IMPROVE Sampler Technical System Audits

Overview of 2017 audits

1/12/2018

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Introduction

The Interagency Monitoring of Protected Visual Environments (IMPROVE) network samplers undergo technical systems audits (TSAs) to ensure the network samplers are operating in compliance with the Quality Assurance Project Plan (QAPP; http://vista.cira.colostate.edu/improve/wp-content/uploads/2017/01/IMPROVE-QAPP-Signed_3_2016.pdf) and relevant standard operating procedures (SOPs; http://vista.cira.colostate.edu/Improve/particulate-monitoring-network/). TSAs consist of two parts: (1) assessment of sampling equipment performance relative to NIST traceable reference standards; and (2) assessment of site conditions and operator sample handling technique. Since 2016, 62 different IMPROVE sampling sites have been audited (Figure 1): 36 in 2016 and 35 in 2017; nine sites were audited both years. This document summarizes the results of audits conducted in 2017. Sampler flow rate comparisons are presented in Tables 1-4 and Figures 2-5, while all other sampling equipment comparisons are displayed in Tables 5 and 6.

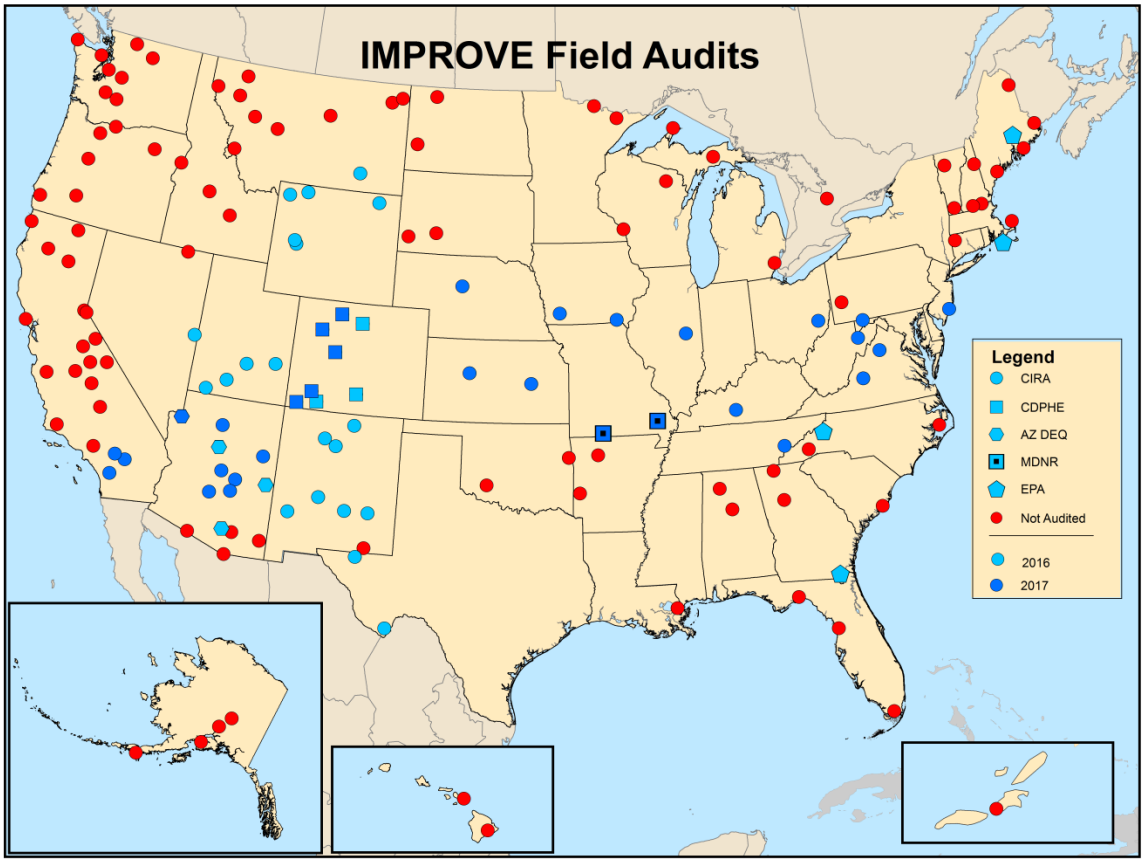

Figure 1. The IMPROVE network sampling sites, showing the sites which have been audited (blue symbols), the various entities performing the audits (various symbols), and sites which have not been audited within the last two years (red symbols).

Auditor Training

In conjunction with the site audits, six auditor training/certification sessions were conducted in 2017. They included Great Sand Dunes, CO with Colorado Department of Public Health and Environment (CDPHE), Phoenix, AZ with Arizona Department of Environmental Quality (AZDEQ), Lake Sugema, IA with Missouri Department of Natural Resources (MDNR), Frostburg Reservoir, MD with Maryland Department of the Environment (MDE), Brigantine, NJ with representatives from EPA region 2, and Mount Baldy, AZ with a US forest service representative from the southwest region. Training partners on proper auditing procedures expands capabilities to conduct regular audits (~25% of the audits conducted in 2016-2017 were done by partners) and ensures that consistent methods are used across the network. There were no false negative audits in 2017 (i.e. reporting a sampler flow rate was not correct when in fact the sampler was running fine), which may, in part, be due to auditor training program.

Sampler Siting Criteria

The IMPROVE sampler siting criteria are thoroughly explained in SOP 126 (http://vista.cira.colostate.edu/Improve/particulate-monitoring-network/) and are not reiterated here. In general, the TSA process notes and documents site properties which could impede sampling aerosol of a regional background nature. Impediments include significant local sources of particulates (automotive, wood smoke, dust, etc.), or obstructions such as trees or buildings which could hamper air flow to the sampler inlet. Problems are reported on the TSA form and the site operator is notified if corrective action is needed (trees trimmed or brush cleared). Although all sites audited in 2017 passed the siting criteria, tree trimming or removal was recommended at Grand Canyon and Great Sand Dunes National Parks.

Sampler Integrity

The TSAs ensure the sampler stand is maintained such that routine access does not pose a risk to the operator, the IMPROVE modules are protected from direct sunlight, and sample changes are protected during inclement weather. The IMPROVE modules are checked to ensure they are fastened securely to the structure, and inlet stacks are seated properly into each module. Electrical wiring and connections are visually examined and photos are taken. During the 2017 audit the sampling stand at Viking Lake, Iowa was found to be very unstable and the sampling stacks were not seated properly into the sampler upon arrival for the audit. The proper regional personnel were notified of the sampler stand condition.

Operator Technique

Site operators should be aware of SOP 201 (http://vista.cira.colostate.edu/Improve/particulate-monitoring-network/), which provides an overview of the IMPROVE sampler and sampling process. The site operator is directed to this resource in the TSA form they are asked to complete

prior to the audit; if the operator is present during the TSA, (s)he is reminded that this resource is available. It is important that good sample change technique is employed to reduce the risk of sample contamination. Tuesday is sample change day throughout the IMPROVE network and thus the only day which guarantees the individual conducting the TSA can meet with the site operator to observe the sample change process. No issues of improper sample handling were observed in 2017.

Sampler Vacuum

The vacuum pressure is measured by starting a particular module's pump, closing a ball valve, which prevents air flow through the system, and then reading the ORI transducer. This measurement is labeled MaxORI on the TSA form. It is indicative of pump strength, air leakage through the system, and proper transducer operation. The TSA test fails if the MaxORI pressure drop is less than 33mV; a pressure drop of 40mV is not uncommon. The TSA measurement is different from the MaxORI readings obtained during routine sample changes because the TSA test measures pressure drop through the entire sample train while during routine sample changes the pressure drop is measured from the solenoids to the pump. The only vacuum pressure failure in 2017 occurred at the Quaker City, OH site. In this case, the IMPROVE MaxORI passed, while the TSA MaxORI test failed. An overview of these results is given in Table 5.

Temperature

The IMPROVE sampler temperature is monitored to accurately calculate sampler flow rates. During TSAs the sampler temperature is compared to the NIST traceable temperature of a BGI tetraCal Air Flow Calibrator. The TSA temperature fails if the temperature of the sampler and the tetraCal differ by more than 10 ˚C. There were no temperature failures for the 2017 TSAs. Temperature comparisons are shown in Table 6.

Sampler Time

The sampler time is compared to cell phone time and adjusted if the difference is greater than 5 minutes. Sampler time notes and comparisons are shown in Table 5 and 6. There were time failures at Weminuche (CO) and at Mingo (MO) that were noted, but the clock was not reset by the auditor. UC Davis is informed of the clock status when TSA reports are sent to them.

Sampler Flow Rate

The IMPROVE sampler consists of four separate channels which are commonly referred to as modules A, B, C, and D. 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. Pressure transducers are used to measure the pressure drop across the cyclone and across the critical orifice/needle valve. During the bi-annual sampler maintenance procedures UC Davis

personnel generate calibration curves which relate the measured pressure drops to sampler flow rates for each module. During an audit the IMPROVE sampler flow rate is compared to a NIST traceable reference standard. For the audits conducted by CIRA the flow rates were measured using a tetraCal flow meter which had been calibrated and certified by Mesa Labs. The audit devices undergo certification annually. Samplers fail the flow rate audit if flows differ from the nominal flow rate by more than 10%. Results are shown in Tables 1-4 and Figures 2-5. Only one module (C module, Meadview) failed the flow rate criteria in 2017.

Table1. Summary Statistics of flow rate comparisons for Module A

Statistic	Audit	Orifice	Cyclone	% Diff Ori	% Diff Cyc
Min.	21.96	22.38	21.79	0.0000	0.04433
1st Qu	22.51	22.80	22.84	0.6037	0.90449
Median	22.80	22.95	23.12	1.0048	1.61502
Mean	22.87	22.99	23.11	1.5443	2.03221
3rd Qu	23.07	23.20	23.36	2.2741	2.73845
Max.	24.16	23.40	24.29	4.5826	7.90760

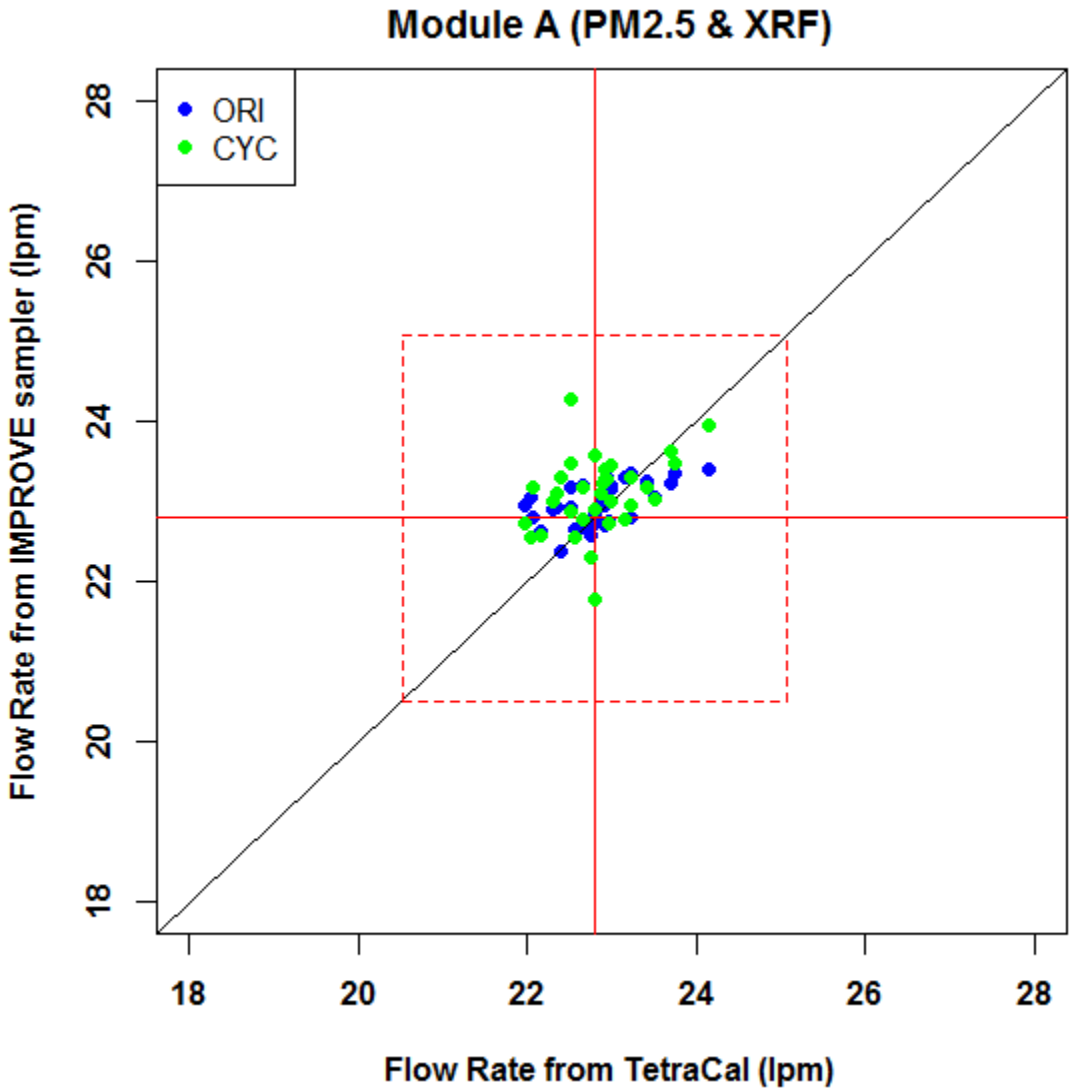

Figure 2. Flow rate comparison for Module A audits in 2017. The solid red line indicates nominal sampler flowrate, while the dashed red line indicates flow rate +/- 10%.

Table 2. Summary Statistics of flow rate comparisons for Module B

Statistic	Audit	Orifice	Cyclone	% Diff Ori	% Diff Cyc
Min.	21.20	22.11	22.02	0.04303	0.2843
1st Qu	22.21	22.64	22.55	1.14994	1.3727
Median	22.79	22.92	22.82	1.62393	2.1459
Mean	22.78	22.82	23.02	2.30026	2.5151
3rd Qu	23.25	23.01	23.32	3.29781	3.3560
Max	24.62	23.51	24.69	8.89521	6.1321

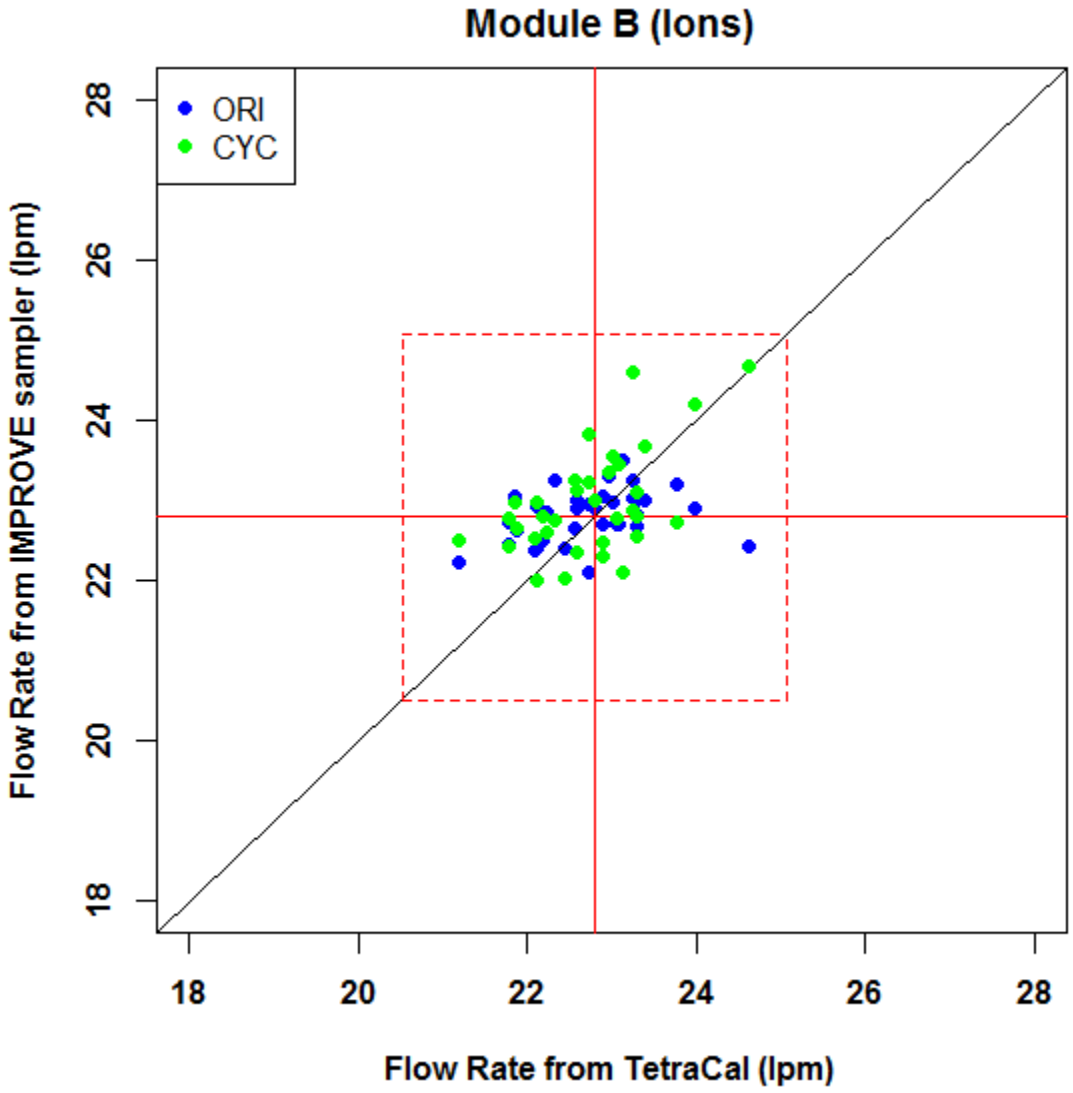

Figure 3. Flow rate comparisons for Module B audits in 2017.

Table 3. Summary Statistics of flow rate comparisons for Module C

Statistic	Audit	Orifice	Cyclone	% Diff Ori	% Diff Cyc
Min	21.05	22.06	21.79	0.0000	0.1298
1st Qu	22.05	22.41	22.34	0.6852	0.8665
Median	22.69	22.71	22.88	1.7219	2.3205
Mean	22.64	22.73	22.93	1.9553	2.5012
3rd Qu	23.12	22.98	23.25	2.6365	3.7778
Max	23.61	23.57	25.04	6.0333	6.0568

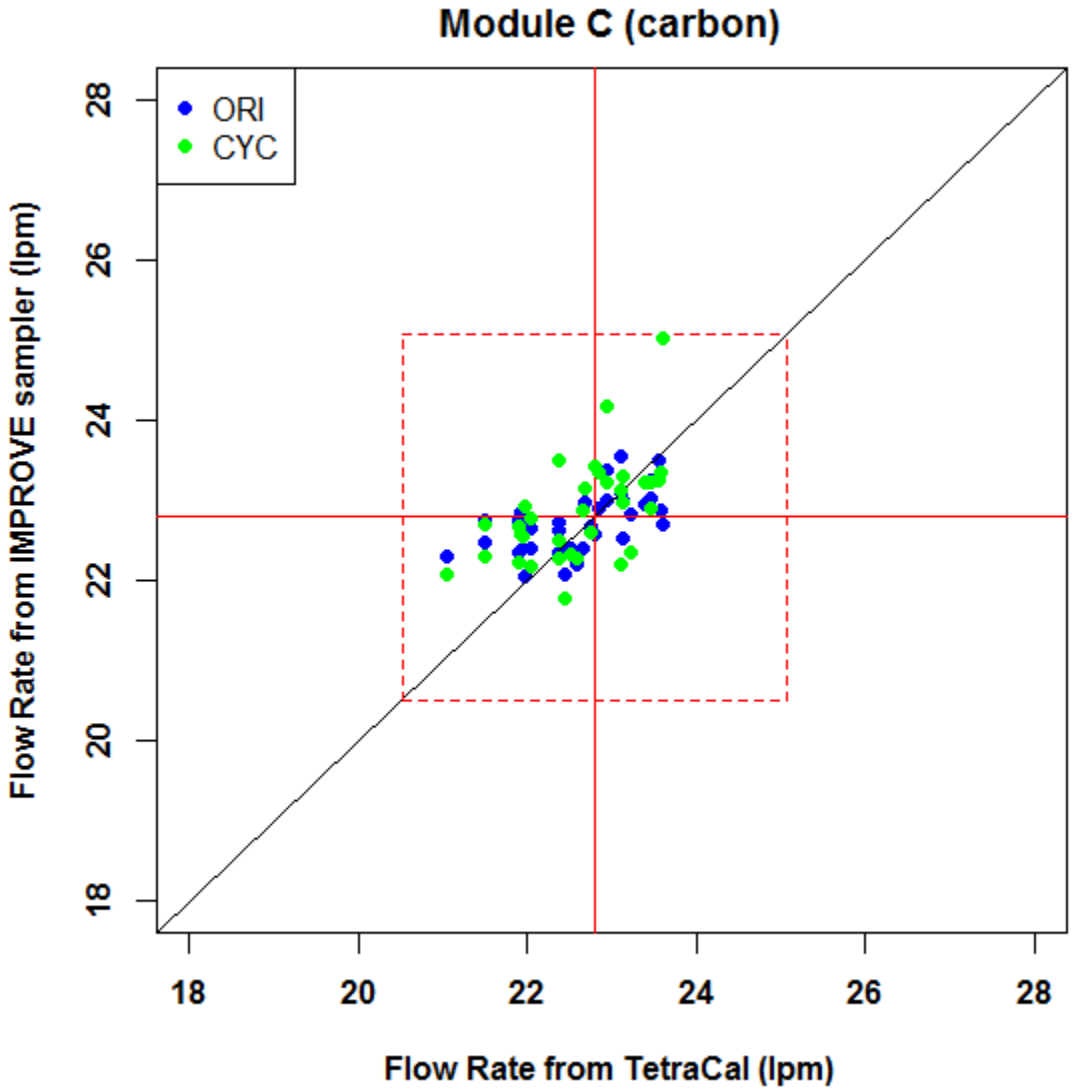

Figure 4. Flow rate comparisons for Module C audits in 2017.

Table 4. Summary Statistics of flow rate comparisons for Module D

Statistic	Audit	Orifice	% Diff Ori
Min.	15.47	16.45	0.05935
1st Qu.	16.43	16.80	0.91728
Median	16.78	17.00	1.73134
Mean	16.73	16.97	2.38387
3rd Qu	17.15	17.07	3.34255
Max.	17.64	17.48	8.33864

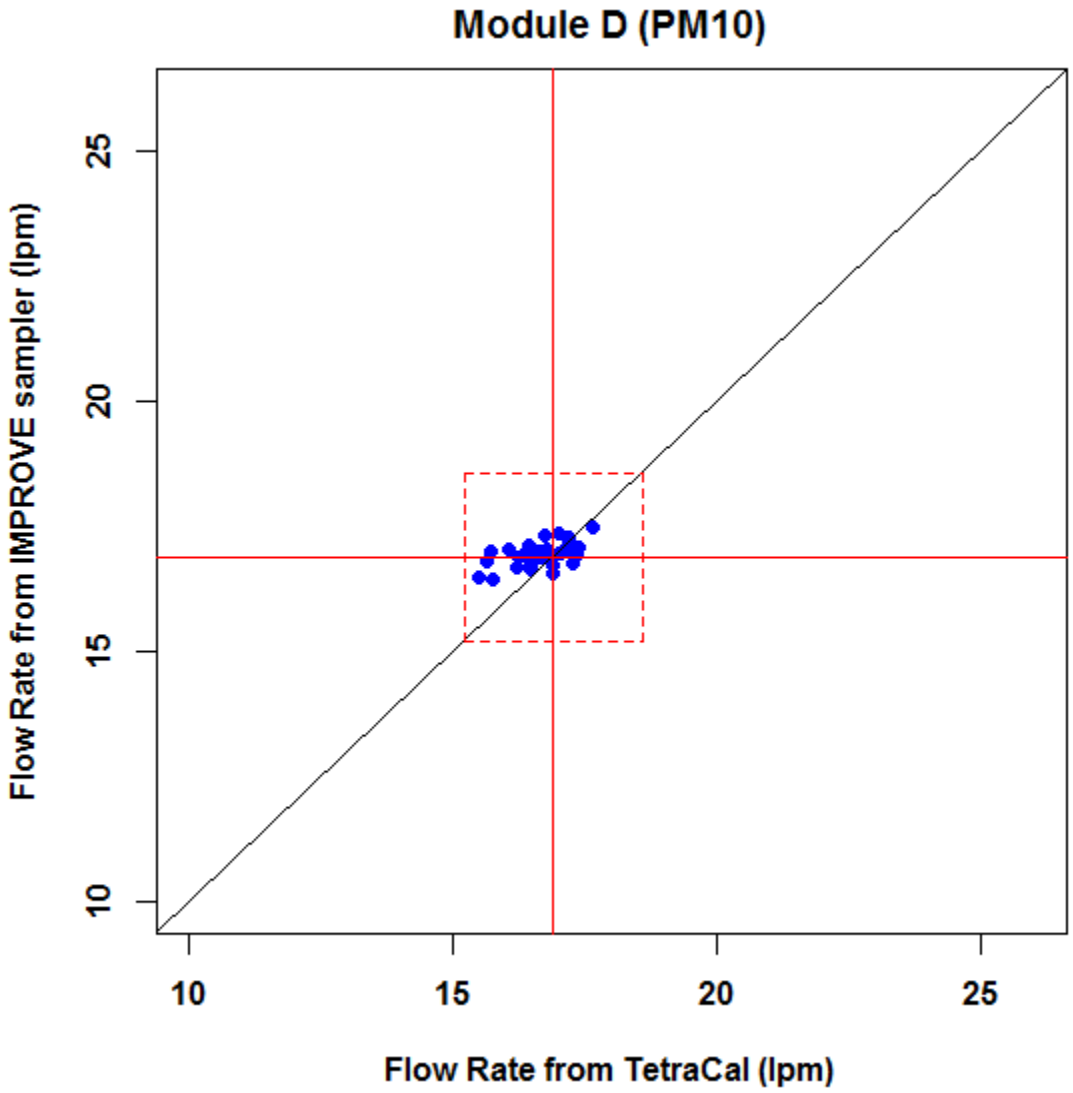

Figure 5. Flow rate comparisons for Module 7 audits in 2017.

Table 5. General audit notes, site/sampler observations, results of sampler clock check

SITE	DATE	Issues/Notes	Follow up
Aqua Tibia	4/20/2017	All Pass	
Bondville	9/14/2017	All Pass	
Brigantine	9/20/2017	Reset Clock; All flow checks pass; Did auditor training.	
Cedar Bluff	9/29/2017	Reset Clock; All flow checks pass	
Dolly Sods	9/18/2017	All Pass	
Flat Tops	9/5/2017	All Pass	
Frostburg Reservoir	9/19/2017	Reset Clock (for auditor training); All flow checks pass but the B module flow rate is high; Did auditor training. Sample day.	
Great Sand Dunes	4/30/2017	All Pass. Tree needs trimming. Did auditor training.	X
Great Smoky Mts	9/26/2017	All Pass	
Hance	4/5/2017	Trees need to be trimmed (southeast side). All modules passed but D flow rate is 8.5% and 7% off.	X
Hercules Glades	5/24/2017	All pass.	
Ikes Backbone	4/6/2017	All Pass.	
James River Face	9/22/2017	Sample day - audited on IMPROVE cassettes (all pass with very small differences in flow rates).	
Joshua Tree	5/5/2017	All Pass.	
Lake Sugema	9/13/2017	Sample day - audited on IMPROVE cassettes. Auditor training.	
Mamoth Cave	9/27/2017	All Pass	
Meadview	7/6/2017	Module C cyc flow rate failed.	X
Mesa Verde	5/24/2017	All Pass	
Mingo, MO	5/23/2017	Time off. All pass.	
Mount Zirkle	9/21/2017	All Pass	
Mount Baldy	5/11/2017	Reset clock. All module flow rates passed.	
Nebraska NF	9/11/2017	All Pass	
Petrified Forest	4/3/2017	All pass.	
Phoenix	5/8/2017	All pass. Did auditor training.	
Quaker City	9/15/2017	MaxOri failed (29.6 mv should be > 33) All else passes. The sampler MaxOri all passed.	X
Rocky Mountain	8/4/2017	All pass. New controller works well for audits.	
San Gorgonio	5/3/2017	All Pass	
Shenandoah	9/21/2017	All Pass	
Sierra Ancha	4/11/2017	All Pass	
Sycamore Canyon	4/4/2017	All Pass	
Tall Grass Prairie	9/28/2017	Reset Clock; All modules passes.	
TontoNationalMonument	5/9/2017	All Pass	
Viking Lake	9/29/2017	Module C stack was not seated into the cyclone T properly. Sampler stand moves (sways) too much. All modules passed.	X
Weminuche	5/24/2017	Time off. All pass.	
White River	9/18/2017	All pass.	

Table 6. Audit Results: Time, Temperature, and Flow Rate

	DATE/TIME				TEMP			A MODULE			B MODULE			C MODULE			D MODULE		AOri	ACyc	BOri	BCyc	COri	CCyc	DOri
Site	Date	Aud	IMP	<5min	Aud	IMP	< 10 C	Aud	Ori	Cyc	Aud	Ori	Cyc	Aud	Ori	Cyc	Aud	Ori	%Diff	%Diff	%Diff	%Diff	%Diff	%Diff	%Diff
Aqua Tibia	4/20/2017	8:27	8:24	Pass	28.3	27.5	0.80	22.9	23.3	23.3	23.0	23.0	23.6	22.8	22.9	23.4	17.2	17.3	1.6	1.5	0.2	2.4	0.3	2.3	0.8
Bondville	9/14/2017	8:34	8:34	Pass	22.2	20.3	1.87	22.9	23.1	23.2	22.2	22.9	22.6	22.0	22.4	22.8	17.0	17.0	1.0	1.5	2.9	1.7	1.7	3.4	0.2
Brigantine	9/20/2017	9:14	9:08	Reset	24.4	24.8	-0.40	23.2	23.4	23.3	22.9	23.1	22.5	23.1	23.6	23.1	17.0	17.4	0.6	0.4	0.7	1.8	2.0	0.1	2.3
Cedar Bluff	9/29/2017	8:03	7:55	Reset	19.4	18.1	1.30	22.8	22.7	23.6	22.2	22.5	22.8	22.0	22.4	22.6	16.9	16.7	0.3	3.4	1.4	2.8	2.1	2.8	1.0
Dolly Sods	9/18/2017	8:08	8:08	Pass	17.3	18.6	-1.27	23.0	22.8	22.7	22.4	22.4	22.0	22.6	22.2	22.3	16.9	16.6	0.9	1.0	0.1	1.8	1.7	1.3	1.8
Flat Tops	9/5/2017	17:02	17:01	Pass	31.1	32.9	-1.80	22.7	22.7	23.2	23.0	23.3	23.4	22.7	23.0	23.2	15.7	16.4	0.2	2.4	1.5	1.7	1.3	2.1	4.6
Frostburg Res	9/19/2017	10:33	10:31	Pass	28.1	28.9	-0.81	23.4	23.3	23.2	24.6	22.4	24.7	23.1	22.5	23.0	17.4	17.1	0.7	0.9	8.9	0.3	2.6	0.6	1.6
Great Sand Dunes	4/30/2017	12:27	12:25	Pass	13.5	15.3	-1.78	22.0	23.1	22.6	21.9	23.1	23.0	23.5	23.3	22.9	16.0	17.1	4.6	2.4	5.5	5.1	0.9	2.4	6.5
Great Smoky Mts	9/26/2017	10:50	10:51	Pass	26.6	26.3	0.27	22.9	23.1	23.1	22.6	22.7	23.3	22.8	22.7	22.6	17.1	17.1	0.8	1.0	0.4	3.1	0.3	0.7	0.3
Hance	4/5/2017	10:25	10:22	Pass	9.5	9.3	0.21	22.4	22.4	23.3	22.1	22.4	22.5	22.0	22.1	22.9	15.5	16.5	0.1	4.0	1.3	2.0	0.4	4.3	6.5
Hercules Glades	5/24/2017	8:38	8:37	Pass	15.0	17.4	-2.40	22.1	22.8	23.2	21.8	22.7	22.8	21.1	22.3	22.1	16.2	16.9	3.4	5.1	4.3	4.6	6.0	4.9	4.2
Ikes Backbone	4/6/2017	11:11	11:13	Pass	22.6	20.8	1.80	23.7	23.2	23.6	23.3	22.8	23.1	23.6	22.9	23.3	17.3	16.9	1.9	0.3	2.0	0.7	2.9	1.0	2.2
James River Face	9/22/2017	7:53	7:56	Pass	20.7	23.7	-3.04	22.8	22.8	22.9	22.8	22.9	23.0	22.5	22.4	22.3	17.1	17.0	0.2	0.6	0.6	0.9	0.5	0.8	0.6
Joshua Tree	5/5/2017	7:16	7:12	Pass	25.8	25.2	0.65	23.2	23.3	22.8	22.6	22.9	22.3	23.1	23.0	23.3	16.8	17.0	0.6	1.6	1.5	1.0	0.5	0.8	1.7
Lake Sugema	9/13/2017	10:45	10:44	Pass	28.1	29.1	-1.04	23.0	23.2	23.0	23.1	23.5	22.1	21.9	22.8	22.2	17.2	17.2	0.8	0.1	1.7	4.3	4.0	1.6	0.1
Mamoth Cave	9/27/2017	8:31	8:30	Pass	25.2	22.9	2.28	23.5	23.0	23.0	23.8	23.2	22.7	23.2	22.8	22.4	17.3	17.0	2.0	2.0	2.3	4.3	1.7	3.8	1.6
Meadview	7/6/2017	11:39	11:38	Pass	44.5	46.5	-2.03	22.3	23.1	24.0	22.5	23.0	24.5	21.2	22.6	24.1	16.5	17.5	3.6	7.6	2.3	8.7	6.8	13.7	6.0
Mesa Verde	5/24/2017	10:38	10:38	Pass	26.2	23.3	2.93	22.3	22.9	23.1	22.1	22.9	23.0	21.5	22.8	22.3	16.4	17.1	2.6	3.4	3.7	3.9	5.9	3.8	4.2
Mingo, MO	5/23/2017	10:36	10:26	Noted	25.3	29.3	-3.96	22.5	22.9	24.3	22.7	22.1	23.8	22.8	22.6	23.4	17.0	17.0	1.9	7.9	2.7	4.8	1.0	2.7	0.3
Mount Zirkle	9/21/2017	12:12	12:12	Pass	15.6	16.7	-1.09	22.7	22.6	22.3	23.2	23.3	22.9	23.6	23.5	23.3	16.5	16.7	0.6	1.9	0.0	1.5	0.2	1.3	1.4
Mount Baldy	5/11/2017	10:54	10:48	Reset	15.1	12.7	2.40	22.6	22.7	22.6	22.1	22.4	22.0	22.5	22.1	21.8	16.5	16.6	0.5	0.0	1.4	0.4	1.6	2.9	1.1
Nebraska NF	9/11/2017	9:08	9:07	Pass	24.6	25.0	-0.40	22.8	22.9	21.8	23.3	23.0	24.6	23.0	23.4	24.2	16.8	17.0	0.6	4.4	1.0	5.8	1.9	5.4	1.5
Petrified Forest	4/3/2017	8:48	8:48	Pass	12.7	12.0	0.71	22.9	22.7	23.3	21.9	22.6	22.7	21.9	22.4	22.7	16.5	16.8	0.9	1.6	3.5	3.5	2.1	3.7	1.8
Phoenix	5/8/2017	10:58	10:59	Pass	33.4	29.3	4.14	24.2	23.4	23.9	24.0	22.9	24.2	23.6	22.7	25.0	17.6	17.5	3.1	0.9	4.4	0.9	3.8	6.1	0.9
Quaker City	9/15/2017	10:15	10:14	Pass	23.1	22.3	0.77	22.9	22.9	23.4	22.9	22.7	22.3	21.5	22.5	22.7	16.9	16.9	0.2	2.2	0.8	2.5	4.6	5.6	0.0
Rocky Mountain	8/4/2017	10:11	10:11	Pass	21.4	22.0	-0.60	22.8	22.8	22.9	23.3	23.0	22.8	23.1	23.1	22.2	16.4	17.0	0.0	0.4	1.3	2.1	0.0	3.9	3.7
San Gorgonio	5/3/2017	8:44	8:43	Pass	26.3	24.3	1.97	23.8	23.4	23.5	23.4	23.0	23.7	23.5	23.0	23.2	17.3	17.1	1.6	1.1	1.6	1.2	1.9	1.0	0.9
Shenandoah	9/21/2017	9:20	9:20	Pass	22.4	22.0	0.42	23.2	22.8	23.0	23.3	22.7	22.6	22.7	22.4	22.9	17.3	16.8	1.8	1.2	2.6	3.1	1.1	1.0	2.8
Sierra Ancha	4/11/2017	9:33	9:36	Pass	21.1	22.8	-1.70	22.5	22.9	22.9	22.7	23.0	23.2	22.4	22.4	22.3	16.7	16.9	1.7	1.6	1.0	2.2	0.0	0.4	1.3
Sycamore Canyon	4/4/2017	9:54	9:56	Pass	11.1	17.2	-6.06	22.0	23.0	22.7	21.2	22.2	22.5	22.4	22.7	23.5	15.6	16.8	4.5	3.5	4.8	6.1	1.6	5.2	7.4
Tall Grass Prairie	9/28/2017	10:05	10:02	Pass	24.4	27.9	-3.45	22.7	23.2	22.8	22.6	23.0	23.1	22.1	22.7	22.2	16.6	17.0	2.4	0.6	1.8	2.4	2.7	0.6	2.4
TontoNationalMon	5/9/2017	9:34	9:34	Pass	18.1	21.5	-3.41	23.0	23.2	23.5	23.1	22.7	23.5	23.0	23.0	23.2	16.7	17.4	0.9	2.1	1.6	1.6	0.2	1.2	3.8
Viking Lake	9/29/2017	8:20	8:22	Pass	22.1	24.1	-2.00	22.5	23.2	23.5	22.3	23.3	22.8	22.4	22.6	22.5	16.6	16.9	3.0	4.3	4.1	1.9	1.1	0.6	1.9
Weminuche	5/24/2017	8:18	8:10	Noted	18.1	22.1	-4.00	22.3	22.9	23.0	21.8	22.5	22.4	21.9	22.9	22.6	15.7	17.0	2.7	3.1	3.1	3.0	4.3	3.0	8.3
White River	9/18/2017	12:06	12:06	Pass	16.5	16.6	-0.08	22.2	22.6	22.6	23.1	22.7	22.8	23.4	23.0	23.2	16.2	16.7	2.1	1.9	1.5	1.2	1.8	0.7	3.0

Conclusions

Thirty five IMPROVE sampling sites were audited and six auditor training sessions were accomplished in 2017. The audits showed 5 sites where the clock was greater than 5 minutes off (three of the clocks were reset and two were only noted in the TSA). One module failed flow check test (Meadview Module C and was reported to UC, Davis). Trees were noted as being an issue at the Grand Canyon and at Great Sand Dunes (operators were notified). At Quaker City the MaxOri (pressure drop check through the system) failed for the audit, however, passed for the sampler. This indicates a small leak somewhere between the solenoids and the inlet. The sampler stand at Viking Lake is not stable and the stacks were not properly seated into the sampler presumably because of the sampler stand motion. The state operators were notified of this issue.