<u>2005 Annual Report</u>

CLEAN AIR STATUS AND TRENDS NETWORK SITE AUDIT PROGRAM

EPA Contract No. 68W02058

Work Assignment No. 3-9

Prepared for:

U. S. Environmental Protection Agency

February 28, 2006

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TABLE OF CONTENTS

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
GPS	geographical positioning system
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
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 dry acid and other forms of atmospheric pollution using a continuous collection filter aggregated over a one week period. Hourly averages of surface ozone concentrations and various 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 spacial 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 January 2003, the network is comprised of 87 active rural sampling sites across the Untied States and Canada. The sites are cooperatively operated by the Environmental Protection Agency (EPA), the National Park Service (NPS), and Environment Canada. MACTEC E & C is responsible for operating the EPA sponsored sites, and Air Resource Specialist, Inc. (ARS) is responsible for operating the NPS sponsored 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 variables 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	≤ ±5.0% above 85.0% RH; ≤ ±20.0% at or below 85.0% RH
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
Temperature Difference	Accuracy	Comparison to station temperature sensor	≤ ± 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	< 8 gm·cm Climatronics; < 10 gm·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	≤ 0.2 gm·cm Climatronics; ≤ 0.3 gm·cm R.M. Young
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	$0.9000 \le m \le 1.1000$
Ozone	Intercept		-5.0 ppb $\le b \le 5.0$ ppb
Ozone	Correlation Coefficient		$0.9950 \le r$
DAS	Accuracy	Comparison with certified standard	≤ ± 0.003 VDC

Performance audits are conducted using standards that are traceable to the National Institute of Standards and Technology (NIST), or another authoritative organization, and certified as current.

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 were 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 - 2005

This report covers the CASTNET sites audited in 2005. Field audits were conducted in October and November of 2005 and consisted of performance and systems audits at eight sites. The locations and dates of the audits are presented in Table 3.1.

Table 3.1 Site Audits

Site ID	Sponsor Agency	Site Location	Visit dates
BFT142	EPA	Beaufort, NC	October 20 & 21
CND125	EPA	Candor, NC	October 23 & 24
BWR139	EPA	Blackwater NWR, MD	October 28 & 29
WSP144	EPA	Washington Crossing St. Park, NJ	October 30 &31
CDR119	EPA	Cedar Creek St. Park, WV	November 8 & 9
PAR107	EPA	Parsons, WV	November 10 & 11
LRL117	EPA	Laurel Hill St. Park, PA	November 14 & 15
SHN418	NPS	Shenandoah Nat. Park, VA	November 16 & 17

4.0 PERFORMANCE AUDIT RESULTS

Performance audit results are summarized by parameter 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.

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

4.1 Ozone

Eight ozone analyzers were audited during 2005. Each was challenged with ozone-free air and four upscale 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 determined with a NIST-traceable transfer standard, certified by the USEPA. The results of the accuracy tests were all within the acceptance criteria established in the CASTNET QAPP, and are presented in Table 4.1.

4.2 Flow rate

The dry deposition filter pack sampling system flow rates at all eight sites were audited. A NIST-traceable dry-piston primary flow rate device was used for the tests. Two of the systems checked were near the acceptance criterion of ± 5.0% and one system was outside that criterion. The results are summarized in Table 4.1.

Table 4.1 Performance Audit Results for Ozone and Flow Rate

Site	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	Vol. Flow observed (lpm)	STP Flow observed (lpm)	Flow DAS (lpm)	Flow (% diff)
BFT142	1.53	2.1	1.0135	-0.1355	1.0000	1.592	1.568	1.50	-4.3
CND125	3.85	4.6	1.0288	0.9674	1.0000	1.521	1.508	1.50	-0.5
BWR139	2.23	2.5	0.9777	-0.2707	1.0000	1.419	1.442	1.51	4.7
WSP144	2.3	4.4	1.0040	1.6016	1.0000	1.478	1.483	1.50	1.1
CDR119	1.15	2.3	1.0021	-1.0946	1.0000	1.514	1.473	1.50	1.8
PAR107	1.18	2.2	0.9966	-1.0819	1.0000	1.550	1.502	1.52	1.2
LRL117	0.88	2.2	0.9973	1.0131	1.0000	1.591	1.514	1.50	-0.9
SHN418	2.18	2.6	1.0167	0.3719	1.0000	1.803	**1.642**	1.50	**-8.6**

4.3 Wind direction

Two performance evaluations of each wind direction sensor were performed. A linearity test was performed to evaluate the ability of the sensor to function properly and accurately throughout the range from 0 to 360 degrees. An orientation test was used to evaluate if the sensor was installed correctly aligned with reference to degrees true.

Due to sensor misalignment, the average errors of two sensors were within one degree of the orientation acceptance criterion of 5 degrees, and one sensor was outside that criterion. However, all of the sensors were within the linearity acceptance criteria. The average errors of the sensors are summarized in Table 4.2. The maximum error encountered for each wind direction sensor is presented in Table 4.3.

4.4 Wind speed

The wind speed sensors at seven of the eight sites visited were audited. The sensor at site BFT142 was not audited due to a problem encountered with the site wind speed system. At that site the wind speed sensor propeller could not be easily removed from the wind speed sensor propeller shaft. The tolerance between the shaft and the propeller should allow the propeller to be easily removed from the shaft in order to prevent damage to the shaft and wind speed bearings during disassembly. Due to the risk of causing damage to the system the wind speed performance audit was not performed. However, the wind speed output of the system appeared to be reasonable at site BFT142.

All of the wind speed systems audited were found to be within the acceptance criteria provided in the CASTNET QAPP. However, as discussed in the Section 6.0, this may not be a completely accurate representation of wind speed data accuracy. The results of the wind speed performance audits are presented in Tables 4.2 and 4.3.

4.5 Temperature and delta temperature

The temperature measurement systems at all of the audited sites, consisted of a temperature sensor mounted at 10 meters on the meteorological tower, and a temperature difference (delta temperature) sensor mounted at 2 meters on the same tower. All site sensors were installed in shields that were designed to be mechanically aspirated with forced air blowers. During the audit, the sensors were removed from the sensor shields, and placed in a uniform temperature bath with a precision NIST-traceable RTD.

The systems report temperature as the measured temperature at the 10-meter height and the delta temperature as the difference between the two temperature measurements. The R. M. Young systems calculate delta temperature as the upper sensor minus the lower sensor, and Climatronics systems calculate delta temperature as the lower sensor minus the upper sensor. At SHN418 the Climatronics system was configured to report the delta temperature as the upper sensor minus the lower, by reversing the zero and full-scale settings for the delta temperature channel in the DAS configuration. This is acceptable provided the data validation procedures account for the system configuration.

Results of the tests indicated that the sensors were within the acceptance criteria at all eight sites. However, since the blowers were not functioning at sites BFT142 and CND125, the measured and recorded site data are not accurate. Issues regarding systems conditions other than sensor accuracy, and their impact on data validity, are discussed further in Section 5.0. The average and maximum errors for both 10-meter temperature and delta temperature are presented in Tables 4.2 and 4.3.

4.6 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 are presented in Tables 4.2 and 4.3. The sensors at R. M. Young equipped sites were operating in naturally aspirated shields. The sensors at Climatronics sites were in shields designed to be mechanically aspirated. During challenges with the primary standard salt solutions, the sensors were removed from the shields.

Since there are separate acceptance criterion for high and low humidity ranges, the results are reported as RH high for humidity tests above 85% relative humidity, and tests below 85% relative humidity are reported as RH low. At all but site LRL117, only one test was performed above 85% relative humidity. Therefore, the average and maximum values reported for the high humidity range are the same at all sites except LRL117. Three of the systems tested were outside the ± 5% acceptance criterion in the range above 85% humidity. All of the sensors were within the criterion below 85%.

4.7 Solar radiation

The solar radiation systems at all eight sites were audited. The ambient conditions encountered during the audit visits were suitable, and high enough for accurate comparisons. A NIST-traceable Eppley PSP and translator were used as the audit standard. This is the same type of standard used by the field operations department at MACTEC to certify the transfer standards used to calibrate the field sites. This system was chosen to eliminate one level of separation between the site measurement device and the measurement standard. The audit results are presented in Tables 4.2 and 4.3.

The system at site PAR107 was found to be outside the acceptance criterion of ± 10%. The calibration information filed onsite for the solar radiation system indicated that the system output was increased by 10% during the last site calibration and maintenance visit on 5/8/2005. This suggests a potential problem with either the transfer system used, or the procedures used during the calibration. This is discussed further in Sections 5.0 and 6.0.

4.8 Precipitation

All eight sites audited used a tipping bucket rain gauge for 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 inches (or mm at SHN418) 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 4.2 and 4.3.

4.9 Surface wetness

The acceptance criteria established for the surface wetness sensors used at the CASTNET sites requires the sensor to have 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 the use of a decade resistance device to be installed in a test-jack fixture within the surface wetness sensor, and 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 kohms. Four of the sensors were operating near the specified range. Three others were less sensitive, and the sensor at SHN418 did not have a functioning test-jack and could not be checked. The results of all the tests, wet response and sensitivity, can be found in Appendix 1, and are not included in Tables 4.2 and 4.3.

Other surface wetness sensor consistency issues were observed at sites PAR107 and LRL117. The sensor grid at PAR107 was positioned too high and did not record the presence of frost and dew which were present the day of the audit. The sensor grid at LRL117 was oriented to the south and not north as specified in the QAPP.

4.10 Data Acquisition Systems (DAS)

Sites PAR107 and BWR139 have primary and backup Odessa dataloggers. Eight of the eleven data channels are recorded on the backup loggers. One site, CND125, has a H2NS logger. SHN418 has an Environmental Systems Corporation (ESC) datalogger. Each of the remaining four sites utilizes one sixteen-channel Odessa logger for data acquisition.

The accuracy of the primary loggers was tested on two different channels with a NIST-traceable Fluke digital voltmeter. The backup loggers were tested on one channel. All of the loggers were within the acceptance criterion of ± 0.003 volts. The results for each of the seven challenge points tested for all dataloggers can be found in Appendix 1, and are not presented in Tables 4.2 and 4.3. Further discussion of DAS evaluation is provided in Section 5.0.

Table 4.2 Meteorological Performance Audit Average Error by Parameter

Site	WDR alignment (from 0 deg)	WDR orientation (deg)	WDR linearity (deg)	WSP low (m/s)	WSP high (% diff)	Temp (deg C)	Delta Temp (deg C)	RH low (%)	RH high (%)	SR (% diff)	Precip (% diff)
BFT142	0	1.3	1.3	NP	NP	0.30	0.27	3.2	3.3	4.4	4.0
CND125	-2	0.5	1.3	0.0	0.0	0.11	0.10	2.9	1.5	1.0	2.0
BWR139	7	4.2	2.8	0.08	0.2	0.29	0.04	3.8	2.5	2.5	1.3
WSP144	4	4.2	0.9	0.1	0.5	0.09	0.05	7.9	**8.4**	5.5	1.3
CDR119	-5	**7.4**	1.4	0.03	0.75	0.12	0.14	1.0	**7.9**	3.6	5.6
PAR107	-2	2.2	0.5	0.03	0.23	0.09	0.10	3.6	3.2	**11.3**	4.0
LRL117	2	3	0.9	0.08	0.85	0.12	0.04	7.1	**6.0**	6.1	1.3
SHN418	1	1.8	0.5	0.0	0.0	0.06	0.05	4.5	1.2	5.1	5.6

Table 4.3 Meteorological Performance Audit Maximum Error by Parameter

Site	WDR orientation (deg)	WDR linearity (deg)	WSP low (m/s)	WSP high (% diff)	Temp (deg C)	Delta Temp (deg C)	RH low (%)	RH high (%)	SR max (% diff)	Precip (% diff)
BFT142	2	2	NP	NP	0.37	0.34	3.8	3.3	-2.6	4.0
CND125	2	2	0.0	0.0	0.15	0.13	-6.5	-1.5	0	4.0
BWR139	6*	4	-0.2	-0.8	-0.41	-0.07	-7.5	2.5	-3.4	2.0
WSP144	5*	3	0.2	1.6	-0.16	-0.11	11.7	**8.4**	4.9	2.0
CDR119	**8**	2	0.1	1.1	0.25	0.15	2.3	**-7.9**	-2.9	-6.0
PAR107	3	1	0.1	0.5	0.14	-0.12	-4.7	-3.2	**11.1**	-5.0
LRL117	5*	1	-0.1	-1.6	0.16	-0.05	-7.2	**-6.6**	7.4	2.0
SHN418	2	1	0.0	0.0	-0.10	0.07	-6.5	1.2	-2.1	-6.0

* **Note:** The acceptance criterion of 5 degrees was only applied to the average of the results. The data validation section of the CASTNET QAPP states that if any wind direction challenge result is outside the acceptance criterion the parameter is flagged. If that rule was applied to the audit results sites LRL117 and WSP144 would be at the acceptance criterion, and BWR139 would be outside the criterion as well as CDR119. The errors presented in Table 4.3 above are reported as the difference of the measurement recorded by the DAS and the audit standard. Negative values indicate readings that were lower than the standard and positive values are readings that were above the standard value.

The parameterized 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 audit visit trip. The audit standards are transported and handled with care, and properly maintained to help prevent such occurrences. No problems with the standards used are apparent.

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 affect accurate data collection are reported. Improvements to some measurement systems or procedures are also suggested.

5.1 Siting criteria

All of the sites visited have been established and operational for at least 10 years. During that time, changes to the regions have occurred, 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. Maps of each site with 1 kilometer, 5 kilometer, and 40 kilometer radius circles are provided in Appendix 2. There were some inconsistencies between the site coordinates listed in Section 1 of the QAPP and Appendix 2 of the QAPP. Those inconsistencies and the difference between the listed coordinates and those obtained with the audit Global Positioning System (GPS) are apparent in the 1 kilometer maps.

Site CND125 underwent a change that was documented during the systems audit. The site location is at the edge of a planted pine forest maintained by the landowner. When the site was established in 1990 the trees had just been planted. The trees are now over 15 years of age, almost 10 meters tall, and within 30 meters of the site. A picture of the tree line, with the sample tower visible is included in Appendix 2. The trees are likely to be harvested within the next 5 years. Any changes to the estimated deposition rates and pollutant fluxes calculated at this site should be evaluated with consideration to site condition changes.

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. These sites are less than ideal however, and the conditions at the sites were documented with the photographs provided in Appendix 2. As indicated by the photographs, sites CDR119 and LRL117 are particularly affected by trees and terrain.

5.2 Sample inlets

With consideration given to the siting criteria compromises described above, all of the sensors and analyzer sample trains 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 inlets. Inline filters and moisture traps are present in the sample trains. With the exception of site SHN418 which had been temporarily by-passed due to rodent damage, the ozone zero, span, and precision calibration gas lines supply test gas concentrations at the ozone sample inlet, through all filters and the entire sample train.

The ozone inlet filter on the sample tower at site PAR107 contained dirt and spiders under the filter backing plate. A photograph is included in Appendix 2.

At sites BWR139 and CDR119, the ozone zero air system canisters are plumbed in a way that can allow charcoal dust to enter the ozone analyzer, when the charcoal is replaced. The site operator at site CDR119 also installed charcoal in the desiccant canister for the ozone zero air system when she was instructed to change it by the MACTEC field operations center. This did not have a detrimental affect on the ozone analyzer as of the time of the audit, but it may lead to problems during high humidity conditions if it is not corrected.

The filter pack quick-connection fitting plate at site CDR119 is attached to the filter pack enclosure lower than normal. This allows the dry deposition filter and the ozone inlet filter, to be exposed to wind-blown rain and may result in excessively wet samples. A photograph of the filter installed in the enclosure is included in the systems audit report for site CDR119 in Appendix 2.

5.3 Data accuracy

Although the performance audit results are correct, and the audited sensors were found to be accurate, some variables had systems problems that allow inaccurate data to be recorded as valid by the DAS. Those sensors include both temperature and delta temperature at sites CND125 and

BFT142, and relative humidity at site CND125, due to malfunctioning blowers. Other problems such as the lack of electrical power supplied to the wind sensor heaters and the rain gauge heater at site CND125, could potentially lead to inaccurate data being recorded as valid.

The temperature blower problem at site BFT142 could have been easily detected had the DAS been configured to recorded the blower status switch condition. The blower switches were found to be working properly, but not recorded, resulting in data being polled as valid which will require detection and invalidation later.

5.4 Data Acquisition Systems

All of the DAS at the sites appear to be recording data accurately, and are adequate for the current scope of the CASTNET project. There were a few conditions that were noted with some of the systems, and two problems with the H2NS system at site CND125.

The DAS at CND125 did not record the data status flag with the wind channels in the intermediate and final data average. Channels were marked as down during the audit but the flags did not appear on the recorded data. This problem had not been detected by the field technicians during previous site calibration visits or by the site operator during routine site checks. Other problems existed which were related to undefined flags, or "range" flags used improperly for no response conditions.

In addition, there is no computer at site CND125. This presents a site operation problem for the site operator. Without a computer, interface with the datalogger is limited to the integral keypad and selection switches. Printouts can not be generated if needed, and review of data for the purpose of equipment diagnostics is difficult.

At site CND125, logbook entries and notes from field technicians indicate that several versions of Firmware have been developed and installed in the H2NS logger for evaluation at the site. This is more typical of a prototype system, and not that of a stable operating DAS at an established monitoring site.

Other issues noted regarding DAS are minor. The backup datalogger time, at site BWR139, is set six minutes slow. This only presents a problem if data need to be recovered from the backup logger. The difference in datalogger time was observed to cause a 2% difference in solar radiation data for the same hour, recorded by both loggers. Although not investigated, similar differences are likely for other variables.

The last observation of concern is related to the hourly data average reporting times. The Odessa and H2NS systems report hours 01:00 through 24:00, and the ESC system reports 00:00 through 23:00 per day. This difference should be resolved automatically during routine data validation procedures and is only reported as a difference between CASTNET site systems.

5.5 Infrastructure

Some problems with the infrastructure at the sites were observed. These include the degradation of exposed signal and power cables as depicted in the photographs of site CND125. Other sites have similar cable conditions, particularly where protective conduit is not used. Some signal cables at sites CDR119 and LRL117 appear to have splices which are only protected by electrical tape and are exposed on the ground or buried just below the surface.

At site BFT142, conduit and junction boxes are used to protect the sensor signal and power cables. However, the extra ports in the junction boxes were not sealed which allows moisture to reach the cable connections. Additionally, insects can access the junction boxes through the open ports and contribute to less than desirable conditions for the sensor connections. Photographs of insect contamination within the junction boxes at site BFT142 are included in Appendix 2.

A similar condition was found at site BWR139 in the aspirated shields for the temperature sensors. Both motor housings were infested with insect nests almost to the point of restricting air flow. Photographs are included in Appendix 2.

Some equipment that is no longer being operated at site CDR119 has been left next to the shelter. This is not a proper storage location, or a correct means of disposal. A photograph is included in Appendix 2.

5.6 Field technician procedures

There appears to be some inconsistency, within the MACTEC operated sites, related to the procedures used by the field technicians performing regular maintenance and calibration visits at the sites. This is most notable in the wind direction sensor alignment results previously described. Inconsistency was also observed in calibration procedures of the solar radiation systems. These differences in either procedures or transfer equipment sometimes lead to opposing results and sensor adjustments during consecutive site visits. This causes increased effort during the data validation process and can result in data invalidation.

There is also a procedural difference between MACTEC and ARS operated sites. There are very few notes and calibration results documented on-site at the NPS site that was audited. It was not clear if systems were found within established operational limits or if instrument maintenance was performed during previous visits by ARS. Various instrument settings were not displayed to verify that instruments were operating as left during the previous calibration.

The NPS site operator procedures are well developed and readily accessible at the NPS site audited. 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. An electronic logbook is also included in the interface software. This system permits easy access to site documentation data. However, as noted previously, there was no data regarding instrument calibration records, and little descriptive site data that could be used for validation purposes.

5.7 Site operators

The site operators at sites CND125, BWR139, CDR119, and SHN418 had not been formally trained by either MACTEC or ARS. They had been given instructions by the previous site operators and over-the-phone instructions from the field operation centers at MACTEC and ARS. The EPA sites (CND125, BWR139, and CDR119) have been visited, in some cases many times, by field technicians from MACTEC without providing training to the site operators.

Site operator training should include review of data for their sites. By understanding the relationship of temperature and delta temperature, and by physically inspecting the lower blower which is accessible, the site operators should be capable of diagnosing the upper blower problems which were observed at BFT142 and CND125.

The NPS site (SHN418) has extensive training material available electronically via the on-site computer. The site operator at site SHN418 was also scheduled to receive training during the next site maintenance visit by ARS, which was planned to be within two weeks of the site audit, and before this report was completed.

In general the site operators are very conscientious and eager to complete the site activities correctly. They have performed sensor replacements and repairs at the sites with support provided by the MACTEC and ARS field operations centers. In most 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. It was not clear if sensors and translators were installed as matched sets.

5.8 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. Most of these problems are a result of inadequate operator training. The operators at sites BWR139 and CDR119 do not understand what the “reasonable conditions” checks on the SSRF mean. The data recorded on the SSRF forms by those operators may not be reliable. The site operator at CDR119 is also unfamiliar with the procedures for datalogger downloads and inline filter replacements. She reported those activities as performed on the SSRF, but she did not perform those activities during the systems audit.

Nearly all logbook entries (hardcopy at EPA sites and electronic at NPS sites) lacked records of serial numbers for equipment removed and equipment installed. These records are used during the data validation process to identify and verify when repairs to the site are made, and track maintenance of site sensors. It was also observed that the most recent versions of the site logbooks have no page numbers. This could potentially lead to abuse of the documentation procedures by allowing pages to be placed in any order.

Not all sites had complete calibration records for installed and operating equipment. This mostly occurred due to the site operator installing the equipment, but failing to retain and file the calibration information.

However as described in Section 5.6 above, SHN418 had no calibration records or they were not available for review. Lack of such records makes it impossible to verify some instrument settings such as ozone offsets and spans, and flow controller settings. The electronic documentation system used at the NPS sites could be better utilized to record and display this information.

Some site documentation is not being properly utilized. There were logbook entries documenting the need for temperature shield refurbishment at site CND125. The entry was nearly a year old, and the site visited at least twice. The shield condition had not been corrected. Photographs are included in Appendix 2. Also noted at site CND125 was an entry referring to fluctuation in the delta temperature signal. It appeared to be related to the translator zero/span test switch. The condition was also observed during the site audit and had not yet been corrected. This condition could possibly cause erratic and inaccurate delta temperature data to be recorded.

The ozone inlet filter at site BWR139 was found to be very dark and soiled. A directive from a field technician with examples of the filter and the correct schedule for replacement was found filed at the site. The directive had previously been posted on the shelter wall for the site operator but was apparently removed and the information not communicated to the new site operator. Photographs of the existing inlet filter, and the directive, are included in Appendix 2.

Another documentation issue involves the identification of sensors 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 are missing serial numbers and/or client ID numbers. Others have numbers that are illegible. Better identification of the sensors should be performed to allow tracking and recording maintenance procedures for the sensors.

It has been reported that when a new number is assigned to a sensor, the sensor is rebuilt and treated as a new sensor. At that point previous records of the sensor identification are purged from the inventory database. That does not appear to be the case. There are instances of new numbers being assigned to sensors in the field when old numbers are missing. Those sensors are not refurbished at that time. The inventory database should account for client ID changes and maintain the manufacturer serial number as needed.

5.9 FSAD sensor identification

The field site audit database contains records for all the sensors encountered during the site audits. The records are used for both the performance and systems audits. The numbers assigned are recorded where available. 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). In general, overall CASTNET site operation is acceptable. Some differences between actual site operations and operations described in the QAPP have been identified and described. Recommended improvements to the field operations of the sites have been addressed in the previous sections. Recommendations for improvements to the audit program are presented in the following sections.

6.1 Model sensitivity

A paper published in the Journal of Geophysical Research entitled ***Sensitivity of the National Oceanic and Atmospheric Administration multilayer model to instrument error and parameterization uncertainty*** by Cooter and Schwede, describes a study that indicates that the MLM is most sensitive to uncertainty in atmospheric turbulence estimates. Atmospheric turbulence is estimated at CASTNET sites using the wind speed and the standard deviation (variation) in the horizontal plane of wind direction (sigma theta) measurements. Those two variables are affected by sensor bearing degradation.

Torque tests of the bearings are performed during calibrations and audits. However, there are no acceptance criteria for wind speed or wind direction bearing torques in Section 4.0 of the CASTNET QAPP. The bearings are replaced during routine site visits on a regular maintenance schedule. The relationships between bearing torques and wind speed/wind direction starting thresholds are described in the calibration manual provided by the manufacturer of the R. M. Young sensors. It can be presumed that the wind measurements are accurate if the bearing torque is measured to be within those specifications, but data accuracy and validation procedures are unclear if bearing torque is found to be outside the manufacturer's specifications. If the bearing torque is higher than specifications turbulence will be understated.

Calibration and audit results may not accurately represent the validity of the wind speed and wind direction variation data if bearing torque is high since during calibrations and audits enough force is applied to overcome degraded bearings. The manufacture recommends wind tunnel tests be used to correlate bearing condition with data accuracy. A possible alternative would be to operate a collocated sensor that is wind tunnel-certified as accurate at selected sites for an extended period. This method could be used to investigate bearing torque affects on model results, rather than sensor starting thresholds.

This technique could be applied to other variables if desired. More sensitive instrumentation could be collocated to evaluate if increased sensitivity to specific variables would provide significantly improved model results. This could be considered a CASTNET site MLM audit and validation study, to further the work presented by Cooter and Schwede.

6.2 Problem tracking

During the audits it was apparent that additional field operation procedures need to be evaluated. There are procedures in place that include the daily review of site data. The review can involve automatic and manual procedures. Information from that review is entered into a problem tracking database and provided to the field technicians that perform site maintenance and calibrations. The field technicians evaluate the identified site problems, perform corrective actions, and report the results of those actions for data validation purposes. All of those procedures are part of the total measurement system.

The site printouts at site BFT142 indicated that the problem observed with the temperature system existed for at least the previous 3 weeks, the extent of the available printout records. Apparently the problem had not been detected by the daily review process since the site operator had not been notified to investigate the problem. The same situation existed for at least a week at CND125. No further investigation was conducted there due to the lack of means to generate site printouts.

Another example of a problem regarding the procedures used for site problem identification and tracking, involves the observed conditions and performance audit results of the relative humidity system at site LRL117. The performance results concluded that the sensor output was nearly 7% low when tested above 85% humidity. A review of the printouts on-site confirmed that the maximum RH values recorded during the previous two week period (all available) were approximately 90% RH, indicating a potential problem. This was apparently not detected during the daily review of the site data, since the records of the maintenance and calibration visit results just conducted were reviewed during the site audit and there were no comments regarding investigation of the condition.

6.3 Data validation

An additional enhancement to the audit program should include data validation audits. These audits would include tracking problems detected during the daily data review process and subsequent entry into the problem tracking database. Evaluation of the information and materials provided to the field operations group and field technicians would be performed.

Preparations for performing corrective actions, prior to site maintenance visits, and the actions and activities performed at the sites would then be audited. Finally, reporting of those results in the problem tracking database, validation of data based on those reports and site documentation would be verified and evaluated. All of the tasks described here are part of the total measurement system.

This is different from a database audit which is designed to verify that data represent the documented changes prescribed by the data editor. A data validation audit would evaluate the systems used to arrive at the prescribed edits. A percentage of the sites scheduled for systems and performance audits could be selected for data validation, or total measurement system audit. Calibration and validation techniques could then be evaluated using the performance audit results.

6.4 Post audit follow-up

Some of the conditions encountered during the audits should be addressed during the next scheduled site maintenance and calibration visit. In order to determine if the problems were addressed, some type of follow-up procedure should be established. This procedure may not need to be another audit, and should not occur two years after the audit when the condition was discovered.

For example, the zero air system was observed to contain charcoal in both canisters at site CDR119 during the audit. The site has been visited since the audit. A review of the calibration documentation and/or a call to the site operator should determine if the condition was corrected during the calibration visit.

Similar procedures could be used for other conditions observed during the audits, such as site operator training, sensor repositioning, and sensor adjustments. The follow-up action would be different depending on the condition observed during the audit.

Quick follow-up to verify that significant problems identified during audits are addressed during regular site maintenance and calibration visits, should be a routine function of network operations and management.

REFERENCES:

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Appendix 1.

Performance Audit Report Forms