2011 Annual Report

CLEAN AIR STATUS AND TRENDS NETWORK
SITE AUDIT PROGRAM

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Submitted by:

Environmental, Engineering and Measurement Services, Inc.
1128 NW 39th Drive
Gainesville, FL 32605

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List of Acronyms and Abbreviations

% diff	percent difference
A/D	analog to digital converter
ARS	Air Resource Specialist, Inc.
ASTM	American Society for Testing and Materials
CASTNET	Clean Air Status and Trends Network
DAS	data acquisition system
DC	direct current
deg	degree
DVM	digital voltmeter
EEMS	Environmental, Engineering & Measurement Services, Inc.
EPA	U.S. Environmental Protection Agency
ESC	Environmental Systems Corporation
FSAD	Field Site Audit Database
g-cm	gram centimeter
GPS	geographical positioning system
k	kilo (1000)
km	kilometer
lpm	liters per minute
MLM	Multilayer Model
m/s	meters per second
mv	milivolt
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OAQPS	Office of Air Quality Planning and Standards
QAPP	Quality Assurance Project Plan
SOP	standard operating procedure
TEI	Thermo Environmental Instruments
USNO	United States Naval Observatory
V	volts
WRR	World Radiation Reference

1.0 INTRODUCTION

The Clean Air Status and Trends Network (CASTNET) is a national air monitoring program developed under mandate of the 1990 Clean Air Act Amendments. Each site in the network measures acidic gases and particles and other forms of atmospheric pollution using a continuous collection filter aggregated over a one week period. Hourly averages of surface ozone concentrations and selected meteorological variables are also measured.

Site measurements are used to estimate deposition rates of the various pollutants with the objective of determining relationships between emissions, air quality, deposition, and ecological effects. In conjunction with other national monitoring networks, CASTNET data are used to determine the effectiveness of national emissions control programs and to assess temporal trends and spatial deposition patterns in atmospheric pollutants. CASTNET data are also used for long-range transport model evaluations and effects research.

CASTNET pollutant flux estimates are calculated as the aggregate product of weekly measured chemical concentrations and model-estimated deposition velocities. Currently, the National Oceanic and Atmospheric Administration's multilayer inferential model (NOAA-MLM) described by Meyers et al. [1998] is used to derive deposition velocity estimates.

As of 2011 all CASTNET ozone monitors adhere to the requirements of 40 CFR Part 58, and ozone concentration and quality assurance data are submitted to the Air Quality System (AQS) database.

As of January 2012, the network is comprised of 82 active rural sampling sites across the United States and Canada, cooperatively operated by the Environmental Protection Agency (EPA), the National Park Service (NPS), Environment Canada, and several independent partners. AMEC, Inc. is responsible for operating the EPA and Environment Canada sponsored sites, and Air Resource Specialist, Inc. (ARS) is responsible for operating the NPS sponsored sites.

All 82 sites collect filter samples for flux estimates. Ozone concentrations are measured at 79 of the 82 sites, and meteorological measurements are made at 4 sites.

2.0 PROJECT OBJECTIVES

The objectives of this project are to establish an independent and unbiased program of performance and systems audits for all CASTNET sampling sites. Ongoing Quality Assurance (QA) programs are an essential part of any long-term monitoring network.

Performance audits verify that all evaluated parameters are consistent with the accuracy goals as defined in the CASTNET Quality Assurance Project Plan (QAPP). The parameter specific accuracy goals are presented in Table 2.1.

Table 2.1 Performance Audit Challenge and Acceptance Criteria

Sensor	Parameter	Audit Challenge	Acceptance Criteria
Precipitation	Response	10 manual tips	1 DAS count per tip
Precipitation	Accuracy	2 introductions of known amounts of water	≤ ±10.0% of input amount
Relative Humidity	Accuracy	Compared to reference instrument or standard solution	≤ ±10.0%
Solar Radiation	Accuracy	Compared to WRR traceable standard	≤ ±10.0% of daytime average
Surface Wetness	Response	Distilled water spray mist	Positive response
Surface Wetness	Sensitivity	1% decade resistance	N/A
Temperature	Accuracy	Comparison to 3 NIST measured baths (~ 0° C, ambient, ~ full-scale)	≤ ± 0.5° C

Sensor	Parameter	Audit Challenge	Acceptance Criteria
Delta Temperature	Accuracy	Comparison to temperature sensor at same test point	≤ ± 0.50° C
Wind Direction	Orientation Accuracy	Parallel to alignment rod/crossarm, or sighted to distant point	≤ ±5° from degrees true
Wind Direction	Linearity	Eight cardinal points on test fixture	≤ ±5° mean absolute error
Wind Direction	Response Threshold	Starting torque tested with torque gauge	< 10 g-cm Climatronics; < 20 g-cm R. M. Young
Wind Speed	Accuracy	Shaft rotational speed generated and measured with certified synchronous motor	≤ ±0.5 mps below 5.0 mps input; ≤ ±5.0% of input at or above 5.0 mps
Wind Speed	Starting Threshold	Starting torque tested with torque gauge	< 0.5 g-cm
Mass Flow Controller	Flow Rate	Comparison with Primary Standard	≤ ± 5.0% of designated rate
Ozone	Slope	Linear regression of multi-point test gas concentration as measured with a certified transfer standard	0.9000 ≤ m ≤ 1.1000
	Intercept		-5.0 ppb ≤ b ≤ 5.0 ppb
	Correlation Coefficient		0.9950 ≤ r
	Percent Difference	Comparison with Standard Concentration	≤ ±10.0% of test gas concentration
DAS	Accuracy	Comparison with certified standard	≤ ± 0.003 VDC

In addition to the accuracy goals defined in the CASTNET QAPP the ozone monitors fall under the requirements of 40 CFR, Part 58 Appendix A, for quality assurance. To comply with Appendix A, the CASTNET audit program includes annual independent ozone performance evaluations (PE). The EEMS field scientists who conduct ozone PE maintain annual certification from the Office of Air Quality Planning and Standards (OAQPS). Methods and procedures used are compliant with the National Performance Audit Program (NPAP).

Performance audits are conducted using standards that are certified as currently traceable to the National Institute of Standards and Technology (NIST), or another authoritative organization. All standards are certified annually with the exception of ozone standards which are verified as level 2 standards at EPA regional labs at least twice per year.

Site systems audits are intended to provide a qualitative appraisal of the total measurement system. Site planning, organization, and operation are evaluated to ensure that good Quality Assurance/Quality Control (QA/QC) practices are being applied. At a minimum the following audit issues are addressed at each site systems audit:

- Site locations and configurations match those provided in the CASTNET QAPP.
- Meteorological instruments are in good physical and operational condition and are sited to meet EPA ambient monitoring guidelines (EPA-600/4-82-060).
- Sites are accessible, orderly, and if applicable, compliant with OSHA safety standards.
- Sampling lines are free of leaks, kinks, visible contamination, weathering, and moisture.
- Site shelters provide adequate temperature control.
- All ambient air quality instruments are functional, being operated in the appropriate range, and the zero air supply desiccant is unsaturated.
- All instruments are in current calibration.
- Site documentation (maintenance schedules, on-site SOPs, etc.) is current and log book records are complete.
- All maintenance and on-site SOPs are performed on schedule.
- Corrective actions are documented and appropriate for required maintenance/repair activity.
- Site operators demonstrate an adequate knowledge and ability to perform required site activities, including documentation and maintenance activities.

3.0 CASTNET SITES VISITED – 2011

This report covers the CASTNET sites audited in 2011. Only those variables that were supported by the CASTNET program were audited. From February through November 2011, EEMS conducted field performance and systems audits at 46 monitoring sites, and 44 site locations (two locations operate collocated sites). Thirty-two of the sites visited are sponsored by the EPA and fourteen sites are sponsored by the NPS. All 46 sites audited measured ozone and three of the sites operated meteorological sensors. The locations and dates of the audits are presented in Table 3.1.

Table 3.1 Site Audits - 2011

Site ID	Sponsor Agency	Site Location	Audit dates
ALC188	EPA	Alabama-Coushatta Tribe, TX	Feb 18, 2011
BBE401	NPS	Big Bend Nat. Park, TX	Feb 22 -23, 2011
PAL190*	EPA	Palo Duro, TX	Feb 24, 2011
CHE185*	EPA	Cherokee Nation, OK	Feb 26 - 28, 2011
CAD150	EPA	Caddo Valley, AR	March 2, 2011
MCK131	EPA	Mackville, KY	March 19, 2011
MCK231	EPA	Mackville (precision site)	March 19, 2011
CDZ171	EPA	Cadiz, KY	March 20, 2011
MAC426	NPS	Mammoth Cave Nat. Park, KY	March 22, 2011
CVL151	EPA	Coffeeville, MS	March 30, 2011
DCP114	EPA	Deer Creek St. Park, OH	April 11
QAK172	EPA	Quaker City, OH	April 12
CKT136	EPA	Crockett, KY	April 14
OXF122	EPA	Oxford, OH	April 14

Site ID	Sponsor Agency	Site Location	Audit dates
SEK430	NPS	Sequoia Nat. Park, CA	May 16
YOS404	NPS	Yosemite Nat. Park, CA	May 18
PIN414	NPS	Pinnacles Nat. Monument, CA	May 19
LAV410	NPS	Lassen Volcanic Nat. Park, CA	May 24
PND165	EPA	Pinedale, WY	June 15
KNZ184	EPA	Konza Prairie, KS	June 21
GLR468	NPS	Glacier Nat. Park, MT	June 27 - 28
YEL408	NPS	Yellowstone Nat. Park, WY	July 5
ROM206	EPA	Rocky Mountain Nat. Park, CO	July 7
ROM406	NPS	Rocky Mountain Nat. Park, CO	July 7
GTH161	EPA	Gothic, CO	July 12
CNT169	EPA	Centennial, WY	July 14 - 15
WNC429	NPS	Wind Cave Nat. Park, SD	July 18 - 19
THR422	NPS	Theodore Roosevelt Nat. Park, ND	July 21
VOY413	NPS	Voyageurs Nat. Park, MN	July 25 - 26
PRK134	EPA	Perkinstown, WI	July 28
ALH157	EPA	Alhambra, IL	August 2
STK138	EPA	Stockton, IL	August 6 - 21
SAN189	EPA	Santee Sioux Tribe, NE	August 9
VIN140	EPA	Vincennes, IN	August 22
BVL130*	EPA	Bondville, IL	August 23 - 24
PED108	EPA	Prince Edward St. Forest, VA	Sept 13

Site ID	Sponsor Agency	Site Location	Audit dates
CND125	EPA	Candor	Sept 20
VPI120	EPA	Horton Station VA Tech, VA	Sept 22
GRS420	NPS	Great Smoky Mountains NP, TN	Oct 13
WSP144	EPA	Washington Crossing St. Park, NJ	Oct 17 - 18
BWR139	EPA	Blackwater NWR, MD	Oct 18
BFT142	EPA	Beaufort, NC	Oct 27
LRL117	EPA	Laurel Hill St. Park, PA	Nov 10
CDR119	EPA	Cedar Creek St. Park, WV	Nov 15
SHN418	NPS	Shenandoah NP - Big Meadows, VA	Nov 15
PAR107	EPA	Parsons, WV	Nov 16

In addition to the sites listed in Table 3.1 that were visited for complete systems and performance audits, the 23 sites listed in Table 3.2 were visited to conduct NPAP Through-The-Probe (TTP) ozone PE. All ozone PE site visits were performed at EPA sponsored sites.

Table 3.2 Site Ozone PE Visits - 2011

Site ID	Sponsor Agency	Site Location	Audit dates
GAS153	EPA	Georgia Station, GA	Feb 8, 2011
SND152	EPA	Sand Mountain, AL	Feb 9, 2011
IRL141	EPA	Indian River Lagoon, FL	Feb 10, 2011
SUM156	EPA	Sumatra, FL	Feb 13, 2011
PNF126	EPA	Cranberry, NC	March 17, 2011
SPD111	EPA	Speedwell, TN	March 18, 2011

Site ID	Sponsor Agency	Site Location	Audit dates
ESP127	EPA	Edgar Evins St. Park, TN	March 21, 2011
COW137	EPA	Coweeta, NC	April 13
SAL133	EPA	Salamonie Reservoir, IN	August 25
HOX148	EPA	Hoxeyville, MI	August 26
UVL124	EPA	Unionville, MI	August 30
ANA115	EPA	Ann Arbor, MI	August 31
WST109	EPA	Woodstock, NH	Sept 17
ABT147	EPA	Abington, CT	Sept 18
ASH135	EPA	Ashland, ME	Sept 19
HOW132	EPA	Howland, ME	Sept 20
HWF187	EPA	Huntington Wildlife Forest, NY	Sept 27
PSU106	EPA	Penn State, PA	Oct 11
ARE128	EPA	Arendtsville, PA	Oct 16
CTH110	EPA	Connecticut Hill, NY	Nov 2
KEF112	EPA	Kane Experimental Forest, PA	Nov 8
MKG113	EPA	M. K. Goddard St. Park, PA	Nov 9
BEL116	EPA	Beltsville, MD	Nov 22

4.0 PERFORMANCE AUDIT RESULTS

Table 4.1 summarizes the number of test failures by variable tested. All test results are those recorded from the site's primary logger. Since only three sites audited operated meteorological sensors those parameters are not included in table 4.1.

Performance audit results are discussed for each variable in the following sections. Tables are included to summarize the average and maximum error between the audit challenges and site results as recorded by the on-site Data Acquisition System (DAS). Linear regression and percent difference (% diff) calculation results are included where appropriate. Results that are outside the CASTNET QAPP acceptance criteria are shaded in the tables.

The errors presented in the tables in the following sections, are reported as the difference of the measurement recorded by the DAS and the audit standard. Where appropriate, negative values indicate readings that were lower than the standard, and positive values are readings that were above the standard value. With the exception of some flow rate audits (discussed in a later section), the errors appear to be random, and without bias. The results are also arranged by audit date. Viewing the results in this order helps to detect any errors that could have been caused by the degradation or drift of the audit standards during the year. The audit standards are transported and handled with care, and properly maintained to help prevent such occurrences. No known problems with the standards were apparent during the year. All standards were within specifications when re-certified at the end of the year.

Detailed reports of the field site audits, which contain all of the test points for each variable at each site, can be found in Appendix 1. The variable specific data forms included in Appendix 1 for each site contain the challenge input values, the output of the DAS, additional relevant information pertaining to the variable and equipment, and all available means of identification of the sensors and equipment.

Table 4.1 Performance Audit Results by Variable Tested

Variable Tested	Number of Tests	Number of tests Failed	% Failed
Ozone	69	3	4.3
Flow Rate	46	7*	15.2*
Shelter Temperature	38	13	34.2
DAS Analog to Digital	34	0	0.0

***Note: Flow rate audit results are in question with most likely only one failure (2.2%)**

4.1 Ozone

Sixty-nine ozone analyzers were audited during 2011. Each was challenged with ozone-free air and four up-scale concentrations. Two challenges were in the range of 30 – 80 ppb, and one in each of the ranges of 150 – 200 ppb, and 360 – 450 ppb. The ozone test gas concentrations were generated and measured with a NIST-traceable standard that was verified as a level 2 standard by USEPA. Of the 69 analyzers tested, all but 2 (PAL190 and ROM206) were within the acceptance criteria of ≤ ±10.0% for the average error from the test gas concentration. Only one analyzer (WNC429) had a maximum error outside ±10.0%, and was outside the slope acceptance criteria established in the CASTNET QAPP. The results are presented in Table 4.2.

All ozone challenges were conducted to comply with the OAQPS Standard Operating Procedures (SOP) which can be found at www.epa.gov/ttn/amtic/. The results of the ozone audits were uploaded to the AQS database at the end of 2011 for all CASTNET sites that reported ozone data to AQS in 2011.

In February of 2011 OAQPS issued a memorandum providing guidance for low-level audits of pollutant gases. The list of audit concentrations was expanded to 10 levels. Beginning in 2012 EEMS will conduct ozone audits using levels from the new expanded list, and in lower concentration ranges. Three consecutive audit levels will be used.

4.2 Flow Rate

The dry deposition filter pack sampling system flow rates at all 46 sites were audited. A NIST-traceable dry-piston primary flow rate device was used for the tests. Seven, or 15.2% of the systems checked were outside the acceptance criterion of ± 5.0%. ***It is very important to note however that due to a recent finding regarding the BIOS primary standard used to audit the flow systems 6 of the 7 audit failures may be in question, resulting in a failure rate of only one site or 2.2%.***

The device in question is a BIOS Nexus which is used in conjunction with the primary dry-piston meter to measure pressure and temperature and convert the volumetric flow rates to standard conditions. The manufacturer has issued a recall that states the pressure measurement sensor in the device is defective and measurements at atmospheric pressures below 700 mmHg are inaccurate resulting in standard conditions flow rate inaccuracies. The audit data supports this finding in as much as the higher elevation sites were found to be bias low when tested with the device.

Additional evidence is indicated from the results of the NPS sites compared to the EPA sites. The NPS contractor does not use the Nexus device to set the flow rates at the NPS sites. The NPS sites show a clear difference from the audit device at higher elevations. The EPA contractor initially used the Nexus device to set flow rates at EPA sites, but recently has switched to a new standard the does not require the Nexus. Audit results indicate agreement between the audit results prior to the change since both the flow rate setting and audit test used the Nexus and disagreement after the change to the new standard.

EEMS has both a new standard and the Nexus device and is in the process of evaluating both during current 2012 audits. Preliminary results indicate an error of approximately 3% to 4%.

4.3 Shelter Temperature

Shelter temperature was audited at all sites visited for a complete systems and performance audit beginning in second quarter 2011. The method consisted of placing the audit standard in close proximity (In situ) with the shelter temperature sensor and recording either instantaneous observations of both sensors, or averages from both sensors. The audit sensors used are either a Resistive Temperature Detector (RTD) or a Thermocouple.

Most of the differences observed were due to the slow response of the site's shelter temperature sensors. Nearly all the site sensors lagged behind the audit sensor during the rapid changes in temperatures observed as the shelter air conditioning or shelter heating cycled. The shelter temperature sensors never reached the minimum or maximum temperature measured with the audit sensor. This is not likely to add a large error to the hourly averaged shelter temperature measurements. However, since the actual shelter temperature does not change following a sine wave curve and the output of the shelter temperature sensors do follow a sine wave curve, if the shelter temperature is set near the lower or higher allowable limits (20 to 30 degrees C) the actual hourly averages may be lower or higher than those measured by the site sensors.

The CASTNET QAPP does not make a distinction between shelter temperature and any other temperature sensor regarding accuracy criteria. However the sensors were evaluated using a 1 degree C acceptance criterion. This criterion more follows the EPA OAQPS guidelines.

The results are summarized in Table 4.2. Flow rate data are reported only for the sites that were visited for complete systems and performance audits. Shelter temperature results are reported beginning with second quarter site visits. Ozone results are included for all site visits.

Table 4.2 Performance Audit Results for Ozone, Shelter Temperature and Flow Rate

Site	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	Shelter temp. average error (C)	Shelter temp. maximum error (C)	STP Flow observed (lpm)	Flow DAS (lpm)	Flow Error (% diff)
GAS153	2.6	2.8	0.97162	0.19265	1.00000					
SND152	1	1.7	0.98209	0.43611	1.00000					
IRL141	6	7	0.92726	1.08850	1.00000					
SUM156	6.8	7.9	0.94199	-0.58958	0.99999					
ALC188	3.8	4.5	0.95273	0.88298	1.00000			1.467	1.50	2.28
BBE401	3.5	5.1	0.97320	-0.90270	0.99999			3.033	3.00	-1.08

Site	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	Shelter temp. average error (C)	Shelter temp. maximum error (C)	STP Flow observed (lpm)	Flow DAS (lpm)	Flow Error (% diff)
PAL190	12.9	18.4	0.90130	-1.59042	0.99996	0.58	-0.83	3.015	3.02	0.15
CHE185	3.4	4.8	0.94418	2.92747	0.99999	0.38	0.47	1.476	1.50	1.65
CAD150	8.4	9.1	0.92039	-0.59267	1.00000			1.505	1.50	-0.31
PNF126	0.9	1.2	0.98708	0.28469	1.00000					
SPD111	5.1	6.6	0.93051	1.33663	1.00000					
MCK131	2.3	5.1	1.00971	1.00998	1.00000			1.496	1.50	0.25
MCK231	2.7	3.2	1.02763	0.05459	1.00000			1.494	1.50	0.42
CDZ171	0.4	1.2	1.00187	0.13192	1.00000			1.492	1.49	-0.16
ESP127	2.9	3.4	0.96525	0.39065	1.00000					
MAC426	2.3	2.5	1.01935	0.23348	1.00000			1.500	1.51	0.56
CVL151	0.9	1.2	0.98749	0.20199	1.00000			1.500	1.50	0.02
DCP114	3.4	4.4	0.95429	0.75424	0.99999	0.52	-1.08	1.515	1.51	-0.35
QAK172	2.1	3.8	0.97993	-0.31445	0.99998	0.22	0.38	1.526	1.51	-1.03
COW137	1.1	3	1.00132	-0.67292	0.99997					
CKT136	2.4	2.5	0.97392	0.75075	0.99999	0.19	-0.31	1.534	1.51	-1.56
OXF122	2.3	2.5	1.01780	0.62626	1.00000	11.38	13.38	1.525	1.50	-1.39
SEK430	2.2	3.1	1.01857	0.48151	0.99999	0.92	0.97	2.991	3.03	1.29
YOS404	6.6	8.3	0.92475	0.87917	0.99997	4.64	-4.74	3.200	3.00	-6.25
PIN414	1.3	4.1	0.99633	0.90197	0.99994	1.25	2.08	2.985	3.00	0.5
LAV410	1.7	4.1	1.01432	0.63199	0.99991	0.38	0.68	3.065	3.01	-1.8
PND165	3.3	4.9	0.94746	1.38683	0.99999	2.96	2.98	3.151	3.00	-4.78
KNZ184	1.3	2.7	0.97354	0.72054	0.99996	0.46	0.68	3.059	3.01	-1.67
GLR468	3	3.5	1.03899	-1.45038	0.99999	0.87	1.83	3.075	3.03	-1.47
YEL408	4.8	5.8	0.93937	1.20274	0.99999	2.94	3.30	3.119	3.00	-3.81

Site	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	Shelter temp. average error (C)	Shelter temp. maximum error (C)	STP Flow observed (lpm)	Flow DAS (lpm)	Flow Error (% diff)
ROM206	10.1	12.2	0.91371	-1.42587	1.00000	0.20	0.23	3.185	3.00	-5.82
ROM406	2.7	4.8	1.01326	0.88562	0.99999	0.49	0.56	3.168	2.98	-5.94
GTH161	4.7	9.2	0.90189	3.57112	0.99992	0.13	-0.24	3.165	2.99	-5.54
CNT169	1.7	2.7	0.96983	1.90861	0.99999	0.85	1.32	3.216	3.01	-6.41
WNC429	9.4	11	0.89615	-0.05541	0.99998	1.98	-2.92	3.372	3.04	-9.85
THR422	3	5.6	1.02245	-2.88443	0.99990	0.44	-0.72	3.436	3.36	-2.22
VOY413	4.5	8.1	1.01912	1.49317	0.99998	0.18	0.29	3.057	2.99	-2.2
PRK134	2.7	3.8	0.97729	0.02451	0.99999	0.69	-1.48	1.543	1.50	-2.81
ALH157	4.6	5.2	1.05033	-0.17775	0.99998	0.52	-0.87	1.518	1.50	-0.97
STK138	3.7	7.5	1.02363	0.84030	0.99998	0.92	1.25	1.502	1.51	0.31
SAN189	1.5	2.5	1.00919	0.28709	1.00000	0.37	-0.62	3.065	3.01	-1.78
VIN140	5.1	5.3	1.04575	0.70293	1.00000	1.07	1.44	1.540	1.48	-3.87
BVL130	3.1	4.4	0.98055	-0.99571	1.00000	0.72	-1.10	1.537	1.50	-2.38
SAL133	5.6	9.8	0.97260	-2.03468	0.99981					
HOX148	4.2	5	0.96230	-0.50305	1.00000					
UVL124	3.9	4.9	0.96860	-0.79091	1.00000					
ANA115	4	5.9	0.96580	-0.64141	0.99997					
PED108	0.8	1.3	0.98980	0.04634	1.00000	0.68	-0.94	1.525	1.51	-1.14
WST109	2	2.6	1.01405	0.40842	1.00000					
ABT147	1.5	2.5	0.99078	-0.28566	1.00000					
ASH135	2.9	4.4	1.04706	-1.37682	1.00000					
HOW132	1.3	2.7	1.00933	-0.70742	0.99999					
VPI120	1.1	2.6	0.98486	1.35285	1.00000	0.87	-1.87	1.504	1.49	-0.94
HWF187	2.6	4	0.95838	1.11983	0.99997					

Site	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	Shelter temp. average error (C)	Shelter temp. maximum error (C)	STP Flow observed (lpm)	Flow DAS (lpm)	Flow Error (% diff)
CND125	4.3	5	1.03943	0.19274	1.00000	1.51	-1.71	1.548	1.50	-3.34
PSU106	3	5	0.98058	-0.62287	1.00000					
GRS420	1.8	2.9	0.99207	-0.29169	0.99996	2.58	2.58	2.519	3.00	19.1
ARE128	2.9	3.9	1.04589	-2.66999	1.00000					
WSP144	0.8	3	0.99848	-0.79700	0.99990	1.65	2.20	1.525	1.49	-2.32
BWR139	1.8	5.1	1.01342	-1.35702	0.99999	1.96	2.68	1.538	1.50	-2.47
BFT142	1.2	2.5	0.99484	-0.06506	0.99999	0.68	0.95	1.527	1.50	-1.79
CTH110	2.1	5	1.02320	-1.84263	0.99999					
KEF112	2.4	5	0.98758	-0.20928	0.99994					
MKG113	6	6.5	0.93769	0.14837	1.00000					
LRL117	4.8	6	0.96127	-0.82936	0.99999	0.31	0.44	1.550	1.50	-3.2
CDR119	0.8	2.6	0.99563	1.02243	0.99999	1.06	-1.54	1.499	1.52	1.4
SHN418	2	4.4	1.00000	2.00000	1.00000	2.12	2.39	1.471	1.50	1.98
PAR107	0.6	1.3	1.00546	-0.37598	0.99997	0.39	-0.73	1.519	1.51	-0.79
BEL116	1.1	2.2	1.00892	-1.08463	0.99999					

4.4 Wind Speed

The wind speed sensors at 3 sites equipped for meteorological measurements were audited. One site, BVL130, was found to be well outside the acceptance limit. The sensor output was found to me less than half of the challenge wind speed input. Through follow-up with the AMEC QA Manager it was discovered that the data logger was programmed for the incorrect type of wind speed sensor. The results of the wind speed performance audits are presented in Table 4.3.

4.4.1 Wind Speed Starting Threshold

The condition of the wind speed bearings was evaluated as part of the performance audits. The data acceptance criterion for wind speed bearing torque is not defined in the QAPP. However, ***Appendix 1: CASTNET Field Standard Operating Procedures***, states that the wind speed bearing torque should be ≤ 0.2 g-cm. To establish the wind speed bearing torque criterion for audit purposes the rational described in the QAPP for data quality objectives (DQO) was applied. The QAPP states that field criteria are more stringent than DQO and established to maintain the system within DQO. Typically field criteria are set at approximately one-half the DQO. Therefore, 0.5 g-cm was used for the acceptance limit for audit purposes. This value is within the manufacture's specifications for a properly maintained system. One site, PAL190, was found to be above this threshold.

4.5 Wind Direction

Two separate tests were performed to evaluate the accuracy of each wind direction sensor. A linearity test was performed to evaluate the ability of the sensor to function properly and accurately throughout the range from 1 to 360 degrees. This test evaluates the sensor independently of orientation and can be performed with the sensor mounted on a test fixture. A separate orientation test was used to determine if the sensor was aligned properly when installed to measure wind direction accurately in degrees true. An audit standard compass was used to perform the orientation tests.

Using the average error of the orientation tests for each of the 3 sensors tested, only one (CHE185) was outside the acceptance criterion of ± 5 degrees. All sensors tested for average linearity, were within the acceptance limit. The results of the wind direction performance audits are presented in Table 4.3.

4.5.1 Wind Direction Starting Threshold

The condition of the wind direction bearings was evaluated as part of the performance audits. The data acceptance criterion for wind direction bearing torque is not defined in the QAPP.

However, ***Appendix 1: CASTNET Field Standard Operating Procedures***, states that the wind direction bearing torque should be ≤ 10 g-cm for R. M. Young sensors. The manufacturer states that a properly maintained sensor will be accurate up to a starting threshold of 11 g-cm. To establish the wind direction bearing torque criterion for audit purposes the rational described in the QAPP for data quality objectives (DQO) was applied. The QAPP states that field criteria are more stringent than DQO and established to maintain the system within DQO. Typically field criteria are set to approximately one-half the DQO. For audit purposes 20 g-cm was used for the acceptance limit for R. M. Young sensors. Climatronics sensors typically have a lower starting torque. For audit purposes a threshold of 10 g-cm was selected for Climatronics sensors. All of the wind direction starting thresholds were with acceptance limits. The test results are provided in Table 4.3.

Table 4.3 Performance Audit Results for Wind Sensors

Site	Wind Direction					Wind Speed				
	Orientation Error		Linearity Error		Starting Torque (g-cm)	Low Range Error		High Range Error		Starting Torque (g-cm)
	Ave (deg)	Max (deg)	Ave (deg)	Max (deg)		Ave (m/s)	Max (m/s)	Ave (% diff)	Max (% diff)	
PAL190	1.5	3	1.3	3	20	0.10	-0.20	0.00	0.00	0.6
CHE185	5.8	10	1.3	4	18	0.08	-0.14	0.04	0.04	0.4
BVL130	3.5	4	1.3	5	5	2.10	4.48	114	117	0.2

4.6 Temperature, Two Meter Temperature, and Delta Temperature

The temperature measurement systems at all 3 sites equipped to measure meteorological variables consist of a temperature sensor mounted at 9 meters on the meteorological tower. All 3 sites also utilized a second sensor to measure temperature at approximately two meters from the ground (2-meter temperature). Delta temperature is calculated as part of the data logger program routine and is also recorded on-site.

All sites use shields to house the sensors that are designed to be mechanically aspirated with forced air blowers. In all cases the sensors were removed from the sensor shields, and placed in a uniform temperature bath with a precision NIST-traceable RTD, during the audit.

Results of the tests indicate that all sensors were within the acceptance criterion. All of the 2-meter temperature sensors were within criterion. The average errors for all sensors are presented in Table 4.4.

4.6.1 Temperature Shield Blower Motors

All of the blower motors encountered during the site audits conducted during 2011 were found to be functioning.

4.7 Relative Humidity

The relative humidity systems at the sites were tested with a combination of primary standard salt solutions, and a certified transfer standard relative humidity probe. The results of the average and maximum errors throughout the entire measurement range of 0% - 100% are presented in Table 4.4.

The relative humidity measurement being made at each of the 3 sites equipped for meteorological measurements is provided by a sensor supplied by any one of three different manufactures. At EPA sponsored sites with R. M. Young equipment, humidity sensors are operating in naturally aspirated shields. At EPA sponsored sites with Climatronics equipment, humidity sensors are operating in shields designed to be mechanically aspirated with forced-air blowers.

During audit tests with the primary standard salt solutions, the sensors were removed from the shields and placed in a temperature controlled enclosure. During audit tests with the transfer standard probe, the sensor and transfer were placed in the same ambient conditions. Therefore the audit tests do not account for differences in the operation of the sensors due to shield configurations.

All sensors were within the acceptance criterion. The results of the tests are included in Table 4.4.

Table 4.4 Performance Audit Results for Temperature and Humidity

Site	Temperature Ave. Error (deg C)	2 Meter Temperature Ave. Error (deg C)	Relative Humidity Range 0 – 100%	
			Ave. Error (%)	Max. Error (%)
PAL190	0.08	0.08	6.35	-7.9
CHE185	0.11	0.24	6.01	7.2
BVL130	0.07	0.08	4.49	-6.3

4.8 Solar Radiation

The ambient conditions encountered during the audit visits were suitable, with high enough light levels for accurate comparisons. A NIST-traceable Eppley PSP and translator were used as the audit standard system.

All of the sites had daytime average results that were within the acceptance criterion. The results of the individual tests for each site are included in Table 4.5. The percent difference of the maximum solar radiation value observed during each site audit is also reported in Table 4.5 although this criterion is not part of the CASTNET data quality indicators. Those values greater than ±10% are bold.

4.9 Precipitation

All sites audited used a tipping bucket rain gauge for the obtaining precipitation measurement data. The audit challenges consisted of entering multiple amounts of a known volume of water into the tipping bucket funnel at a rate equal to approximately 2 inches of rain per hour. Equivalent amounts of water entered were compared to the amount recorded by the DAS. All systems were within the acceptable criterion. The results are summarized in Tables 4.5.

4.10 Surface Wetness

The acceptance criteria established for the surface wetness sensors used at the CASTNET sites requires the sensor has a positive response from a condition of dry to a condition of wet. All of the sensors tested exhibited a positive response to a wet condition.

In the CASTNET QAPP, ***Appendix 1: CASTNET Field Standard Operating Procedures***, a regular maintenance and calibration procedure is described for the surface wetness sensor. The procedure is a sensitivity adjustment intended to provide consistent response from the surface wetness sensors at all of the CASTNET sites. The procedure requires that a decade resistance device be installed in a test-jack fixture within the surface wetness sensor circuit to by-pass the sensor grid. Then, to adjust the sensor response to the specifications provided, independent of the response to a wet condition. This test was performed during the audits to determine if the sensor responded within the specified range of 235 to 245 k ohms.

Since there are no DQO identified for the sensitivity tests, they are not considered in the evaluation of data quality. The results are presented in Table 4.5 as the resistance required for the sensor response to change from dry to wet (on), and from wet to dry (off). As stated in the paragraph above, all sensors responded when the grid surface was wet and were near the specified sensitivity.

Table 4.5 Performance Audit Results for Solar Radiation, Precipitation, and Surface Wetness

Site	Solar Radiation Error				Precipitation Ave. Error (% diff)	Surface Wetness	
	Daytime Ave. (% diff)	Max. Value (w/m2)	Max. Observed (w/m2)	Max. Value (% diff)		Sensitivity On (k ohm)	Sensitivity Off (k ohm)
PAL190	1.59	787	796	1.1	0.0	190	200
CHE185	8.91	433	478	10.4	3.0	210	220
BVL130	3.32	788	812	3.0	3.0	120	130

4.11 Data Acquisition Systems (DAS)

All of the NPS sponsored sites visited utilized an ESC logger as the primary and only DAS. All EPA sites visited operated Campbell loggers as their only DAS. The results presented in tables 4.1 and 4.6 include the tests performed on the primary logger at each site.

4.11.1 Analog Tests

The accuracy of each primary logger was tested on two different channels (if two channels were available to be used) with a NIST-traceable Fluke digital voltmeter. At some of the EPA sponsored sites the channels above analog channel 8 could not be tested since there were no empty channels available to test. One NPS sponsored site (THR422) did not have an open channel below channel 8 to test. All data loggers were within the acceptance criterion of ± 0.003 volts.

4.11.2 Functionality Tests

Other performance tests used to evaluate the DAS included the verification of the date and time, and operation of the battery backup system used to save the DAS date, time, and configuration during a power outage. All DAS were set to the correct date and within ±5 minutes per the acceptance criterion for time. All battery backup systems were found to be functioning at the sites tested. The results of these tests are included in Table 4.6.

Table 4.6 Performance Audit Results for Data Acquisition Systems

Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
	Low Channel		High Channel			
	Average	Maximum	Average	Maximum		
PAL190	0.0001	-0.0001	0.0001	-0.0001	Y	0.08
CHE185	0.0013	-0.0014	0.0001	-0.0001	Y	
SEK430	0.0002	0.0004	0.0002	0.0004	Y	0.25
YOS404	0.0001	0.0001	0.0001	0.0001	Y	0.8

Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
	Low Channel		High Channel			
	Average	Maximum	Average	Maximum		
PIN414	0.0004	0.0007	0.0001	0.0003	Y	0.43
LAV410	0.0001	-0.0001	0.0001	-0.0003	Y	0.85
PND165	0.0000	0.0000			Y	
KNZ184	0.0001	-0.0001			Y	0.42
GLR468	0.0002	0.0004	0.0002	0.0004	Y	1.25
YEL408	0.0003	0.0005	0.0003	0.0005	Y	0.33
ROM206	0.0001	-0.0002			Y	0.32
ROM406	0.0001	-0.0001			Y	1.53
GTH161	0.0001	-0.0002			Y	0.4
CNT169	0.0001	-0.0002			Y	0.12
WNC429	0.0002	-0.0004			Y	0.68
THR422			0.0001	0.0002	Y	0.75
VOY413	0.0001	-0.0001			Y	0.55
PRK134	0.0002	-0.0002			Y	0.03
ALH157	0.0002	-0.0005			Y	
STK138	0.0001	-0.0001			Y	0.08
SAN189	0.0002	-0.0003			Y	0.05
VIN140	0.0002	-0.0004			Y	
BVL130	0.0001	-0.0002			Y	0.25
PED108	0.0002	-0.0003			Y	
VPI120	0.0001	-0.0001			Y	0.17
CND125	0.0001	-0.0002			Y	0.05
GRS420	0.0000	0.0001			Y	2.55
WSP144	0.0001	-0.0002			Y	0.25

Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
	Low Channel		High Channel			
	Average	Maximum	Average	Maximum		
BWR139	0.0001	-0.0001			Y	0.23
BFT142	0.0009	-0.0014			Y	0.05
LRL117	0.0003	-0.0005			Y	0.32
CDR119	0.0001	0.0002			Y	0.05
SHN418	0.0000	0.0001			Y	1.63
PAR107	0.0001	-0.0004			Y	

5.0 SYSTEMS AUDIT RESULTS

The following sections summarize the site systems audit findings, and provide information observed regarding the measurement processes at the sites. Conditions that directly affect data accuracy have been reported in the previous sections. Other conditions that affect data quality and improvements to some measurement systems or procedures are suggested in the following sections.

5.1 Siting Criteria

All of the sites that were visited have undergone changes during the period of site operation which include population growth, road construction, and foresting activities. None of those changes were determined to have a significant impact on the siting criteria that did not exist when the site was initially established.

Some sites that are located in state and national parks are not in open areas, and have trees within the 50 meter criterion established in the QAPP. Given the land use and aesthetic concerns, these sites are acceptable and represent an adequate compromise with regard to siting criteria and the goal of long-term monitoring.

5.2 Sample Inlets

With consideration given to the siting criteria compromises described in the previous section, the sites visited this year have analyzer sample trains that are sited properly and in accordance with the CASTNET QAPP. The filter packs and ozone inlets are designed to sample from 10 meters. Teflon tubing of adequate diameter is used for the ozone inlets. Most of the filter pack sample lines are also Teflon. Inline filters are present in the sample trains. The ozone zero, span, and precision calibration test gases are introduced at the ozone sample inlet, through all filters and the entire sample train. All sample trains contain only Teflon fittings and materials.

5.3 Infrastructure

Many of the sites have been improved by repairing the site shelters which had deteriorated throughout the years of operation. During the installation and upgrade of the data loggers many of the degrading signal cables were replaced. This has been a much needed improvement to the network infrastructure, and represents an extensive effort on the part of the field operations staff.

A few of the site shelters are still in need of repair, but overall the condition of the sites has improved during the past year.

5.4 Site Operators

Generally the site operators are very conscientious and eager to complete the site activities correctly. They are willing to, and have performed sensor replacements and repairs at the sites with support provided by the AMEC and ARS field operations centers. In some cases, where replacements or repairs were made, documentation of the activities was not complete, and did not include serial numbers of the removed and installed equipment.

Many of the CASTNET site operators also perform site operator duties for the National Atmospheric Deposition Program (NADP). Many of the NPS site operators also perform other air, or environmental quality functions within their park. All are a valuable resource for the program. Some of the site operators mentioned that the CASTNET features in the NPS "Monitor" are informative, helpful, and appreciated.

Still many of the site operators have not been formally trained to perform the CASTNET duties by either AMEC or ARS. They had been given instructions by the previous site operators and over the phone instructions from the field operation centers at AMEC and ARS.

5.5 Documentation

There were some documentation problems with the Site Status Report Forms (SSRF) completed by the site operators each week during the regular site visits. Common errors included improper reporting of "initial flow", "final flow", and "leak check" values. A few operators do not use the "chain-of-custody" label.

The NPS site operator procedures are well developed and readily accessible at all of the NPS sites visited. There is an electronic interface, "DataView 2", available to view, analyze, and print site data. There are electronic "checklists" for the site operator to complete during the site visits; however, all of the CASTNET filter pack procedures are not included in the "checklists". Flow rates and leak check results are not recorded electronically.

An electronic logbook is included in the interface software. This system permits easy access to site documentation data. Complete calibration reports have been added to the system and accessible through the site computer.

5.6 Site Sensor and FSAD Identification

Improvement has also been made in the area of documentation of sensors and systems used at the sites. It is important to maintain proper sensor identification for the purposes of site inventory and to properly identify operational sensors for data validation procedures. Many sensors have had new numbers affixed for proper identification.

Where possible the identification numbers assigned (serial numbers and barcodes) are used within the field site audit database for all the sensors encountered during the site audits. The records are used for both the performance and systems audits. If a sensor is not assigned a serial number by the manufacturer, that field is entered as "none". If it is unknown whether an additional client ID number is assigned to a sensor, and a number is not found, the client ID is also entered as "none". If it is typical for a manufacturer and/or client ID number to be assigned to a sensor, and that number is not present, the field is entered as "missing". If either the serial number or the client ID numbers cannot be read, the field is entered as "illegible". An auto-number field is assigned to each sensor in the database in order to make the records unique.

6.0 SUMMARY AND RECOMMENDATIONS

The CASTNET Site Audit Program has been successful in evaluating the field operations of the sites. The results of performance and systems audits are recorded and archived in a relational database, the Field Site Audit Database (FSAD). Most areas of CASTNET site operations are acceptable. Some differences between actual site operations and operations described in the QAPP have been identified and described. Procedural differences between EPA and NPS sponsored sites have also been described.

As discussed previously the shelters have received some much needed attention. It was also observed that improvements were made to the shelter temperature control systems. As a requirement in 40 CFR Part 58 for ozone monitoring, shelter temperature is an important variable. Additional improvement could be made to accurately measure and report shelter temperature.

The previous paragraphs and sections included some recommendations for improving the field operations systems. One recommendation for improving the audit program is presented in the following section.

6.1 Follow-up visits

It is recommended that some of the conditions encountered during the audits should be addressed when the sites are visited during the next scheduled site maintenance and calibration visit. In order to determine if that occurred some type of follow-up procedure should be established. This procedure may not need to be another audit, and should not be performed two years after the audit when the condition was first discovered.

Additional data validation audits could be conducted to determine if polled data are scaled correctly. Review of the polled data and site documentation should be performed routinely to ascertain and correct these types of problems.

6.2 In Situ Comparisons

An improvement to the audit procedures designed to evaluate the differences in measurement technique would be to develop an "In Situ" audit measurement system. This would require a suite of sensors that would be collocated with the site sensors. Ideally the audit sensors would address the inconsistent sensor installations observed throughout the network. By deploying a suite of certified NIST traceable sensors installed and operating as recommended by the manufacturer and to EPA guidelines, subtle differences in the operation of the existing CASTNET measurement systems could be evaluated. The "In Situ" sensors would be operated at each site for a 24 hour period and the measurements would be compared to the CASTNET measurements.

REFERENCES:

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