Interagency Monitoring of Protected Visual Environments (IMPROVE) Network 2024 Technical Systems Audit: Monitoring Sites

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Date: 6 February 2025

Introduction

In accordance with the quality system of the Interagency Monitoring of Protected Visual Environment (IMPROVE) network, technical system audits (TSAs) are conducted annually. TSAs are used to determine if individual (IMPROVE) sampling sites are being operated in accordance with the Quality Assurance Project Plan (QAPP) and relevant standard operating procedures (SOPs). In addition, the results from individual audits are combined to determine how the network is performing overall. The full quality system is described in the network QAPP, and the management structure is outlined in the network Quality Management Plan.

Audit Program Overview

The drafting of the IMPROVE QAPP in 2016 introduced the current TSA process. A selection of sites is audited annually, with all network sites to be audited in a 10-year period. The auditor is required to be familiar with the network and trained by a previously approved auditor but cannot be involved in the routine operation of the monitoring sites. In 2016, the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University began overseeing the TSA program for the IMPROVE network with Derek Day serving as the audit coordinator and quality assurance lead for the network. In 2023, Bonne Ford was hired as the new audit coordinator.

The previous audit coordinator also conducted several training sessions in 2017 for outside auditors from EPA Region 2, CO, AZ, MO, WY, and DE. This training program was designed to ensure consistency of audits throughout the network and increase the number of audits completed each year. In 2024, only auditors from Missouri Department of Natural Resources (MDNR) and Colorado Department of Health and the Environment (CDPHE) are continuing to audit IMPROVE sites. Additionally, these auditors do not conduct a full TSA (described below) but generally only audit instrument performance and siting. The new audit coordinator (Bonne Ford) has reached out to CDPHE and MO DOE to coordinate continuing these audits and update training. A combined audit was coordinated with CDPHE in July 2024. A combined audit with MDNR is tentatively planned for summer 2025.

There are currently (as of December 2024), 155 IMPROVE sites. During the current 10-year audit period of 2016-2025, 148 of these sites have been audited (some multiple times) along with several sites that are no longer in operation. Seven sites have not been audited as of December 2024; however, four of these sites will be audited in 2025 (3 in January 2025). Thus, there will

only be 3 sites that will not have been audited for the audit period outlined in the QAPP. However, one of these sites, MacDonald Pass (MAPA1), was installed in October 2024, and is a replacement for Gates of the Mountain (GAMO1), which was audited in 2018. Toolik Lake (TOOL1) was unable to be audited during the 2022 audit trip to the region to do inclement weather, and Egbert (EGBE) is in Canada and has not been audited due to lack of proximity to other sites.

The map below shows the location of sites, colored by the year of the last audit. To note, no audits were conducted by CIRA personnel in 2020 (due to travel restrictions) or 2023 due to personnel changes.

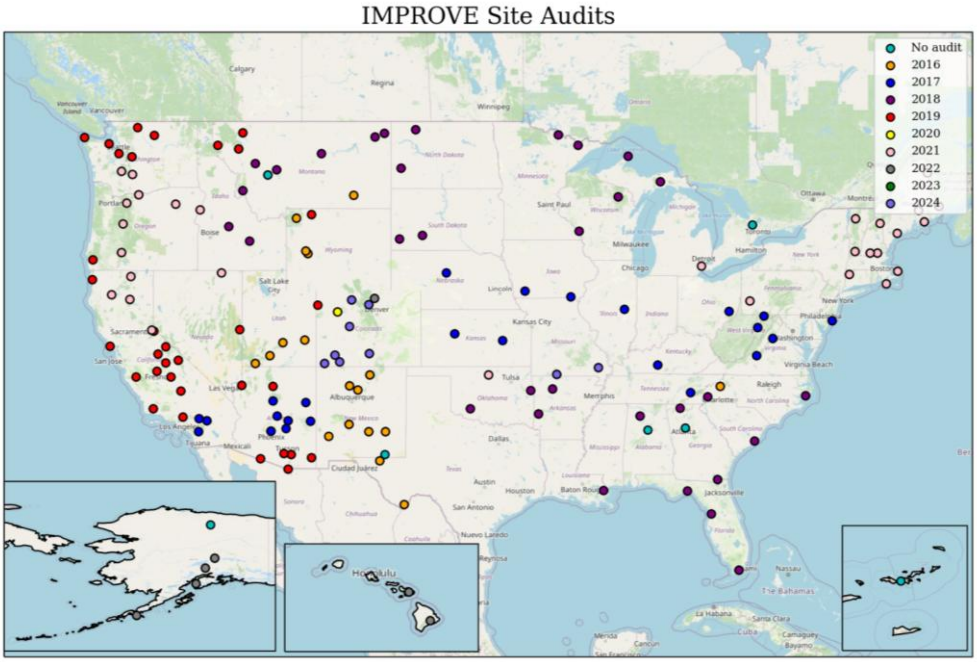

Figure 1. Locations of IMPROVE monitoring sites, colored by the year of the most recent audit.

Audit Procedure

All audits consist of verifying the coordinates and elevation of a site location, verifying the sampler's date and time, and measuring the vacuum pressure, temperature, and the flow rate of each module. A certified flow meter that is calibrated and recertified annually is used to measure flow rates. A full TSA also includes checking the sampler stand (or shed) for safety and integrity and ensuring that the site is configured for proper sample collection with no obstructions. Pictures of the sampler modules, sampler stand/building, and surroundings are taken. It is preferable to schedule TSAs in coordination with site operators in order to observe sample changing techniques and ensure that the operator has adequate sampler and sample change knowledge following the questions outlined in the approved TSA workbook. The site operators are asked about sampling safety concerns and about whether the current IMPROVE Operations Contractor (UC Davis) field team is providing adequate support to help the operator maintain high quality sampling at the site. The sampler siting criteria is reviewed, which ensures the samples collected represent local ambient background conditions as outlined in the IMPROVE SOP 126: Site Selection.

An approved TSA form is used for all audits. A copy of this form is available on the IMPROVE website (https://vista.cira.colostate.edu/Improve/technical-system-audits/). These forms are sent to site operators prior to the audit to inform them of the procedure. Completed audit forms are also sent to the site operators and managers following the audit along with any recommendations or necessary resources. Completed forms are also sent to the field team manager along with updated site photos.

Audited Sites in 2024

Nine site audits were completed in 2024: 1 by CIRA, 2 by MDNR, and 6 by CDPHE (one in conjunction with CIRA). Only the GRSA audit is considered a full TSA; however, all of these sites have been previously audited within the 10-year audit period. Locations of these sites are noted in Figure 1.

Audit Results for 2024

Individual site results are provided in TSA workbooks, and the results are summarized here. All flow rate, temperature, time, and vacuum tests passed for all modules at all sites as described below.

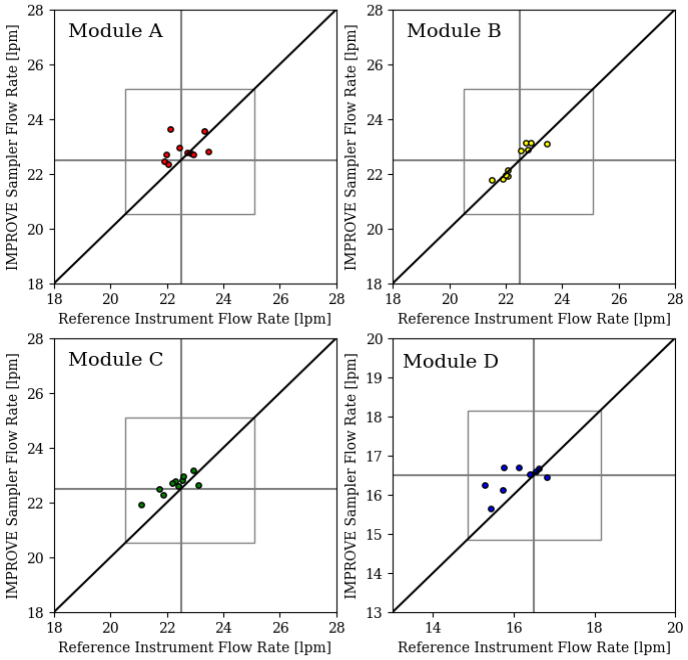

Figure 2. Flow rates results for all sites audited in 2024 for Modules A, B, C, and D (includes any duplicate measurements). Gray horizontal and vertical lines represent the nominal flow rate of the instrument; black line denotes the 1:1, and gray box denotes the range of acceptable values. The flow rate as given by the module is on the y-axis while the flow rate measured by the reference (audit) instrument is on the x-axis.

The IMPROVE sampler consists of four separate modules (A, B, C, and D); some sites include a fifth module (X) which is a duplicate measurement of one of the standard modules. Modules A, B, and C operate at a nominal flow rate of 22.8 liters/minute (lpm) and utilize a cyclone to achieve a 2.5-micron size cut. Module D operates at a nominal flow rate of 16.9 lpm and utilizes

an impactor at the inlet to achieve a 10-micron size cut. Modules fail the flow rate test if the audit device flow rate differs from the nominal flow rate by more than 10%. All modules audited in 2024 past the flow tests, as shown in Figure 2. The sampler vacuum is also measured to ensure minimal air leakage throughout the sample train (the value must be below 3.5 psi to pass). As shown in Table 1, all modules at all sites passed the leak test.

Table 1. Leak check values for all modules. Modules pass if the value is below 3.5 psi.

Site ID	Module A	Module B	Module C	Module D
GRSA	1.9	2.0	1.6	0.9
HEGL	1.5	1.1	1.2	2.2
MEVE	2.2	2.7	2.8	1.1
MING	1.5	2.0	2.1	1.6
MOZI	1.0	1.3	1.4	0.8
ROMO	1.2	1.2	1.0	0.9
SHMI	1.3	1.2	1.2	0.9
WEMI	1.2	1.0	1.2	0.9
WHRI	1.2	1.7	0.9	1.2

As a full TSA was not completed on any of the sites other than GRSA, there are few extra notes or findings. The MDNR auditors did check paperwork at HEGL and MING, and they noted that the MING site had been moved since their previous audit. They also cleaned inlet covers to remove spider webs. CDPHE noted that they compromised a denuder during reassembly of inlet B, but they had already reached out to the field team to have a replacement sent to the operator. At GRSA, the structure was noted to be in poor condition and swayed when pressure was put on it. It was suggested that the site operator and manager coordinate with the NPS to have the structure replaced.

Figure 3. Photo of the GRSA stand showing disrepair.

Audit Results Compared to Previous Audits

Great Sand Dunes (GRSA) was previously audited in 2016, 2022, and 2023. In 2022, it was noted that the stacks for Modules B and C were not seated into the sampler inlet. It was assumed that this was likely due to strong winds. The field team installed extra collars on all the inlet stacks (these are generally only on Module D stacks) and that appears to have worked to keep the stacks seated. GRSA has never failed a flow or temperature audit, but the agreement between the audit instrument has improved over time, specifically for Module D.

Rocky Mountain National Park (ROMO) was previously audited in 2016 (CIRA), 2018 (CIRA), 2019, 2020, and 2022. Shamrock Mines (SHMI) was previously audited in 2016 and 2023. Mesa Verde (MEVE) was previously audited in 2016, 2017, and 2020. No issues have been noted in previous audits for these sites.

Hercules Glades (HEGL) was previously audited in 2017, 2020, and 2021 (CIRA). In 2021, it had a leak check fail for Module A.

Mingo NWR (MING) was previously audited in 2019, 2020, 2021 (CIRA), and 2022. In 2019, it was noted that the shelter was in poor condition. By the 2022 audit, it had been replaced and moved up the hill slightly. By the 2024 audit, it had been moved back down the hill. In 2022, it was also noted that the touchscreen had failed, and a USB mouse was installed for operation. The 2022 audit, as in the 2024 audit, noted excessive spider webs that were cleaned off inlets.

Mount Zirkel (MOZI) was previously audited in 2016, 2018 (CIRA), 2020, and 2023. Module A failed the flow test in 2020. In 2023 and 2024, the modules all passed the flow tests.

Weminuche Wilderness (WEMI) was previously audited in 2016 (CIRA) and 2020. The 2016 audit noted that the sampler stand needed work and that there were several trees too tall and too close to the inlets. The Forest Service was notified that these would need to be trimmed back. Module B also failed the leak check. All modules passed in 2020 and no site issues were noted.

White River (WHRI) was previously audited in 2016, 2019, 2020, 2021, and 2023. In 2016, all modules passed. However, in 2019, Module D failed the flow test; in 2020, Module C failed the flow test (and the display was not reading correctly); in 2023, Module D failed and Module B was close to failing. In 2024, all passed, but Module D was close to failing with a 10% difference between the audit instrument and module.

Summary

The audit results demonstrate that the IMPROVE network is currently working properly and that the quality and management systems in place are adequate. Comparison to previous years' audits shows that there were fewer issues at sites, no failures of flow or leak checks, and that overall operation of the network has improved over time. In particular, the technical improvements to modules and other work of the field team have eliminated many of the problems noted in earlier audits (e.g., clock and display issues, stacks not seated, etc.). The introduction of the flow control should also prevent modules from failing flow tests; several sites with flow control will be audited in 2025.

The 10-year audit period finishes in 2025, and only 2 of the 155 current sites will not have been audited. The IMPROVE QAPP will also undergo an update that coincides with this timing.

Thus, there may be new updates to the TSA procedure and the results of the audits should be useful in informing those decisions. Conducting more training sessions and recruiting auditors from partner agencies should also be a priority for the next audit period.

Documents Referenced in Report:

Document	**Webpage Link with Document**
IMPROVE QMP	https://vista.cira.colostate.edu/Improve/quality-assurance/
IMPROVE QAPP	https://vista.cira.colostate.edu/Improve/quality-assurance/
IMPROVE SOP 126: Site Selection	https://vista.cira.colostate.edu/Improve/particulate-monitoring-network/
Technical Systems Audit Form	https://vista.cira.colostate.edu/Improve/technical-system-audits/