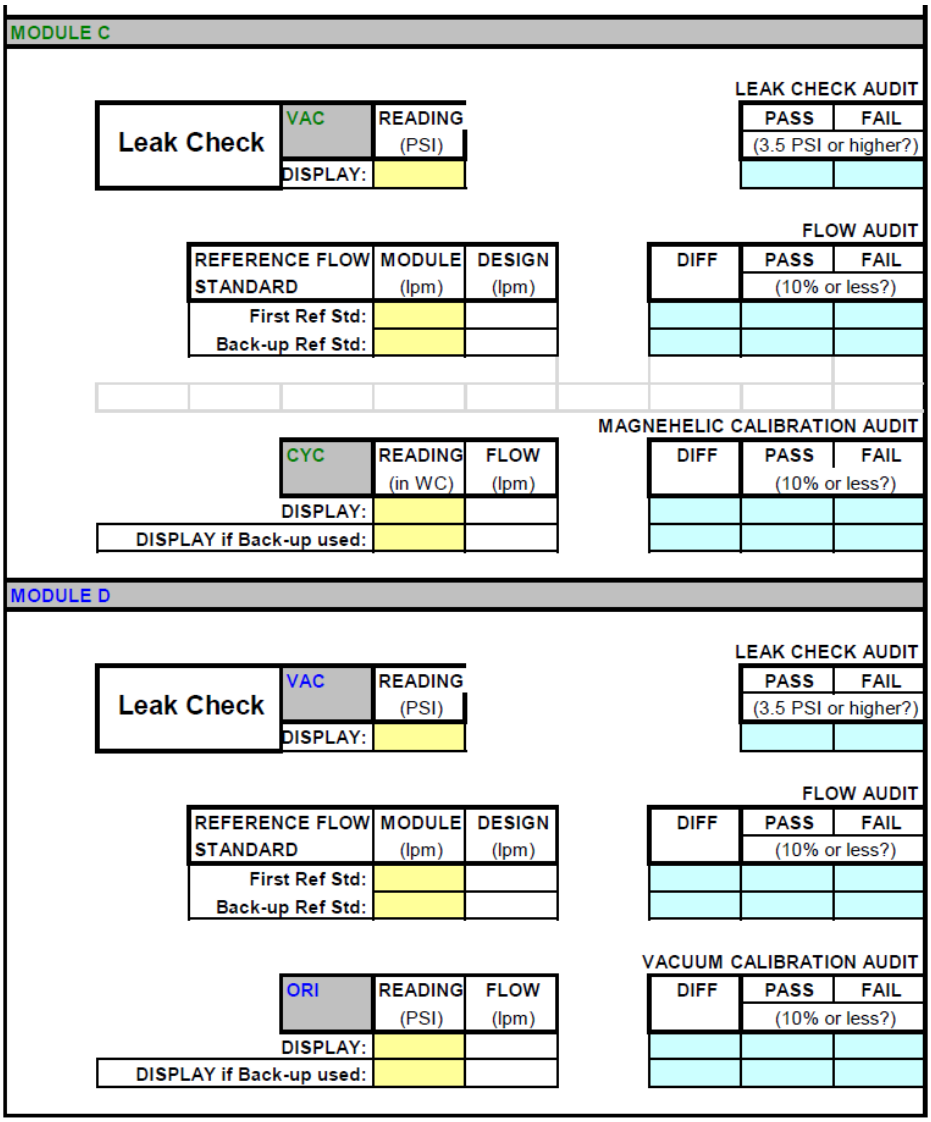
FLOW AUDIT

DIFF	PASS	FAIL
	(10% or less?)	

	CYC	READING (in WC)	FLOW (lpm)
	DISPLAY:		
DISPLAY if Back-up used:			

MAGNEHELIC CALIBRATION AUDIT

DIFF	PASS	FAIL
	(10% or less?)	



MODULE C

Leak Check

	VAC	READING (PSI)
DISPLAY:		

LEAK CHECK AUDIT

PASS	FAIL
(3.5 PSI or higher?)	

REFERENCE FLOW STANDARD	MODULE (lpm)	DESIGN (lpm)
First Ref Std:		
Back-up Ref Std:		

FLOW AUDIT

DIFF	PASS	FAIL
	(10% or less?)	

	CYC	READING (in WC)	FLOW (lpm)
DISPLAY:			
DISPLAY if Back-up used:			

MAGNEHELIC CALIBRATION AUDIT

DIFF	PASS	FAIL
	(10% or less?)	

MODULE D

Leak Check

	VAC	READING (PSI)
DISPLAY:		

LEAK CHECK AUDIT

PASS	FAIL
(3.5 PSI or higher?)	

REFERENCE FLOW STANDARD	MODULE (lpm)	DESIGN (lpm)
First Ref Std:		
Back-up Ref Std:		

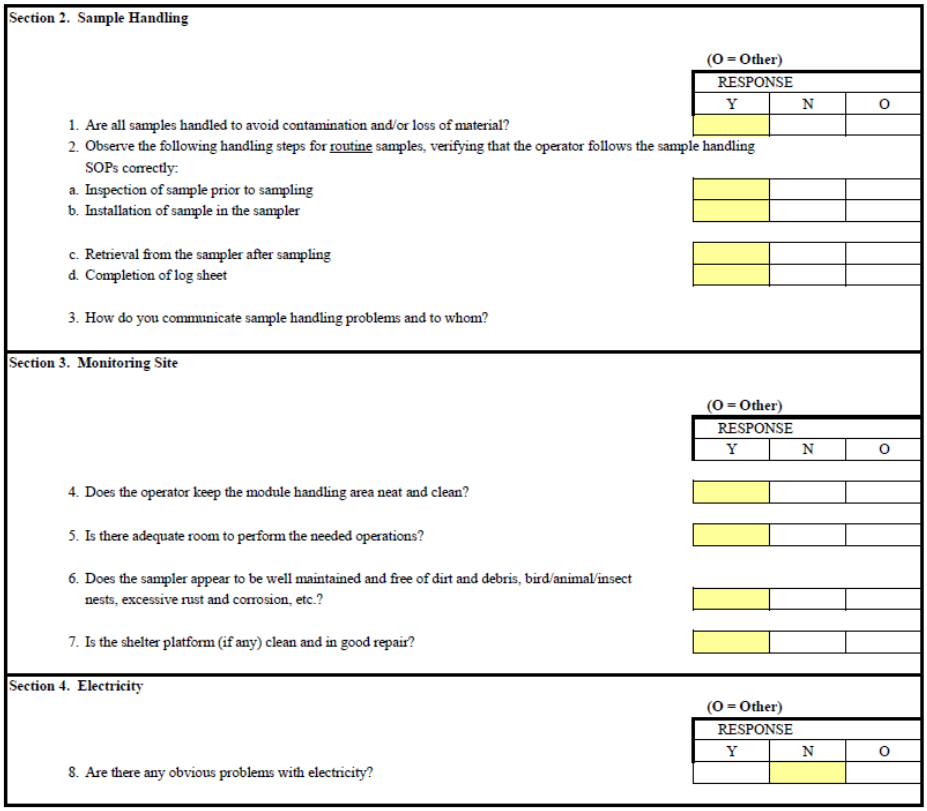
FLOW AUDIT

DIFF	PASS	FAIL
	(10% or less?)	

	ORI	READING (PSI)	FLOW (lpm)
DISPLAY:			
DISPLAY if Back-up used:			

VACUUM CALIBRATION AUDIT

DIFF	PASS	FAIL
	(10% or less?)	



Section 2. Sample Handling

	(O = Other) RESPONSE Y	N	O
1. Are all samples handled to avoid contamination and/or loss of material?			
2. Observe the following handling steps for routine samples, verifying that the operator follows the sample handling SOPs correctly:			
a. Inspection of sample prior to sampling			
b. Installation of sample in the sampler			
c. Retrieval from the sampler after sampling			
d. Completion of log sheet			
3. How do you communicate sample handling problems and to whom?			

Section 3. Monitoring Site

	(O = Other) RESPONSE Y	N	O
4. Does the operator keep the module handling area neat and clean?			
5. Is there adequate room to perform the needed operations?			
6. Does the sampler appear to be well maintained and free of dirt and debris, bird/animal/insect nests, excessive rust and corrosion, etc.?			
7. Is the shelter platform (if any) clean and in good repair?			

Section 4. Electricity

	(O = Other) RESPONSE Y	N	O
8. Are there any obvious problems with electricity?			

5.3 Average method detection limits (MDLs) for recent IMPROVE data

The following table presents the MDLs and percentage of reported data above the MDLs calculated for 2020, 2021, 2022, and 2023.

Species	2020		2021		2022		2023	
	Average MDL (ng/m^3)	% Above MDL	Average MDL (ng/m^3)	% Above MDL	Average MDL (ng/m^3)	% Above MDL	Average MDL (ng/m^3)	% Above MDL
Chloride	8	76	5	80	4	80	5	80
Nitrite	10	6	20	8	30	7	10	9
Nitrate	8	98	7	99	9	98	7	98
Sulfate	8	100	8	100	8	100	8	100
Organic Carbon (OCR)	90	95	80	96	80	95	80	95
Elemental Carbon (ECR)	20	90	20	90	20	92	30	87
Total Carbon	100	96	80	96	90	96	90	95
Organic Carbon	30	28	30	28	30	26	30	32

(OC1)								
Organic Carbon (OC2)	20	90	30	88	30	86	30	88
Organic Carbon (OC3)	40	92	30	93	40	93	40	92
Organic Carbon (OC4)	20	96	20	97	20	97	20	97
Organic Pyrolyzed (OPR)	10	93	20	93	8	94	10	94
Elemental Carbon (EC1)	8	98	10	98	5	98	7	97
Elemental Carbon (EC2)	20	85	20	86	20	89	20	84
Elemental Carbon (EC3)	0.3	2	0.3	1	0.3	1	0.3	1
Na	5	88	5	81	8	67	8	69
Mg	2	78	2	79	4	66	4	67
Al	2	95	2	95	2	94	2	92
Si	2	96	2	97	2	97	2	97
P	0.2	44	0.2	53	0.2	52	0.2	47
S	0.4	100	0.4	100	0.3	100	0.3	100
Cl	0.5	78	0.8	73	0.2	78	0.2	81
K	0.8	100	0.8	100	0.5	100	0.4	100
Ca	4	90	6	89	1	98	1	98
Ti	0.2	91	0.2	92	0.2	90	0.2	89
V	0.1	32	0.1	26	0.1	26	0.1	24
Cr	0.1	29	0.2	28	0.1	38	0.1	32
Mn	0.2	77	0.3	79	0.3	77	0.2	77
Fe	1	97	1	98	1	97	1	96
Ni	0.1	21	0.1	22	0.1	24	0.1	22
Cu	0.2	65	0.2	67	0.4	32	0.4	31
Zn	0.3	88	0.5	83	0.6	76	1	77
As	0.2	9	0.2	9	0.1	5	0.1	5
Se	0.1	39	0.1	39	0.2	26	0.2	26
Br	0.1	94	0.1	94	0.1	94	0.1	94
Rb	0.2	16	0.2	16	0.2	16	0.2	15

Sr	0.2	62	0.2	62	0.2	51	0.2	49
Zr	0.8	17	0.8	17	1	9	1	10
Pb	0.4	45	0.4	45	0.6	36	1	38
$PM_{2.5}$	300	97	300	97	300	97	300	98
PM_{10}	400	98	400	98	400	99	400	99
fAbs	0.1	97	0.1	97	0.1	92	0.1	94

5.4 Analysis Flags

The following table lists the definitions and application criteria of automatic flow flags for $PM_{2.5}$ and PM_{10}.

Automatic Flow Flag	**Definition**	**Type**	**$PM_{2.5}$ Criteria for Application**	**PM_{10} Criteria for Application**
CL	Clogged Filter	Terminal	Flow rate < 15 L/min for more than 6 hours if controller or flashcard data are used. Average flow rate < 15 L/min if log sheet values are used.	Flow rate < 10 L/min for more than 6 hours if controller or flashcard data are used. Average flow rate < 10 L/min if log sheet values are used.
CG	Clogging Filter	Informational	Flow rate < 18 L/min for more than 6 hours if controller or flashcard data used. Average flow rate < 18 L/min if log sheet values are used.	Flow rate < 14 L/min for more than 6 hours if controller or flashcard data are used. Average flow rate < 14 L/min if log sheet values are used.
LF	Low/high flow rate	Informational	Average flow rate < 19.7 L/min or > 24.1 L/min	Average flow rate < 15 L/min or > 18 L/min
PO	Power Outage	Terminal	Elapsed time < 1080 minutes (18 hours)	Elapsed time < 1080 minutes (18 hours)
EP	Equipment Problem	Terminal	Elapsed time > 1800 minutes (30 hours) or is missing	Elapsed time > 1800 minutes (30 hours) or is missing
TO	Timing Outside	Informational	Elapsed time between	Elapsed time

	normal bounds		1080 minutes (18 hours) - 1380 minutes (23 hours) or 1500 minutes (25 hours) – 1800 minutes (30 hours)	between 1080 minutes (18 hours) - 1380 minutes (23 hours) or 1500 minutes (25 hours) – 1800 minutes (30 hours)
SD	Short Duration Sample	Informational	1 second < Elapsed time < 1080 minutes (18 hours); controller stopped sampling when flow rate < 15L/min for at least 15 minutes while the vacuum is low. The status is terminal for the Regional Haze Rule but remains valid for other purposes.	1 second < Elapsed time < 1080 minutes (18 hours); controller stopped sampling when flow rate < 15L/min for at least 15 minutes while the vacuum is low. The status is terminal for the Regional Haze Rule but remains valid for other purposes.

The following table gives the status flags assigned during the Level 1 and 2 validation processes at AQRC. Samples associated with "Terminal" flag are invalidated for a variety of reasons, and no concentration, uncertainty, or MDL values are reported, whereas those associated with "Informational" flag are still valid samples and concentrations, uncertainties, and MDLs are reported. The "Temporary" flags are assigned for a variety of reasons to aid data validation; they are replaced before final data reporting.

Status Flag	**Description**	**Flag Type**	**AQS Code**
BI	Bad Installation of Sample Cartridge or Filter	Terminal	BJ
CG	Sample Flow Rate Out of Spec.	Informational	W
CL	Sample Flow Rate Out of Limits	Terminal	AH
DA	Sample not analyzed	Terminal	AM
DE	Reported value is an estimate	Informational	LJ
EP	Equipment Problem	Terminal	AN
LF	Sample Flow Rate Out of Spec.	Informational	W
NF	No Flow	Temporary	

NM	Normal	Informational	
NS	No Sample Collected/Late Sample Change	Terminal	AF
OL	Site Off Line	Terminal	AD
PO	Power Outage	Terminal	AV
QD	Questionable Data	Temporary	4
QV	Data quality check (for AQRC Data Group only)	Informational	
SA	Sampling Anomaly	Informational	
SO	Still out in field	Temporary	
SP	Same-day Field Blank/Sample Swap	Informational	1
SW	Sampling Dates Swap	Informational	
TO	Timing Outside normal bounds	Informational	Y
TU	Incorrect Time (with time shift >= 6hrs)	Informational	3
UN	Undetermined Weight	Informational	AM
XX	Sample Destroyed, Damaged or Contaminated	Terminal	AJ
PM	Undefined but allowed by SWAP as informational	No longer used	
NR	Not Reanalyzed by DRI	No longer used	
NA	Not Applicable	No longer used	AM
QA	Quality Assurance	No longer used	4
QC	Quality Control	No longer used	
RF	Really High Flow Rate	No longer used	W
PC	Possible Contamination	No longer used	4

The following table describes the IMPROVE carbon analysis flags (as also presented in DRI *SOP 2-226: DRI Model 2015 Multiwavelength Carbon Analysis (TOR/TOT) of Aerosol Filter Samples - Method IMPROVE_A*, Appendix 5.1.3).

Validation Flag	**Sub Flag**	**Description**
a		Sample received with punch removed
	a1	Sample received with one punch removed
	a2	Sample received with two punches removed

Validation Flag	Sub Flag	Description
	a3	Sample received with three punches removed
b		Blank.
	b1	Field/dynamic blank.
	b2	Laboratory blank.
	b3	Distilled-deionized water blank.
	b4	Method blank.
	b5	Extract/solution blank.
	b6	Transport blank.
c		Analysis result reprocessed or recalculated.
	c1	XRF spectrum reprocessed using manually adjusted background.
	c2	XRF spectrum reprocessed using interactive deconvolution
d		Sample dropped.
	d1	Dropped sample punch prior to analysis.
	d2	Dropped sample filter prior to analysis.
f		Filter damaged or ripped.
	f1	Filter damaged, outside of analysis area.
	f2	Filter damaged, within analysis area.
	f3	Filter wrinkled.
	f4	Filter stuck to PetriSlide.
	f5	Teflon membrane separated from support ring.
	f6	Pinholes in filter.
g		Filter deposit damaged.
	g1	Deposit scratched or scraped, causing a thin line in the deposit.
	g2	Deposit smudged, causing a large area of deposit to be displaced.
	g3	Filter deposit side down in PetriSlide.
	g4	Part of deposit appears to have fallen off; particles on inside of PetriSlide.
	g5	Ungloved finger touched filter.

Validation Flag	Sub Flag	Description
	g6	Gloved finger touched filter.
h		Filter holder assembly problem.
	h1	Deposit not centered.
	h2	Sampled on wrong side of filter.
	h4	Filter support grid upside down- deposit has widely spaced stripes or grid pattern.
	h5	Two filters in PetriSlide, analyzed top filter
i		Inhomogeneous sample deposit.
	i1	Evidence of impaction - deposit heavier in center of filter.
	i2	Random areas of darker or lighter deposit on filter.
	i3	Light colored deposit with dark specks.
	i4	Non-uniform deposit near edge - possible air leak.
m		Analysis results affected by matrix effect.
	m1	Organic/elemental carbon split undetermined due to an apparent color change of non-carbon particles during analysis; all measured carbon reported as organic.
	m2	Non-white (red) carbon punch after carbon analysis, indicative of mineral particles in deposit.
	m3	A non-typical, but valid, laser response was observed during TOR analysis. This phenomenon may result in increased uncertainty of the organic/elemental carbon split. Total carbon measurements are likely unaffected.
	m4	NDIR drift quality control failure
	m5	Non-white (grey) carbon punch after carbon analysis
n		Foreign substance on sample.
	n1	Insects on deposit, removed before analysis.
	n2	Insects on deposit, not all removed.
	n3	Metallic particles observed on deposit.
	n4	Many particles on deposit much larger than cut point of inlet.

Validation Flag	Sub Flag	Description
	n5	Fibers or fuzz on filter.
	n6	Oily-looking droplets on filter.
	n7	Shiny substance on filter.
	n8	Particles on back of filter.
	n9	Discoloration on deposit.
o		Valid. Quality check(s) outside typical guidelines.
	o1	Valid. Multiple point calibration outside typical quality guidelines.
	o2	Valid. Calibration peak outside typical quality guidelines.
	o3	Valid. Auto calibration outside typical quality guidelines.
	o4	Valid. Manual injection outside typical quality guidelines.
q		Standard.
	q1	Quality control standard.
	q2	Externally prepared quality control standard.
	q3	Second type of externally prepared quality control standard.
	q4	Calibration standard.
r		Replicate analysis.
	r1	First replicate analysis on the same analyzer.
	r2	Second replicate analysis on the same analyzer.
	r3	Third replicate analysis on the same analyzer.
	r4	Sample re-analysis.
	r5	Replicate on different analyzer.
	r6	Sample re-extraction and re-analysis.
	r7	Sample re-analyzed with same result; original value used.
s		Suspect analysis result.
t		Parameter changes which require reprocessing raw data.
	t1	Reprocessed, integration threshold changed.
	t2	Reprocessed, integration method changed.
	t3	Reprocessed, gas transit time changed.

Validation Flag	Sub Flag	Description
	t4	Reprocessed, mass flow meter flow calibration(s) changed.
	t5	Reprocessed, laser calibration(s) changed.
	t6	Reprocessed, temperature calibration(s) changed.
v		Invalid (void) analysis result.
	v1	Quality control standard check exceeded ± 10% of specified concentration range.
	v2	Replicate analysis failed acceptable limit specified in SOP.
	v3	Potential contamination.
	v4	Concentration out of expected range.
	v5	Instrument error
	v6	Operator error
	v7	Software error
w		Wet Sample.
	w1	Deposit spotted from water drops.
y		Data normalized
	y1	XRF data normalized to a sulfate/sulfur ratio of three
	y2	Each species reported as a percentage of the measured species sum