Quality Assurance Project Plan

for the

CWM Meteorological Network

Revision 7

March 2017

Prepared for:

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1.0 Project Description

Effective October 1, 1990, CWM Chemical Services, Inc. (CWM) received a Part 373 Permit-to-Operate Secure Landfill 12. The permit was issued by the New York State Department of Environmental Conservation (NYSDEC) for operation of a landfill at the CWM facility in Model City, New York. Appendix H-1 of the permit (No. 90-86-1137) stated that CWM must provide "telemetry of wind speed and direction measured by the permitee's on-site meteorological station to the NYSDEC Albany office ...". The objective of this special condition was to provide the NYSDEC direct access to on-site meteorological information for use in correlating transport of air contaminants in and around the Model City facility. Currently, in CWM’s Part 373 Operating Permit (Effective August 21, 2013) Attachment N requires that an NYSDEC-approved meteorological monitoring network shall be operated and maintained at the CWM Model City facility. Temperature, barometric pressure, wind speed and direction shall be continuously measured and recorded at CWM's on-site meteorological station. CWM shall also measure and record the date, or dates, duration (in hours), and amount (in inches) of all precipitation events at the facility's meteorological station. Other parameters shall be measured if deemed necessary by the NYSDEC. The meteorological monitoring network shall be maintained in accordance with the November 2013, and any subsequently Department approved revisions of, "CWM Meteorological Monitoring Network - Quality Assurance Project Plan".

CWM is contracted with O'Brien & Gere to maintain the meteorological monitoring network that will satisfy the requirements of the NYSDEC. Requirements of a state-mandated monitoring network are specified by the NYSDEC in their guidance document DAR-2, Air Guide-19, dated Dec 16, 1997. To satisfy the requirements of DAR-2, the network must (1) obtain the oversight of the NYSDEC, Division of Air Resources, and (2) satisfy the required standards of practice.

On May 11, 1999, the CWM network was upgraded with new data acquisition software and new computer hardware to make the Network compliant with the year 2000. On June 1, 1999 the NYSDEC shut down their polling system and no longer required the CWM Network data to be telemetered each day to the NYSDEC computer system.

On May 16, 2006, the Climatronics strip chart recorder (repair support of which was discontinued by the manufacturer) was replaced with an Omega RD8800 paperless electronic (digital) strip chart recorder. The Omega recorder provided improved accuracy and resolution over the Climatronics analog paper recorder, and was unaffected by paper/pen hysteresis and drift that are inherent with paper recorders.

On December 11, 2007, the network data collection computer was upgraded from a personal computer (PC) operating under Windows 98 to a PC operating under Windows XP. The data acquisition software was transferred to the new Windows XP system and remained the same.

On September 3, 2009, the network data acquisition system was upgraded from the Odessa Engineering system to a new Campbell Scientific system consisting of a Campbell Scientific Model CR1000 data logger and Campbell Scientific Loggernet data acquisition software. The network barometric pressure and precipitation sensors were also replaced with new sensors of equivalent accuracy and specifications. The CR1000 data logger records, averages and provides interim data storage. The Loggernet data acquisition software permanently stores data from the CR1000 electronically to a PC. The CR1000 is located at the tower site and is connected to the sensors directly via signal cables. Loggernet resides on the network PC at the receiver station, and communicated with the CR1000 using a dedicated phone line. Since the data logger accepts direct inputs from each sensor, sensor signal conditioners (translators) were eliminated from the system. The sigma theta computer was eliminated from the system as well since the CR1000 calculates sigma theta directly from the wind direction data. The data logger was configured to store both 1-hour (primary) and 1-minute (backup) time-averaged data, thereby eliminating the Omega electronic chart recorder backup data storage device.

On December 13, 2012, a Raven XT cellular modem was installed at the tower site to allow the network PC at the receiver station to communicate with and retrieve data wirelessly from the data logger via TCP/IP through the internet. The existing telephone line previously used for data communication remained in place to serve as a backup to the cellular communication system. Additionally, the data logger was configured to host a security-enabled HTML page to provide CWM and emergency site personnel quick access to weather station data.
This Quality Assurance Project Plan (QAPP) includes detailed discussions on each network element. Network elements, as defined in DAR-2, are identified below:

- Network Design & Installation
- Network Operation
- Data Transmission and Receipt

- Quality Assurance/Quality Control
- Data Review
- Data Reporting

Revision 1 of this QAPP was submitted to NYSDEC for approval prior to official data collection. It thereby allowed NYSDEC the opportunity for oversight of each of the monitoring network's elements. Notification of approval of this updated version of this document (revision 5), via a signature of an individual representing NYSDEC, is provided on the title page.

In general, all elements of the monitoring network must satisfy the standards of practice specified by NYSDEC. Appendix A of DAR-2 references two primary sources of meteorological monitoring guidelines, listed below. The guidelines described in these two documents are incorporated into the procedures set forth in this QAPP.

- *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV. Meteorological Measurements*, EPA-600/4-901003.
- *Ambient Monitoring Guidelines for Prevention of Significant Deterioration*, EPA-450/4-87-007.

2.0 Project Organization

To assure proper operation of the meteorological monitoring network and effective implementation of this QAPP, it is important to identify the organizational structure and responsibilities assigned to each project member. Figure 2-1 illustrates the organizational structure and identifies general areas of responsibilities of each individual or group.

The overall operation of the meteorological network is the responsibility of CWM. CWM is supported by an independent consulting firm, O'Brien & Gere, which is responsible for conducting system maintenance and internal quality assurance (QA) audits. In addition, NYSDEC has the option of conducting external QA audits to independently evaluate the accuracy and performance of the network.

The meteorological network's program manager is accountable for all activities in support of this program. Through on-going review and interaction with the operations manager, the program manager will ensure that the program remains effective and continues to generate credible data. The program manager will provide supervision and authority over all project schedules and budgets and will act as liaison between CWM, NYSDEC, and other outside parties.

The program manager will also be responsible for oversight of the on-site daily operation of the meteorological monitoring program. The program manager will implement the QA plan in order to provide an accurate and credible meteorological database. To achieve this objective, the operations manager will monitor day-to-day operations and review the meteorological database routinely to assess the accuracy and completeness of the reported data. He or she will work with the station operators in order to maintain a complete understanding of the system status. The station operator(s) are responsible for daily checks on the network's status and daily review of data. They will conduct routine operations as described in Section 4.2 of this QAPP and be responsible for maintaining documentation describing the network's operations, status and activities. All these activities will support the credibility of the database.

Fig 2-1

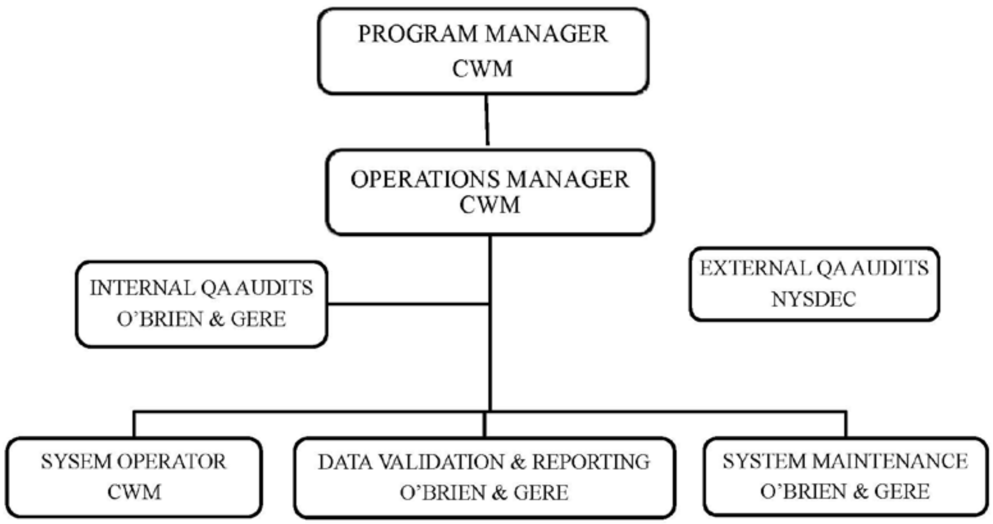

Figure 2-1
Project Organization
CWM Meteorological

O'BRIEN & GERE

System maintenance, data validation and internal QA audits will be performed by the independent consultant, and therefore, are the responsibility of the consultant's project manager. System maintenance includes field calibrations, preventive maintenance, and non-routine maintenance, as described in Sections 4.3 through 4.5 of this QAPP. In completing these activities, the consultant will ensure that the network meets or exceeds the QA objectives pertaining to system accuracy and data completeness. A QA field team, independent from the system maintenance team, will conduct internal QA audits, as discussed in Sections 6.1 and 6.2 of this QAPP. These audits are designed to assess the accuracy of the collected data and to provide an assurance check on quality control activities.

As part of the oversight requirements as dictated in DAR-2, NYSDEC has the option of conducting external QA audits. These audits will provide another level of assessment of data accuracy and network performance. A written report generated after this audit will be submitted directly to NYSDEC. NYSDEC will then inform CWM of the findings.

Table 2-1 provides a summary of the current personnel assignments to the network positions, described above, and the corresponding titles of each individual held within the respective organization.

Table 2-1
Network Personnel Assignments
as of November 2013
CWM Meteorological Network

Network Position	Personnel	Organization	Title
Program Manager	Jill Banaszak	CWM	Technical Manager
Operations Manager	Jill Banaszak	CWM	Technical Manager
Station Operators	Lauren Scalzo Anthony Notaro Jessica Hardy Jonathan Rizzo	Antea Golder Golder CWM	Environmental Technician Environmental Technician Environmental Technician Permitting Manager
Project Manager	Scott Manchester	O’Brien & Gere	Project Manager
QA Manager	Katie Cooper	O’Brien & Gere	Meteorologist

3.0 Monitoring Network Description

This section describes the monitoring station location, network configuration, instrument siting, equipment specifications, sensor orientation and QA objectives.

3.1 Station Location

The meteorological monitoring station is located within the CWM Model City facility. The facility is in the Townships of Lewiston and Porter, approximately eight miles north of Niagara Falls, New York. Figure 3-1 illustrates the location of the monitoring station in relation to the CWM facility and the nearest town and county roadways. The coordinates and elevation (measured at the base of the instrument tower) of the monitoring station are as follows:

Latitude:	43° 13' 20"
Longitude:	78° 58' 46"
UTM Coordinates:	North - 4,787,220 meters
	East - 664,400 meters
Elevation:	317 feet (96.6 meters) msl

3.2 Network Configuration

The network consists of an instrument tower, meteorological sensors, and a data acquisition and communication system. Wind speed, wind direction and standard deviation of wind direction (Sigma A) are measured with sensors installed at the top of a 40-foot aluminum tower. Signals generated by the sensors are continuously recorded and averaged by the data acquisition system (data logger). Data stored on the data logger is retrieved (polled) automatically by the receiver station PC located approximately one mile away using cellular modems the data logger and receiver station. Figure 3-2 illustrates the station layout and location of the network components.

CWM measures additional meteorological parameters, including standard deviation of wind direction (sigma theta), temperature (T), barometric pressure (BP), and precipitation (PCP) for internal use. These parameters are discussed further in this QAPP.

Fig. 3-1

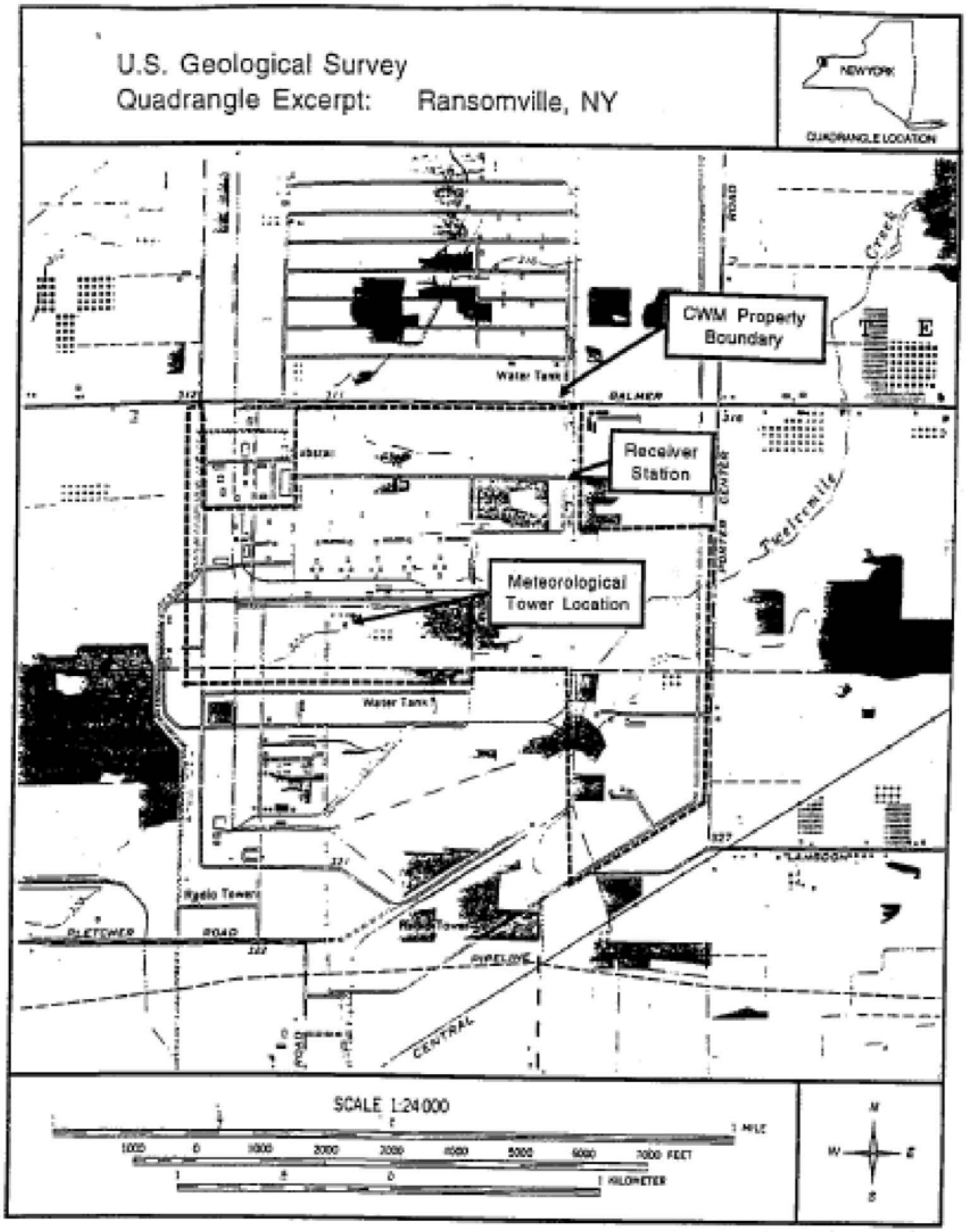

Figure 3-1
Site Location
CWM Meteorological Network

Fig. 3-2

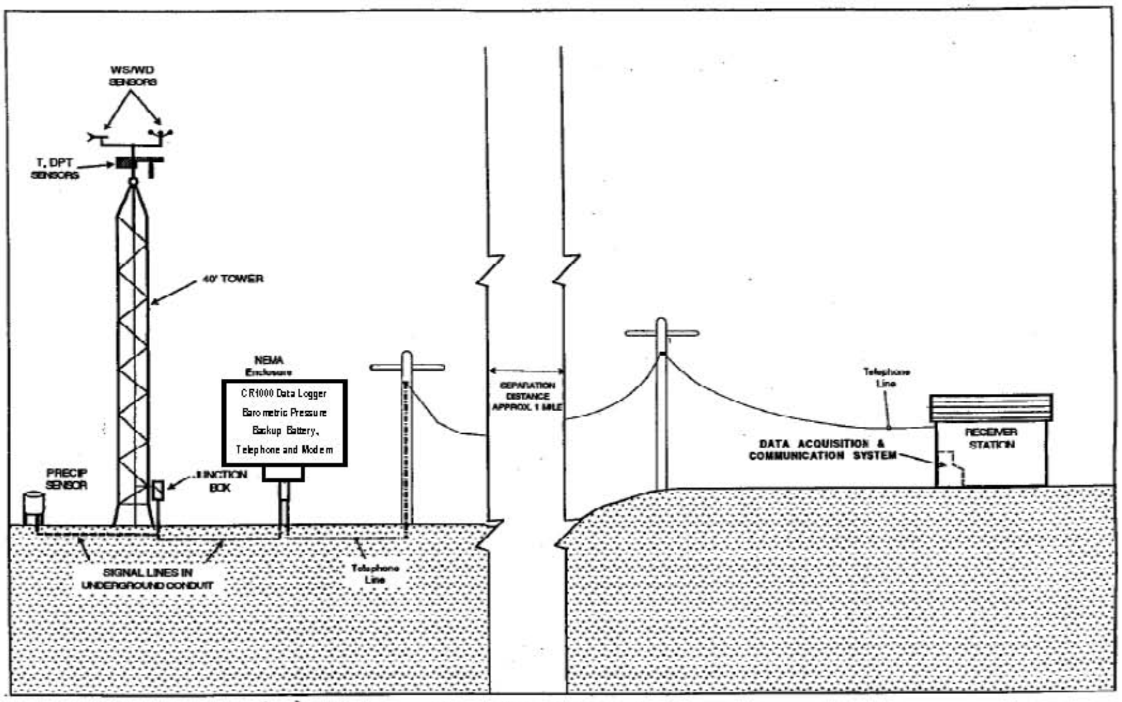

Figure 3-2. Site Layout
CWM Meteorological Network

The data logger and barometric pressure sensor are located in an unheated NEMA enclosure located near the tower base. Signals from the meteorological sensors on the tower are input to the data logger via signal cable. The data logger records incoming data once per second for wind speed and one per 10 seconds for other parameters) and saves it to internal non-volatile memory as 1-hour and 1-minute time-averaged data (see Section 3-4).The 1-hour data is used as the primary data source and the 1-minute data is used as a backup data source and to detect and diagnose potential system malfunctions. External communication with the data logger and transmission of data is made available via CDMA cellular modem in the NEMA enclosure housing the data logger. An external telephone line and analog modem are also located in the NEMA enclosure for use as secondary/backup communication.

An IBM-compatible network PC with Loggernet data acquisition and management software is located at the receiver station approximately one mile away from the tower and data logger. Data is polled from the data logger and cellular modem via Loggernet . Communication through the cellular modem from the network PC is made through TCP/IP protocol using a static IP address. The network computer is programmed to retrieve the hourly and 1-minute average values from the internal memory of the data logger each hour. The computer archives the polled data by appending each new data record into a comma delimited ASCII data file that is accessible via Windows spreadsheet software by CWM to print out daily reports for internal use. On-line transmission of hourly data to the network PC or other offsite PCs can also be accomplished through Loggernet software and standard internet connection. The cellular modem and Loggernet software allows two-way communication including real-time access of the network PC and data logger.

3.3 Sensor Siting

As discussed in Section 3.2, wind speed and direction sensors are installed at the top of a 40-foot tower. Actual sensor elevation above grade is 44 feet. This sensor height was selected, in lieu of the standard height of 10 meters, because of the potential for nearby obstacles to create wind flow disturbances at the sensor level. The 10-meter level is most commonly used for data input to atmospheric modeling applications. However, the objective use of this data, as stated in Section 1.0, is to correlate transport of potential air contaminants in and around the CWM facility. This sensor height provides data that are more representative of actual mean wind flow patterns. Therefore, it was decided, with the concurrence of NYSDEC, that a sensor height of 40 feet would best serve the objective of the monitoring program.

A temperature sensor is also installed on the tower at the 10-meter level. The sensor is protected from solar radiation by a motor-aspirated shield. Precipitation is measured at one meter above the ground by a heated tipping bucket rain gauge installed approximately 5 meters west of the tower base. The barometric pressure sensor is located in the NEMA enclosure at the lower base.

The instrument tower is located in a open grassy field with berms to the south and west, a group of trees and brush to the east, a single tree to the northeast, and one and two-story buildings to the north. A survey was made of the site to measure obstacle heights and distances from the tower. Figure 3-4 illustrates the locations of all potential obstacles and provides elevations above mean sea level (msl) for the tower base and the tops of all obstacles.

Siting requirements for 10-meter meteorological instruments are provided in the PSD guidelines, referenced in Section 1.0. These guidelines allow the minimum distance from the instruments to obstacle to be fives times the height of the obstacle above the base of the tower. Table 3-1 provides a summary of obstacle heights (including differences in ground elevations), distances from the tower, and minimum allowable distances from the tower according to the PSD guideline. As noted in Table 3-1, all obstacles are greater than the minimum allowable distances except for a tree to the east, a bush to the northeast, a bush to the north and a bush and a tree to the northwest. These trees and bushes have the potential for flow disturbance of winds out of the northwest to east, therefore, a sensor height greater than 10 meters was selected.

Fig 3-3

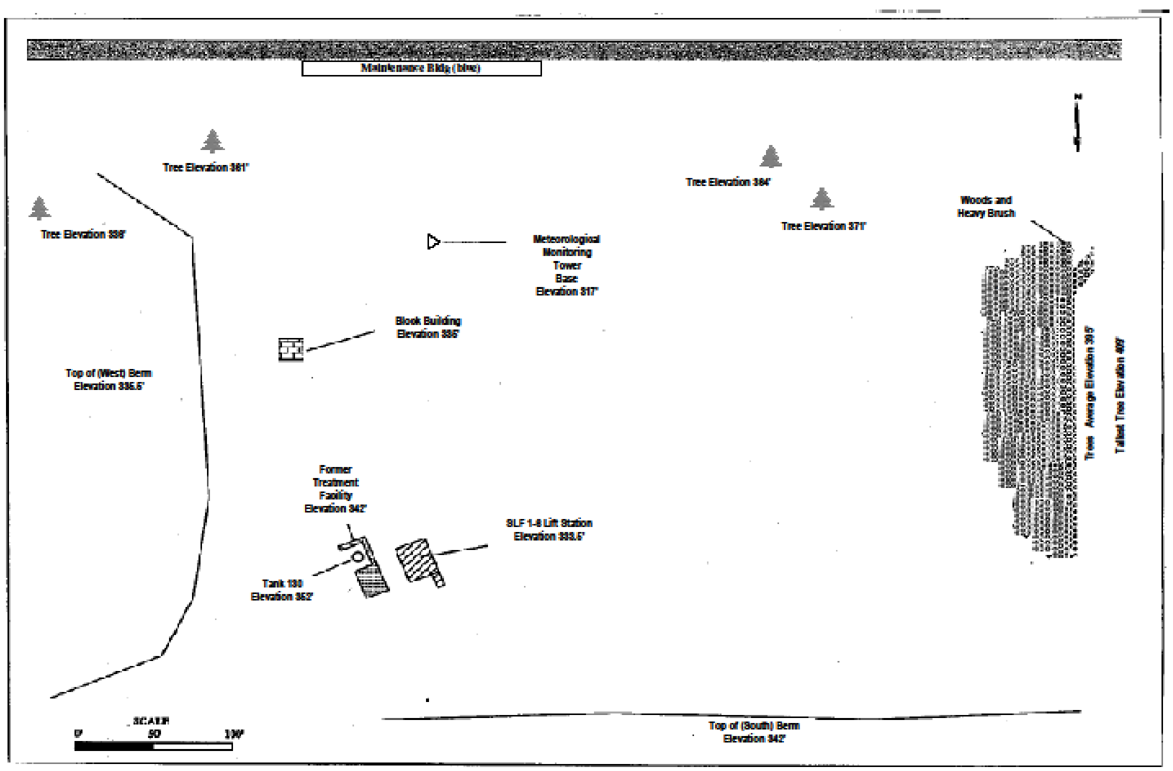

Figure 3-3. Site Plan and Obstructions
CWM Meteorological Network

Table 3-1
Instrument Obstruction Distances and Heights
CWM Meteorological Network

Obstruction	Height Above Tower Base (feet)	Distance from Tower (feet)	Minimum Allowable Distance from Tower (feet)[a]
West Berm	18.5	158	92.5
South Berm	25	309	125
East Tree Line	76[b]	393	385
Tallest Tree[c]	83	409	415
Northeast Tree	50	300	225
Northeast Bush	11	40	55
North Bush	17	60	85
Northwest Bush	20	70	100
Northwest Tree	35	150	175
Block Building	18	100	90
Tank 130	35	218	175
Former Pretreatment Facility	25	203	125
SLF 1-6 Lift Station	16.5	200	82.5

[a] Based on PSD guidelines of five times the height of the obstruction.
[b] Based on average heights of all trees or brush.
[c] Tallest tree in eastern tree line.

3.4 Instrument Specifications

Instrumentation in the monitoring network is designed to meet or exceed specifications recommended in the guidelines referenced in Section 1.0. One other guideline document, not referenced in DAR-2, but useful in designing meteorological monitoring networks, is *Meteorological Program Guidance for Regulatory Modeling Applications*, EPA-454/R-99-005, February 2000.

Tables 3-2 and 3-3 provide specifications of instrumentation for which guidance is available. The tables also compare the instrument specifications with the most restrictive specification suggested in any of the referenced guidance documents. Accuracy specifications, as provided in the tables, are the combined accuracy of the sensor, translator, and data logger (i.e., system accuracies). Tables 3-2 and 3-3 indicate that all instrument specifications meet or exceed guideline specifications.

3.5 Sensor Orientation

In order to ensure proper orientation of the wind direction sensor, the True Solar Noon (TSN) method was employed to orient the theodolite used for wind sensor crossarm alignment. The TSN method calculates the time at which the sun reaches its zenith, at a particular longitude, on a particular date. The TSN time is when the sun intersects the North-South plane created by the North Pole, the South Pole, and the selected longitude. The azimuth line to the sun at TSN (for CWM) was considered True South. To find the TSN for the CWM station, two calculations were necessary. The first finds the Local Apparent Noon (LAN) from the longitude of the station, using the following formula:

$$T_{LAN} = 12{:}00{:}00 + 4(\text{Long.} - 15n)$$

Where:

n = the number of time zones from Greenwich Mean Time

For CWM:

$n = 5$ Long. = 76.1° T_{LAN} = 12:15:55 EST

Table 3-2
Instrument Specifications
NYSDEC Parameters
CWM Meteorological Network

Instrument	Manufacturer	Model	Specification	Design	Guidelines[a]
Wind Speed	Climatronics	100075	Range	0 to 100 mph	Not Applicable
			Accuracy	± 0.15 mph or ± 1.0%	≤± 0.45 mph + 5% of expected
			Starting Threshold	0.5 mph	≤ 1.1 mph[b,c]
			Distance Constant	9.84 feet	≤ 16.4 feet[b]
Wind Direction	Climatronics	100076	Range	0 to 540°	Not Applicable
			Accuracy	± 2°	± 5°
			Starting Threshold	0.5 mph	≤ 1.1 mph[b,c]
			Damping Ratio	0.4	0.4 to 0.65[c]
			Distance Constant	3.7 feet	〈 16.4 feet[b]
Data Logger	Campbell Scientific	CR1000	Resolution	± 0.01 mph ± 0.1°	± 0.2 mph[b] ± 1°[b]
			Sampling Rate	1 per 10 sec	≤ 1 per 60 sec [b,c]

[a] Based on the more restrictive of guideline documents.
[b] Reference: *On-Site Meteorological Program Guidance for Regulatory Modeling Applications*, EPA-450/4-87-013, June 1987.
[c] Reference: *Ambient Monitoring Guidelines for Prevention of Significant Deterioration*, EPA-450/4-87-007.

Table 3-3
Instrument Specifications
Additional Parameters
CWM Meteorological Network

Instrument	Manufacturer	Model	Specification	Design	Guidelines[a]
Temperature	Climatronics	100075	Range Time Constant	-30 to 50°C 3.6 seconds	-30 to 50°C [c] ≤ 60 seconds [c]
Barometric Press.	Climatronics	100388	Range Accuracy	700 to 800 mm Hg ± 1.0 mm Hg	Not Applicable ± 2.3 mm Hg [b]
Precipitation	Qualimetrics	6021-A	Range Resolution Accuracy	0 to 1.00 in 0.01 in 0.5 %	Not Applicable 0.01 in[b,c] ± 10 %[b,c]
Sigma Theta	Campbell Scientific	CR1000	Range Averaging Scheme No. of samples per averaging interval	0 to 100 degrees Yarmartino 360	Not Applicable Yarmartino or 360[b]

[a] Based on the more restrictive of guideline documents.
[b] Reference: *On-Site Meteorological Program Guidance for Regulatory Modeling Applications*, EPA-450/4-87-013, June 1987.
[c] Reference: *Ambient Monitoring Guidelines for Prevention of Significant Deterioration*, EPA-450/4-87-007.

The second, correction for the Ephemeris of the Sun, corrects T_{LAN} according to the day of the year which the measurement is made and follows this formula:

$$T_{TSN} = T_{LAN} - A$$

Where:

A = the Ephemeris correction

A = 00:05:32 (for August 9)

The true south azimuth was then obtained by observing the position of the sun at TSN, using a theodolite. A watch, calibrated to within one second of the Universal Standard Time, timed the theodolite as it tracked the sun. When the TSN was indicated, the sun was sighted along the theodolite's external sights. The azimuth at the instant of TSN was set at 180° True South. The theodolite was then considered correctly oriented and sightings of the crossarm alignment were made. In addition, measurements of direction from the tower to appropriate landmarks were then made to assist in subsequent theodolite orientation. Figure 3-5 illustrates the station landmarks and corresponding directions from the tower.

3.6 Quality Assurance Objectives

The monitoring program has been designed to meet or exceed specific QA objectives. QA objectives are expressed in terms of data completeness and accuracy. Data completeness is defined as the percentage of the number of valid observations (i.e., hourly values) compared with the number of total possible observations (i.e., 24 hours per day). Valid observations are determined according to the procedures outlined in Section 5.5. The QA objective for data completeness for this project is 90 percent over a 12-month period.

Accuracy is defined as the degree of agreement of a measurement with an accepted reference or true value. Accuracy is measured by QA performance audits, as discussed in Section 6.2. The QA objective for accuracy for this project, summarized in Table 3-4, is based on the system accuracy guidelines discussed in Section 3.4.

Figure 3-4

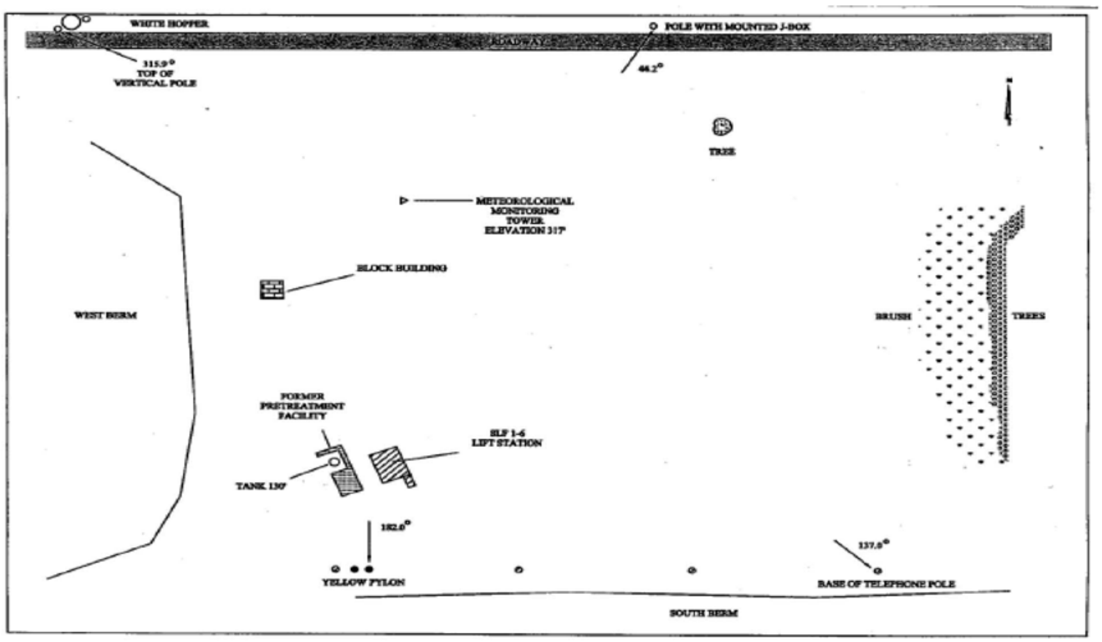

Figure 3-4. Sensor Orientation Landmarks
CWM Meteorological Network

Table 3-4
Acceptable Accuracy Objectives
CWM Meteorological Network

Parameter	Acceptable Accuracy
Wind Speed	< ± 0.45 mph [a]
Wind Direction	< ± 5°

[a] Plus 5% of observed value.

4.0 Quality Control Activities

This section describes the type and frequency of quality control (QC) activities that will be conducted on a routine basis to ensure that collected data are both accurate and complete. The purpose of these activities is not to assess accuracy (which is accomplished by performance audits), but rather to ensure that accuracy objectives are maintained until performance audits are conducted. The following sections provide general discussions of the various QC activities. Specific, step-by-step procedures are provided in Standard Operating Procedures (SOPs) presented in Appendix A.

4.1 Documentation

Documentation is essential to providing the basis for data validation. Documentation also provides a historical record of station operations, and helps to clarify questions that occasionally arise during data checking and validation procedures. Therefore, all QC activities, no matter how small, will be fully documented. To facilitate efficient and complete documentation, a station log and field forms have been developed.

The bound station log book is located at the receiver station. All personnel performing work on the station are required to sign in, noting the time and specific activities to be performed. All entries in the station log will be complete and provide enough specific information so that a person not familiar with the station may understand the activities performed. Corrections in the station log will be made by crossing out the mistake with one line, then initialing and dating the corrections. All log entries will be signed and dated immediately following the entry.

Field forms have been developed for each QC activity, including routine station visits, and semiannual calibrations. Forms function to control problem solving and minimize uncertainties at the station only when completed in their entirety, with no blank entries. All entries called for on the forms will be made; no blank entries will be allowed. Any other information that the operator deems useful will be noted in the station log.

Blank copies of field forms will be kept in adequate supply at the station. Station log and field form originals will remain at the receiver station. Field forms, specific to each QC activity, can be found attached to the appropriate SOP. In the following subsections describing quality control activities, documentation requirements will be discussed in general terms. Activity-specific SOPs will provide more detailed documentation requirements.

4.2 Routine Operation

The station operators will conduct routine operations. These activities include station inspections and electronic calibrations. Routine operations include: (1) physical inspections of the instrumentation to verify proper operation and to detect potential instrument malfunctions, and (2) inspections of recorded data to detect potential data irregularities, and (3) performance of translator electronic calibrations to verify proper conversion of sensor output to analog voltages.

4.2.1 Station Inspection

Station inspections of the receiver station will be conducted daily Monday through Friday, excluding holidays (or other Non-Operating days). Station inspections of the tower station will typically be conducted twice weekly. Additional inspections of both stations may be performed after major weather events such as local thunderstorms, power outages, or ice storms to ensure proper instrument operation.

During each receiver station inspection, a station inspection checklist will be completed, and an entry in the station log will be made. The checklist will act as a reminder or prompt to make all necessary checks. Inspection checks include, but are not limited to:

- check PC and Loggernet local host time and date,
- check for proper data logger battery voltage check that hourly data files are up to date, and
- check reasonableness of recorded data

During tower inspections, only a qualitative evaluation of the "reasonableness" of the data can be made. This evaluation involves the comparison of readings with perceived weather conditions. The extent and effectiveness of these checks increase as the operator's experience with the system and perception of ambient weather conditions develops. For example, the direction to which the vane is pointing can be compared to the wind direction readings, or the speed at which the wind cups are rotating can gauge the perceived wind speed and should be consistent with the wind speed readings.

Leaving the stations in proper working order and completing all required documentation can be tasks that are often overlooked or deemed insignificant. Procedures for leaving the station are discussed in detail in the station inspection SOP (Number 400-160) and are prompted by the station inspection checklist, also found in the SOP.

4.3 Field Calibrations

Field calibrations of all monitored parameters except for sigma theta are conducted every six months as a scheduled routine QC check. Field calibrations are also conducted during initial installation, after sensor failure and replacement, before and after sensor maintenance or repair, and before and after system shutdown for any duration greater than 24 hours.

Field calibrations involve assessing the performance specifications of each component of the monitoring system (sensors, signal cables, and data logger). The calibration control plan specific for this monitoring network is described in detail in SOP 400-710. Assessment of performance specifications includes checking instrument accuracy. Accuracy is checked in field calibrations; however, it is formally assessed and reported by QA performance audits.

Calibration results will be compared with acceptance criteria presented in Table 4-1. Except where noted, if any results exceed these criteria, then the instruments will be adjusted, repaired, or replaced. Calibration will be conducted again until instrument maintenance succeeds in bringing the system within the acceptance criteria.

Table 4-1
Field Calibration Acceptance Criteria
CWM Meteorological Network

Instrument	Acceptable Limits[a]
Wind Speed	
Starting Threshold	≤ 1.1 mph
Synchronous Motor Check	≤± 0.45 mph + 5% of observed
Wind Direction	
Starting Threshold	≤ 1.1 mph
Combined Crossarm and Vane Alignment Check	≤± 5°
Temperature	≤± 0.5 °C
Barometric Pressure	≤± 2.25 mm Hg
Precipitation	≤± 10 percent of expected

[a] Detailed procedures for each field calibration are provided in the instrument-specific SOPs found in Appendix A and identified in Table 4-2.

Table 4-2
Field Calibration Standard Operating Procedures
CWM Meteorological Network

SOP Number	SOP Title
300-200	Field Calibration: Climatronics F460 Wind Speed and Direction Sensors
300-300	Field Calibration: Thermistor-type Temperature Sensors
300-450	Field Calibration: Tipping Bucket Precipitation Gages
300-800	Field Calibration: Barometric Pressure Sensors

4.4 Preventive Maintenance

A plan of regularly scheduled weekly and semiannual preventive maintenance will be implemented to limit instrument downtime and increase efficiency. All maintenance will be thoroughly documented in the station log. The log entry will include all model and serial numbers, date, time, description of maintenance, shipment and expected return dates if a part is to be removed from the station for repair.

4.4.1 Weekly Maintenance

Weekly maintenance is conducted during station inspections previously discussed in Section 4.2. These checks are performed to verify proper system operation and to help minimize periods of invalid or missing data. Specific procedures are discussed in detail in the Routine Site Inspection SOP Number 400-160.

4.4.2 Semiannual Maintenance

Semiannual preventive maintenance will include all of the aforementioned weekly procedures. Semiannual maintenance will be conducted along with the field calibrations previously discussed in Section 4.3. Semiannual maintenance provides a more thorough physical inspection of the tower, sensors, and data acquisition instrumentation. Generally, semiannual maintenance procedures include:

- checks of all tower structural and fastening hardware for looseness and/or deterioration,
- checks of cables, sensors, and junction boxes for looseness or deterioration,
- verification that crossarm and sensors are securely fastened, properly oriented, and undamaged,
- sensor and solar shield cleaning,
- checks of cups and vane for damage or excessive wear, and verification that both are securely mounted on the sensor shafts,
- check the balance of the wind vane,
- checks that sensor heater elements are not interfering with the free rotation of the cups and vane,
- replace wind speed and wind direction shaft bearings, if necessary,
- check the operation of the temperature aspirator motor,
- check that the precipitation gauge is level, clean, and free of obstructions,

- bearings will be routinely replaced. Field calibrations will be performed on the wind sensors prior to and immediately after bearing replacement so that "end-of-period" and "beginning-of-period" sensor conditions can be thoroughly documented.

Semiannual maintenance will be scheduled just prior to semiannual QA audits.

4.5 Non-routine Maintenance

Non-routine maintenance will be performed as needed to correct malfunctions or problems in the network's operation. Such maintenance will be performed as soon as possible after the problem is detected to minimize downtime and to limit periods of invalid or missing data. Upon discovery, the problem will be identified, its causes diagnosed, solutions investigated, and corrective action initiated.

Field calibrations will be performed on the failed instrument once the instrument is made operational. In most cases, field calibrations will not be possible on instrumentation that has had a complete failure because of the instrument's lack of response.

All non-routine maintenance activities will be thoroughly documented in the station log. The entry for this will include all pertinent information regarding repair or maintenance, and may include model and serial numbers, date and time of repair, description of maintenance, date and time when instrument is back on-line, and shipment and expected return dates if a part is to be removed from station for repair.

5.0 Data Reduction, Validation, and Reporting

This section describes procedures pertaining to the collection reduction, validation, and reporting of data for CWM's internal use.

5.1 Data Transmittal

Currently NYSDEC does not remotely access the CWM network either for real-time data review or downloading. However, should that need be required in the future, the CWM network data logger can be accessed via Loggernet communications software to allow authorized users dialup remote access to raw data on the data logger.

As mentioned earlier, data reviewed through Loggernet will not have undergone data validation. However, periods of calibration, known instrument malfunction or other non-valid data events will be noted by the operator as invalid data in the site log.

5.2 Data Submittal From The Field

A data package from the station must be compiled monthly. It will contain digital copies of all printouts, and copies of station logs and data forms, Monthly summary data will contain all hourly data from 0100 hour on the first day through 2400 hour on the last day. Digital electronic raw data from the chart recorder and data logger will be stored on the station PC and sent electronically from the station PC or data logger for off-site validation. The data package of paper records will be reviewed by the operations manager or designee to ensure that the package is complete. The data package will then shipped to the consultant for use in data validation. A station log entry will be made when the data package is removed from the station. The entry will include a description of material removed, the date, and to whom the data are being sent.

5.3 Initial Data Review

Once the data package is received from the field, an initial review will be conducted to ensure that the following items are complete and included in each data submittal:

- all data logger records have been consistently reviewed during weekly site checks, semi-annual calibrations are documented in the site log,
- each printout is identified as to station name,
- all station logs are complete, legible, and cover the entire data period being submitted, and
- all calibration field forms are complete, legible, and cover the entire period being submitted.

5.4 Data Reduction

The continuous raw voltage data from the receivers must be reduced into hourly averages and expressed in engineering units. This procedure is accomplished by the data logger and associated PC software. Voltages from all channels except wind speed and wind direction are measured once every 10 seconds by the data logger and stored in the logger's internal memory. Wind speed and wind direction are measured and recorded once per second. At the end of every minute, the data logger calculates 1-minute averages for each parameter. At the end of every hour, the data logger calculates hourly averages, converts them to the appropriate engineering units, and stores these in internal memory. These hourly averages are calculated by the data logger separately from the 1-minute averages. At approximately 10-minutes past each hour, the PC automatically polls the data logger and retrieves the past hour's data. The electronic data is appended to a file in the PC that is automatically setup to append and archive data.

The station operator will copy the electronic data file monthly to create an identical file to be used for data editing. Therefore, at any one time there are two backup files to the original raw hourly data file. Quarterly, after data validation and reporting procedures are completed for each month of data, the edited data file will be copied to compact disk. The edited data file will remain on the PC's hard drive for at least two years, when a duplicate copy of the earliest year of data will be made on another disk.

5.5 Data Validation

This section describes the procedures to identify non-valid data and to edit the database. The end product of these procedures is a final database with accurate and valid data, ready for reporting and historical archiving. Data validation consists of reviews of data logger data, field forms, and documentation.

All parameters will be validated with the exception of sigma theta. Sigma theta data response will be monitored and noted in the station log during routine daily inspections of the station. Although formal data validation will not be performed on this parameter, CWM will edit blocks of data as necessary when instrument down-time occurs (power failures, etc.).

If raw data from the primary data source (data logger one-hour averages) is invalid or missing, and it is determined that the raw data from the back-up data source (data logger one-minute averages) is valid for that period, then the back-up data will be summarized into hourly averages and used to in place of the primary data. Note that to account for the 0 to 360 degree nature of wind direction data, averaging of wind direction chart recorder data will be performed in a Microsoft Office Excel spreadsheet using polar coordinate averaging as follows:

Average Hourly Wind Direction = WD_{obs}(ATAN2(Ve,Vn)) + FLOW

Where: Ve = -(1/N)∑SIN(Radians(WD_{obs})

Vn = -(1/N)∑COS(Radians(WD_{obs})

FLOW = 180 for ATAN2(Ve/Vn) <180

FLOW = -180 for ATAN2(Ve/Vn) >180

WD_{obs} = Observed chart recorder 1-minute average wind direction

5.5.1 One-Minute Data Review

The first step in data validation is examination of the character of the one-minute data. This is done by using Microsoft Office Excel to chart the one-minute data into line graphs. The graphs (traces) can then be reviewed visually. An unusual trace is the first indication that a component in the monitoring network may have been malfunctioning. There are several characteristics of the trace that may indicate potential problems, such as:

- a flat or seemingly non-varying recorder trace,
- abrupt spikes up and down,
- excessive drifting, and
- a trace that is zero, full scale, or some other constant value for long periods.

If any of these characteristics are observed, additional review of all operational status checks and calibration information for the parameter during the period in question will be conducted.

5.5.2 Calibration Review

The second step of data validation is review of the electronic calibration and QC calibration field forms. Data collected during times of calibration will be scrutinized carefully to identify calibration times and periods of invalid data. Also, if calibrations identified components that exceeded acceptance criteria, then the data will again be reviewed for problems. If data are found to be erroneous because of component malfunction, the interim reporting period in question will be removed from the final database.

5.5.3 Documentation Review

All station logs and routine inspection checklists will be reviewed for indications of component problems. Data collected during periods of suspect malfunctions will be scrutinized carefully. If the review reveals potential problems, other sources including the site log should be consulted.

5.6 Data Reporting

Data reporting will be conducted on a monthly basis. Once monthly data edit files have been validated, data are reported for CWM's internal use. Reporting includes accumulation of documentation and generation of monthly summary reports. Monthly data summary printouts, field documentation, and data documentation will be accumulated from the various individuals involved in data validation. These documents will be archived in a separate cabinet files.

Hard copy reports of all hourly data for the month will be generated by a Microsoft Excel spreadsheet. Copies of the edited data files will be saved on portable media drives or disks, and stored at the receiver station on the portable media and/or on the Network PC.

6.0 Quality Assurance Activities

Quality assurance (QA) activities consist of system, performance, and data validation audits that assess the implementation of the QA plan and the accuracy and credibility of the collected data. The purpose of QA audits is to provide an objective and quantitative accuracy assessment. Therefore, the audits are conducted by an independent staff not affiliated with the staff responsible for routine operation, system maintenance, or data reduction. The following subsections outline audit procedures and requirements that apply specifically to the CWM Meteorological Network. Step-by-step procedures for conducting these audits are found in the SOPs (Appendix A).

6.1 System Audits

System audits will be conducted annually. A system audit is a general assessment of how the monitoring network is being operated relative to the stated QC procedures established in this QAPP. Inspections of the monitoring stations and interviews with the station operators are conducted to determine:

- status of changes to the system configuration and any recommendations implemented as a result of a previous audit,
- the effect of instrument outages and component failures or malfunctions that may have affected the quality and quantity of collected data,
- whether the type of field measurements, data recovery rates, and form of output data are sufficient for the purpose of the program,
- the level of preventive and non-routine maintenance since the previous audit,
- the adequacy and completeness of documentation in station logs and field forms
- the suitability of equipment used for calibration and operational checks; and
- the degree to which routine operations, field calibrations, maintenance, and QA activities have adhered to the procedures set forth in this QAPP.

The system auditor will review with CWM personnel the findings of the system audit and present them in a formal written audit report. Further guidance concerning the system audit is provided in SOP Number 700-600.

6.2 Performance Audits

Performance audits of wind speed and wind direction will be conducted semiannually. Performance audits are a quantitative assessment of the accuracy of the collected data. The audit employs sensor control (SC) method, which consists of challenging each parameter with artificial field devices. SOP Number 700-670 provides more details on performance audits.

Though SC methods are also used for calibrating the wind speed and wind direction parameters, performance audits of the sensors are conducted using different equipment/standards than those used for the calibration. Each wind speed audit will be conducted by rotating the cupset (shaft) of the wind speed sensor at known rates using synchronous motors. Each wind direction audit will be conducted by manually pointing the wind direction sensor vane in several known directions, determined using a solar-oriented sighting device (theodolite). The observed wind speed and wind direction responses will be observed and recorded from the data logger digital display, and compared to the expected (true) wind speed and wind direction responses. In addition, the starting threshold torque of the wind sensors will be audited using separate torque gages.

6.3 Data Validation Audits

A data validation audit of wind speed and wind direction data will be performed on one hourly data point per day for each parameter. A data validation audit consists of averaging an hourly data point, representatively selected, from one-minute data records and comparing the hourly average to the primary hourly data. The personnel responsible for QA data validation audits will be independent from the staff responsible for data reduction and validation.

The results of the data comparisons audit should be within the tolerance criteria presented in Table 6-1. If the results do not meet these criteria, further verification must be performed before data are reported.

Details on data reduction audits and procedures are in SOP Number 700-190.

Table 6-1
Data Validation Audit
Data Comparison Tolerance Criteria

Parameter	Criteria
Wind Speed	±2.0 mph
Wind Direction	±10 degrees

Appendix A
Standard Operating Procedures

STANDARD OPERATING PROCEDURES INDEX

SOP Number	**SOP TITLE**
300-200	Field Calibrations: Climatronics F460 Wind Speed and Wind Direction Sensors
300-300	Field Calibrations: Thermistor-Type Temperature Sensors
300-450	Field Calibration: Tipping Bucket Precipitation Gages
300-800	Field Calibration: Barometric Pressure Sensors
400-160	Routine Site Inspection Procedures: CWM Meteorological Network
400-176	PC-System Routine Inspection: CWM Meteorological Network
400-710	Calibration Control Plan: CWM Meteorological Network
700-190	Data Collection, Reduction, and Validation Procedures: CWM Meteorological Network
700-600	System Audit Procedures
700-670	Performance Audit Procedures: Meteorological Instrumentation
900-110	PC-System Start-up and Shut-down: Campbell Scientific Loggernet Software Within Windows XP Software Environment
900-121	Data Analysis and Reporting: CWM Meteorological Network

STANDARD OPERATING PROCEDURE

NUMBER 300–200
Revision 3 – 04/27/10

FIELD CALIBRATION

CLIMATRONICS F460 WIND SPEED AND DIRECTION SENSORS

CWM METEOROLOGICAL NETWORK

1.0 APPLICABILITY

This document provides information on the procedure necessary for the initial and periodic calibration and routine maintenance of the Climatronics F460 wind speed and direction sensors. The procedures assess the performance specifications of the sensors before (end–of–period) and after (beginning–of–period) maintenance is performed.

2.0 TEST EQUIPMENT REQUIRED

2.1 Waters torque meter (appropriate range), RM Young Torque Wheel, or equivalent.

2.2 Variable speed motor, or synchronous motors calibrated to NIST-traceable standard.

2.3 Sighting compass or theodolite

2.4 Construction square

3.0 SUPPORTING DOCUMENTS

3.1 Climatronics F460 Instruction and Operators Manual

3.2 Variable speed motor setting versus RPM calibration curve

3.3 Wind Sensor Calibration Field Form (attached)

3.4 USGS map of area for magnetic declination

4.0 END–OF–PERIOD CALIBRATION

This procedure provides an indication of the sensor condition at the end of a monitoring period prior to sensor maintenance or repair. Sensor adjustments can be made only after completion of this procedure.

4.1 Determine the expected crossarm alignment. Conventional F460 installations require that the wind speed sensor is aligned to true north and wind direction to true south. Record the expected alignment on the field form.

4.2 Measure the crossarm alignment with either a sighting compass or theodolite. If a compass is used, record the magnetic compass readings, documented angle of declination, and corrected true compass readings onto calibration form. Compute average deviation from expected alignment.

4.3 Lower tower, if applicable, onto a suitable stand that permits vane and cups to rotate freely.

4.4 Perform calibrations of wind direction sensor.

4.4.1 Check vane alignment.

4.4.1.1 Align vane pointing first toward cups and then away from cups. Record data logger values onto calibration form. Record expected wind direction values as measured from step 4.2, onto the field form.

4.4.1.2 Calculate and record the difference between the expected wind direction and the response from the data recorder. If the difference is greater than ±5 degrees, then sensor alignment is unacceptable and in need of realignment. Do not realign until all end–of–period calibrations are complete.

4.4.2 Check linearity.

4.4.2.1 Record values from Step 4.4.1 into appropriate blanks in Linearity Test section of field form.

4.4.2.2 Align vane perpendicular to crossarm to achieve three more output values. When aligning to as direction perpendicular to the crossarm, use a construction square or other suitable tool with 90° angle to assist in sighting the vane. Record data logger values at each position onto calibration form.

4.4.2.3 Compute differences between data recorder responses and expected responses obtained in Step 4.4.1. If the difference of any calibration point is greater than ±5 degrees, then the sensor potentiometer is unacceptable and in need of replacement. Do not replace until all end–of–period calibrations are complete.

4.4.3 Check starting threshold.

4.4.3.1 Remove vane after an inspection of its condition, and test starting threshold using the appropriate range torque watch gage, RM Young Torque Wheel, or equivalent. Record torque and corresponding starting threshold (mph) onto calibration form.

4.4.3.2 Compute the corresponding starting threshold using the following equation:

$$\text{mph} = 2.2\,(T/29.8)^{1/2}$$

where: T = torque in gm–cm

If the starting threshold is greater than 1.1 mph, then the sensor performance is unacceptable and the sensor bearings need to be replaced (see Section 5.0).

4.5 Perform calibration of wind speed.

4.5.1 Check starting threshold.

4.5.1.1 Remove cups and inspect their condition. Note deteriorated or unusual conditions onto field form.

4.5.1.2 Test starting threshold using a torque watch gage or torque wheel. Record torque and corresponding starting threshold (mph) onto calibration form.

4.5.1.3 Compute corresponding starting threshold using the following equation:

$$\text{mph} = 2.2\,(T/1.4)^{1/2}$$

If the starting threshold is greater than 1.1 mph, then the sensor performance is unacceptable and the sensor bearings need to be replaced (see section 5.0). Do not replace bearings until all end–of–period calibrations are complete.

4.5.2 Test sensor using known rates of rotation.

4.5.2.1 Using the synchronous motors and/or the variable speed motor and generate rotational rates to simulate speeds over the range of the sensor.

4.5.2.2 Since there are only two synchronous motor speeds, the variable speed motor will be necessary for at least two of the speeds. Record the rpm setting of the variable speed motor or rated rpm of the synchronous motors. Calculate expected wind speed from rpm by the following equation:

mph = 0.05257 * rpm + 0.5 for vinyl and aluminum cups
mph = 0.04796 * rpm + 0.5 for stainless steel cups

In each case, record the expected mph and data logger responses onto the calibration form and compute differences between the data recorder responses and expected speeds. If the difference of any calibration point is greater than ±0.45 mph plus 5 percent of the observed speed, then the sensor performance is unacceptable. Do not make any adjustments until all end–of–period calibrations are complete.

4.6 Label calibration form as "End–of–Period Conditions."

4.7 Evaluate each sensor as acceptable or not acceptable. If the sensor is unacceptable for any part of the calibration checks described above, then the sensor performance as a whole is deemed not acceptable.

4.8 Make sure the rest of the field form is completed in its entirety, then sign and date the form and give to supervisor for quality control review.

5.0 ROUTINE MAINTENANCE

5.1 Wind speed and direction sensors should be inspected thoroughly when removed for calibration. Attention should be directed to vane and cup condition; check for cracks and signs of weathering. Sensors should have gaskets checked and replaced if worn.

5.2 Replace sensor bearings semiannually or whenever the starting threshold is found to be unacceptable by the end–of–period calibrations. Refer to the instruction manual for bearing change procedure.

5.3 If, after replacing the bearings of the wind direction sensor the starting threshold is still unacceptable, the sensor's potentiometer may need to be replaced. Sometimes the torque of the potentiometer alone is enough to fail the sensor's starting threshold criteria. Refer to the manufacturer's instruction and operation manual for the potentiometer change procedure.

6.0 BEGINNING–OF–PERIOD CALIBRATION

6.1 If the wind speed sensor's performance was found unacceptable during the end–of–period calibrations, the sensor should be returned to Climatronics for repair and a spare sensor installed in its place. Calibrations, as described in Step 4.5, must be performed again on the replacement sensor.

6.2 If wind speed sensor bearings have been replaced, repeat wind speed calibration checks as in Step 4.5.

6.3 If the wind direction crossarm/vane alignment was found unacceptable as in Step 4.4.1, and if the source of error is primarily due to the crossarm alignment, then adjust the crossarm and repeat Step 4.4.1 until a difference of less than ±1 degree is measured. Repeat Step 4.4.1.

6.4 If the wind direction sensor bearings and/or potentiometer have been replaced, or the vane/crossarm alignment is still unacceptable, then adjust the vane alignment by holding the tail toward the cups, and loosening the crossarm–to–sensor base set screws. Adjust the sensor base until the sensor response equals the expected response (±1°). Repeat Step 4.4 and adjustments, if necessary, until sensor response is acceptable.

6.5 Raise tower back to its monitoring position and repeat Step 4.2.

6.6 Record data onto new calibration form, and label form as "Beginning–of–Period Conditions". Evaluate each sensor as acceptable or not acceptable. If the sensor is unacceptable for any part of the calibration checks described above, then the sensor performance as a whole is deemed not acceptable. Make sure the rest of the field form is completed in its entirety, then sign and date form and give to supervisor for quality control review.

6.7 Make a note in site log of all calibration activities, bearing changes, sensor replacements (include serial numbers), alignment adjustments, and the operational status of each sensor at the end of the calibration.

7.0 ACTIONS REQUIRED

7.1 Log Book Entry

An entry into the site log book should include information on time and date of calibration, activities performed, and notes on any non–routine occurrences.

7.2 Invalid Data Log

Annotate site log or field form with instrument downtimes.

7.3 Calibration Form

The calibration form must be completed in its entirety and signed by the operator. Submit original forms to the quality control manager for review and signature.

8.0 STANDARDS TRACEABILITY

8.1 Torque Meters

Waters torque meters must have certified accuracies using weights which are certified by NIST. Models 366–1M and 366–3M must have accuracies within ±5 and ±10 percent, respectively, of full scale. The accuracies must be certified within 12 months prior to its use. Torque wheel weights should also be certified within ±10 percent of their reported weight. Weights may only be certified once throughout their life unless visible signs of damage are evident.

8.2 Variable Speed Motor

Variable speed motors must be calibrated (setting versus rpm) via a certified phototachometer within 12 months prior to its use. Alternately, the variable speed motor rpm may be read directly at the time of use by a certified phototachometer. The tachometer must be certified by standards traceable to NIST within 12 months prior to motor calibration or use. The tachometer must meet or exceed the requirements of MIL–STD–45662/A.

8.3 Synchronous Motor

Synchronous motors must be checked every 12 months with a certified phototachometer as described in 8.2. The motors must be accurate to within ±1 percent of rated speed.

8.4 Compass and Theodolite

Compasses and theodolites are siting devices and are not considered standards. Therefore, they do not require certification. However, proper maintenance and set of the theodolite and accurate measure of the angle of declination for compasses must be considered.

Attachment

Wind Sensor Calibration Field Form

O'BRIEN & GERE
www.obg.com

Wind Direction Calibration Form

Station:________________________________ **Date:**__________

Location:__________________________ **As found / As left**

Sensor Model:________________________ **Sensor Range:**______

Sensor Serial Number:__________________ **Sensor Height:**______

Calibration Device:

NIST-Traceable Standard Model/SN (Starting Threshold):__________________

NIST-Traceable Standard Cal. Date:__________

Crossarm Alignment:

Expected Alignment (Degrees)	Measured Alignment (Degrees)	Difference (Degrees)

Sensor Starting Threshold:

gm-cm (T)	mph[a]

[a](Tolerance: ≤1.1 mph)
$mph=((T/K)^{0.5})*2.237$
K= 29.8

Dynamic Accuracy Response:

Vane direction	Expected Datalogger Response (degrees)	Observed Datalogger Response (degrees)	Difference (degrees)[b]
at cups			
away from cups			
+ 90° from cups			
- 90° from cups			

[b]Criteria: ±5°

Within Acceptance Criteria? Yes___
No___

Comments:____

____

____

____

Performed By:________________ **Date:**__________

Reviewed By:________________ **Date:**__________

O'BRIEN & GERE
www.obg.com

Wind Speed Calibration Form

Project Name:_____________________________________ **Date:**____________

Location:_______________________________ **As found / As left**

Sensor Model:___________________________ **Sensor Height:**_____

Sensor Serial Number:_____________________

Calibration Devices:

Starting Threshold:____
NIST-Traceable Standard Cal. Date:___________

Variable Speed Motor:____
NIST-Traceable Standard Cal. Date:___________

Sensor Starting Threshold:

gm-cm (T)	mph[a]

[a]**Criteria: ≤1.1 mph (≤0.5 m/s)**
$mph=((T/K)^{0.5})*2.237$
K= 1.4

System Dynamic Response:

Motor Speed (rpm)	Expected Datalogger Response (mph)	Observed Datalogger Response (mph)	Difference (mph)[b]

[b]**Criteria: ±(0.45 mph + 5% of observed)**
mph=(RPM/0.05257)

Within Acceptance Criteria? Yes___
No___

Comments:____

Performed By:________________ **Date:**____________

Reviewed By:________________ **Date:**____________

O'BRIEN & GERE
www.obg.com

Temperature Calibration Form

Station:________________________ **Date:**______________

Location:________________________ **As found / As left**

Sensor Model:________________________ **Sensor Range:**_______

Sensor Serial Number:________________________ **Sensor Height:** __10M__

Calibration Devices:

NIST-Traceable Standard Model/SN:________________________

NIST-Traceable Standard Cal. Date:__________

System Response:

Reference Temperature			Datalogger Response (°C)	Temperature Difference[a] (°C)
$°F_{uc}$	Correction	$°C_c$		

$°F_{uc}$: uncorrected **$°C_c$: corrected**
Correction based on NIST calibration of Standard
[a]Criteria: ±0.5 °C (USEPA)

Maximum Difference: _______

Within Acceptance Criteria? **Yes**___
No___

Comments:____

____

____

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Performed By:____________________ **Date:**______________

Reviewed By:____________________ **Date:**______________

O'BRIEN & GERE
www.obg.com

Precipitation Calibration Form

Project Name:______________________________ **Date:**____________

Location:______________________________ **As found / As left**

Sensor Model:______________________________ **Sensor Diam.:**________

Sensor Serial Number:______________________

Cup Volume/Tip Threshold Tests:

	Expected Volume (ml)	Actual Volume (ml)	Difference
Left Cup 1st			
2nd			
3rd			

Average Difference		% Difference	

	Expected Volume (ml)	Actual Volume (ml)	Difference
Right Cup 1st			
2nd			
3rd			

Average Difference		% Difference	

Simulated Precipitation Test Results:

Total Volume of Water (ml)	Depth of Water (in.)	Datalogger Response (in.)	Difference	% Difference[a]

[a]Criteria: ≤±10 %

Maximum % Difference:_____

Within Acceptance Criteria? Yes___
No___

Comments:____

Performed By:____________________ **Date:**______________

Reviewed By:____________________ **Date:**______________

O'BRIEN & GERE
www.obg.com

Barometric Pressure Calibration Form

Station:______________________________________ **Date:**______________

Location:_____________________________________ **As found / As left**

Sensor Model:_________________________________ **Sensor Range**________

Sensor Serial Number:__________________________ **Sensor Height**________

Calibration Device:

NIST-Traceable Standard Model/SN:____

NIST-Traceable Standard Cal. Date:______________

System Accuracy Response:

Reference Pressure (mmHg)	Datalogger Response (mmHg)	Pressure Difference[a] (mmHg)

[a]**Criteria: ±1.1mmHg**

Maximum Difference:_______

Within Acceptance Criteria? Yes___
No___

Comments:____

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____

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____

____

Performed By:____________________ **Date:**______________

Reviewed By:____________________ **Date:**______________

STANDARD OPERATING PROCEDURE

NUMBER 300-300
Revision 5 – 12/1/08

FIELD CALIBRATION

THERMISTOR or PLATINUM RTD – TYPE TEMPERATURE SENSOR

CWM METEOROLOGICAL NETWORK

1.0 APPLICABILITY

This document provides information on procedures necessary for initial and periodic calibration of thermistor-type temperature sensors. The procedures apply to the Climatronics temperature sensor P/N-100093 or equivalent.

2.0 TEST EQUIPMENT REQUIRED

2.1 Constant Temperature Water Bath.

2.2 Thermometer calibrated against NIST traceable thermometer.

3.0 SUPPORTING DOCUMENTS

3.1 Manufacturers instruction and operators manual.

3.2 Temperature Calibration Field Form (attached).

4.0 CALIBRATION PROCEDURE

4.1 Remove temperature sensor assemble from its sun shield and inspect. Remove thermistor from aspiration shield and inspect for wear or cracks.

4.2 If the thermister is part of a thermister/relative humidity probe assembly, enclose the assembly inside of a water proof plastic bag if it would be damaged by direct immersion. Completely immerse the thermistor in an ice bath along with a calibrated thermometer. Allow both to stabilize and record the thermometer and sensor temperatures (from strip char and data logger) onto calibration form.

4.3 Adjust water bath temperature to at least two more temperature points which are equally spaced between 32°F and 110°F, and record the stable thermometer and sensor temperatures onto calibration form.

4.4 For each temperature point, compute absolute difference between thermometer and sensor temperatures and record onto calibration form.

4.5 Compute average temperature difference, and record onto calibration form, along with maximum temperature difference.

4.6 If sensor exceeds the project's tolerance criteria, troubleshoot system to determine cause.

4.7 If sensor replacement is warranted, recalibrate newly installed sensor. Indicate on calibration form, the new serial number.

4.8 Reinstall thermistor into aspirator housing. Reinstall sensor assembly on tower. Check for proper operation.

5.0 ROUTINE MAINTENANCE

5.1 Clean the outside of the aspirator housing with a mild cleaner and a soft cloth. Check the inside of the aspirator for obstructions to air flow, clean if necessary. Check all electrical connections in the aspirator for corrosion. Check all power and signal cables for wear or cracked insulation, replace or repair as necessary.

6.0 ACTIONS REQUIRED

6.1 Log Book Entry

An entry into the site log book must include information on time and date of calibration, activities performed, instrument downtimes and any non-routine occurrences.

6.2 Invalid Data Log

Annotate logbook with downtimes. Use data logger flag switches if available.

6.3 Calibration Forms

Calibration forms must be completed in entirety and signed by the calibration technician. Distribute forms as required by the network QAPP.

7.0 STANDARDS TRACEABILITY

Mercury in glass field thermometers should e calibrated using a standard thermometer whose calibration is traceable to standards from the National Institute of Standards and Technology. Mercury-in-glass field thermometers need not be recalibrated unless separation of mercury occurs.

STANDARD OPERATING PROCEDURE

NUMBER 300-450
Revision 3 – 04/27/10

FIELD CALIBRATION

TIPPING BUCKET PRECIPITATION GAGE

CWM METEOROLOGICAL NETWORK

1.0 APPLICABILITY

This document provides procedures for the calibration of tipping bucket precipitation gages. The procedures assess performance specifications before (end-of-period) and after (beginning-of-period) repairs or adjustments are performed.

2.0 TEST EQUIPMENT REQUIRED

2.1 1-liter separatory funnel, or WVR Precipitation Gage Calibrator (8" gages or larger)

2.2 250-milliliter (ml) graduated cylinder

2.3 10 milliliter graduated syringe

2.4 Squeeze bottle with water

2.5 Ruler or tape measure

2.6 Silicone spray lubricant

3.0 SUPPORTING DOCUMENTS

3.1 Precipitation gage instruction and operator's manual.

3.2 Precipitation Calibration Form (attached).

4.0 END-FO-PERIOD CALIBRATION PROCEDURE

This procedure provides an indication of the sensor condition at the end of a monitoring period prior to sensor maintenance or repair. Sensor adjustments can be made only after completion of this procedure.

4.1 Note as found precipitation total on precipitation calibration field form so that the total daily precipitation may be calculated after calibration is complete.

4.2 Inspect condition of exterior of gage and note the presence of any foreign material that may be blocking the collecting funnel or screen. Pour some water into the gage and verify proper drainage through gage.

4.3 Carefully remove the outer shield and inspect the interior of the gage. Check that the heater, if so equipped, is properly attached to the funnel and connected to its power source. If ambient temperature is cold enough to activate heater, check if heater is working. Examine the sensor bubble level, and note if the sensor is level or not on the calibration field form.

4.4 Manually tip the bucket at least ten times. Verify that the same number of tips are recorded at the primary data recorder. Any discrepancy should be noted in the comments section of the calibration field form. Record the expected and observed values and compute the difference and % difference. For acceptable performance, the % difference (as calculated using Equation 1) between the expected and observed values must be ≤±10%. Computations of difference should be based on responses of the primary data recorder.

% Difference = [(observed – expected)/expected]*100 Equation 1

4.5 Measure the diameter of the collecting funnel, and use the equations found on the calibration form to calculate the amount of water, V_1 (ml), which will be necessary to simulate 1 inch of rainfall under standard temperature conditions.

4.6 Multiply V_1 by the inches of rainfall per tip. Record this value as the expected amount (ml) of water necessary for one tip.

4.7 Wet both buckets of the tipping mechanism with water.

4.8 Using the 10 ml graduated syringe and with the collection funnel in place, slowly drip water into the right tipping bucket until one drop causes the bucket to tip. Repeat at least two more times. Compute the average difference and % difference (Equation 1) for the tips. For acceptable performance, % difference must be ≤±10%.

4.9 Repeat Step 4.8 for the left-side tipping bucket.

4.10 Calculate and measure out a volume of water to simulate an expected rainfall depth of at least 0.2 inches. Measure this amount using the 10 ml syringe and 250 ml graduated cylinder, and pour into the squeeze bottle, or the gage calibrator.

4.11 If the squeeze bottle is to be used, mount the spout of the bottle so that it is approximately 1 inch above the surface of the gage funnel and 1 inch off-center of the gage funnel. Record the , then drip the water into the gage at the rate less than 1 inch per hour.

4.12 On 8” or larger gages, the VWR precipitation gage calibrator may be used. If the VWR calibrator is to be used, then place the filled calibrator bottle in its holder inside the precipitation gage. The tip of the calibrator bottle should be approximately 1 inch off center and not touching the gage funnel.

4.13 After the contents of the bottle or calibrator have emptied, check the buckets on the gage. If the bucket is greater than 1/2 full, manually tip the bucket to empty the water. Record the data logger and chart recorder values. Compute the difference and % difference (Equation 1). For acceptable performance, the % difference between the expected and observed values must be $\leq \pm 10\%$. Computations of difference should be based on responses of the primary data recorder.

4.14 Evaluate the overall performance of the gage. If its response was unacceptable for either of the first two checks, only then repair or adjustments should be performed, though its overall performance acceptable. If its response was unacceptable on the third test (simulated rainfall), then its overall performance rating is unacceptable.

5.0 ACTIONS REQUIRED

5.1 Clean all debris out of the orifice.

5.2 Wipe out dirt and debris from the tipping buckets.

5.3 Oil the pivot points of the tipping bucket with light silicone oil. Maintenance procedures should be performed regularly, as required, to insure optimal operation of the instrument.

5.4 If the gage is out of level, adjust the mounting feet to bring the bubble level within tolerance.

6.0 TIPPING BUCKET ADJUSTMENT

This procedure needs to be performed only if the gage has been deemed unsatisfactory, or in need of adjustment or repair.

6.1 If the manual tip test indicated unsatisfactory performance, test the tip mechanism and the mercury or magnetic switch for proper operation. Repair or replace if defective.

6.2 If the tipping volume or the simulated rainfall results are unsatisfactory, adjust the tipping volume of buckets by adjusting stops located under each bucket. Raising the stops will reduce the volume of water for each tip; lowering the stops will increase the volume per tip. The tipping buckets should be adjusted so that each bucket will tip with approximately the same volume of water.

7.0 BEGINNING-OF-PERIOD CALIBRATION

If adjustments or repairs have been made to the gage which may affect its response, the following beginning-of-period calibration procedures must be performed.

7.1 If adjustments were made in Step 6.1 or 6.2, perform Steps 4.1 to 4.13 (recalibration).

7.2 Record results of Step 7.2 onto new field calibration form and label the form as “beginning-of-period” conditions.

8.0 ACTION REQUIRED

8.1 Log Book Entry

An entry onto the site log book must include information on time and date of calibration, activities performed, instrument downtime, and any nonroutine occurrences.

8.2 Calibration Forms

Complete calibration forms in their entirety, sign, and submit for internal quality control review and signature of reviewer.

9.0 STANDARD TRACEABILITY

9.1 Graduated cylinders are calibrated to meet ASTM E1272 Class B specifications.

STANDARD OPERATING PROCEDURE

NUMBER 300-800
Revision 2 – 04/27/10

FIELD CALIBRATION

BAROMETRIC PRESSURE SENSORS

CWM METEOROLOGICAL NETWORK

1.0 APPLICABILITY

This document provides procedures for initial and periodic calibration of ambient barometric pressure sensors.

2.0 TEST EQUIPMENT REQUIRED

2.1 Barometer with a calibration traceable to the National Institute of Standards Traceability (formerly National Bureau of Standards.

3.0 SUPPORTING DOCUMENTS

3.1 Manufacturer's instruction and operation manual site barometer.

3.2 Barometric Pressure Calibration form (attached).

4.0 CALIBRATION PROCEDURE

4.1 Complete the Barometric Pressure Calibration form and indicating the correct units of pressure to be recorded on the form.

4.2 Determine whether the site barometer measures uncorrected or corrected (to sea level) pressure. If corrected, determine the site elevation to the nearest meter, measure the temperature at the site barometer, and calculate a correction factor.

4.3 Position the standard barometer at a similar height to the site barometer.

4.4 Allow the standard barometer ample time to equilibrate to the same temperature of the site barometer.

4.5 Record the responses of both the site barometer and the standard barometer. Compute the difference between the site barometer response and the standard barometer response. Record this value on the calibration form.

4.6 Repeat Steps 4.3 through 4.5 throughout out the day as barometric pressure values change.

4.7 If the difference between the site barometer and the standard barometer exceeds applicable tolerance limits at any test point, return the sensor to the manufacturer for repair.

5.0 ACTIONS REQUIRED

5.1 Log Book Entry

An entry into the site log book must include information on time and date of calibration, activities performed, instrument downtime, and any non-routine occurrences.

5.2 Calibration Forms

Complete calibration forms in their entirety and have them signed by the site operator. Submit original forms to the quality control manager for review and signature.

6.0 STANDARDS TRACEABILITY

The standard barometer must have an accuracy of $\leq\pm 0.05$ inches of mercury. The accuracies must be calibrated traceable to NIST or other authoritative standard within 12 months prior to its use.

STANDARD OPERATING PROCEDURE

NUMBER 400-160
Revision 5 - 04/27/10

ROUTINE SITE INSPECTION PROCEDURES

CWM METEOROLOGICAL NETWORK

1.0 APPLICABILITY

The information contained in this document provides procedures for the routine site inspection of the CWM Meteorological Network. Tower inspection is scheduled to be performed no less than twice per week and no less than three days between each inspection. The receiver station inspection is to be performed daily, except for weekends and holidays (no more than 3 days between inspections). These procedures are used to assist in the detection of instrument problems on a routine basis. These procedures provide vital information for data validation procedures. In no way do these procedures attempt to assess data accuracy.

2.0 SUPPORTING DOCUMENTATION

Routine Site Inspection Checklist (attached).

3.0 TOWER SITE INSPECTION

3.1 Upon arrival at the site, conduct a general inspection of the tower for signs of physical damage caused by vandalism, lightning, heavy winds, or other adverse conditions.

3.2 Verify that wind vanes and cups are moving freely, responding properly, and have no holes or missing sections.

3.3 Verify that sensor mounts are vertically oriented.

3.4 Verify that no loose cables or wires are dangling from the tower or sensor mounts.

3.5 Verify that temperature aspirator shield is operating by feeling or listening for sound of motor.

3.6 Verify that the wind sensor crossarm is aligned properly and that it has not been moved since the last visit.

3.7 Verify that the precipitation gage is clean and free of obstructions, and that the heater is functioning.

3.8 Verify that datalogger power is on.

3.9 Verify the datalogger date and time are correct (±5 minutes of Eastern Standard Time – EST or Eastern Daylight Time – EDT). If data logger time is incorrect, reset the datalogger time to the data collection PC time using Loggernet Software.

4.0 RECEIVER STATION INSPECTION

4.1 Verify that Windows is running and the date and time are correct on the data collection PC (±5 minutes of EST or EDT).

4.2 Verify Loggernet 3.4.1. is running and the “Connect Screen” is open, and that “Local Host” is connected.

4.3 Verify the battery voltage to the datalogger is greater than 13 volts.

4.4 Review the station data files and verify that the 1-minute and 60-minute averaged data files are up to date.

4.5 Review the previous 24-hours of 60-minute averages for comparison to actual conditions and visually scan for data anomalies.

5.0 DATA INSPECTION

5.1 Data Reasonableness

5.1.1 Observe the current wind speed data and determine whether it is reasonable in comparison to the perceived current wind speed as indicated by the relative rotational speed of the wind cups.

5.1.2 Observe the current wind direction data and determine whether it is reasonable in comparison to the vane position relative to the crossarm. If current wind direction data indicates north winds, the vane should be observed pointing at the wind speed cups.

5.1.3 Observe the current sigma theta data and determine whether it is reasonable in comparison to the variation in wind direction. Periods of variable wind directions tend to occur during periods of low wind speeds. Higher sigma theta values will be evident during these conditions.

5.1.4 Observe the current temperature data and determine whether it is reasonable in comparison with the perceived ambient temperature. When determining perceived temperature, consider the absence of wind chill and solar incidence. Determine whether the past chart tracings are normal and exhibit a typical diurnal patterns.

5.1.5 Observe the current barometric data and determine whether it is reasonable in comparison with meso-scale weather patterns. During fair weather, barometric pressure should read higher than during periods of stormy weather. Pressure readings should not jump or step.

5.1.6 Observe the current precipitation reading and determine weather it is reasonable in comparison with recent precipitation events. Precipitation should rarely increment more than 0.2 inches or so for a single event, even during periods of heavy precipitation.

6.0 UPON DEPARTURE

Make a site log entry with date, time arrived, name, activities conducted (i.e., routine inspections, maintenance), as-found conditions of instruments and data (i.e., instruments operating properly, data is reasonable), and corrective actions taken.

7.0 ACTIONS REQUIRED

7.1 A Routine Site Inspection Checklist must be completed in its entirety for each site inspection. The operator must sign the checklist and leave the original at the site.

7.2 An entry must be made in the site log during each site inspection. All identified problems or potential problems, actions taken and to be taken must be discussed in the entry.

7.3 The site operator must immediately inform the operations manager of all problems or potential problems. The operations manager must take actions to verify, troubleshoot, and resolve problems.

STANDARD OPERATING PROCEDURE

NUMBER 400-176
Revision 1 – 04/27/10

PC DATA ACQUISITION SYSTEM ROUTINE INSPECTION

CWM METEOROLOGICAL MONITORING NETWORK

1.0 APPLICABILITY

This SOP provides step-by-step procedures for routine inspection of the CWM PC-based data acquisition system, and is used to verify proper PC system operation as-needed, such as when the PC system is experiencing problems or direct communication with the data logger is required. The procedures in this SOP are to be performed in addition to the procedures presented in SOP Number 400-160 (Routine Site Inspection), and in no way attempts to assess the accuracy of the data being recorded.

2.0 SUPPORTING DOCUMENTS

2.1 Meteorological Monitoring System Daily Inspection Report

3.0 DAILY INSPECTION

3.1 Examine the computer display. Verify Loggernet 3.4.1. is running and the “Connect Screen” is open, and that “Local Host” is connected.

3.2 Verify the server and station date and time are correct and that the clocks are running.

3.3 Using the numeric data display from the Connect Screen, verify the connection from the data logger to the PC is working and data is being updated at a frequency of approximately once per every 10 seconds.

3.4 Complete all questions on checklist, and make comments whenever abnormal conditions are found.

STANDARD OPERATING PROCEDURE

NUMBER 400-710
Revision 5 - 04/27/10

CALIBRATION CONTROL PLAN

CWM METEOROLOGICAL NETWORK

1.0 APPLICABILITY

This document describes the overall calibration control strategy to be utilized in the CWM Meteorological Network for wind speed, wind direction, temperature, barometric pressure, and precipitation.

2.0 SUPPORTING DOCUMENTS

2.1 Standard Operating Procedures for specific equipment.

3.0 CALIBRATION

3.1 Test equipment shall be identified on the calibration field form by manufacturer, model number, serial number, and last calibration data.

3.2 A reference calibration unit must have equal or better accuracy and precision than the unit under test. When two different reference units are used, the one with the better accuracy and precision shall be designated as the standard.

3.3 Calibrations of test equipment and standards shall be traceable to NIST or other authoritative standards.

3.4 Sensors shall be calibrated:

- in place whenever feasible;
- upon installation;
- prior to shutdown;
- at a minimum interval of every three months
- after bearing replacement;
- and after repair or replacement of any component affecting calibration.

3.5 Wind Speed

3.5.1 Sensor bearings shall be checked via torque meters or torque wheels prior to calibration and after bearing replacement.

3.5.2 Sensor bearings will be replaced whenever torque tests indicate starting thresholds above instrument specifications or at least every six months.

3.5.3 A dynamic span check will consist of challenging sensor photochopper with synchronous motors at a minimum of two speeds.

3.5.4 Refer to SOP 300-200 for detailed procedures.

3.6 Wind Direction

3.6.1 Sensor bearings shall be checked via torque meters or torque wheels prior to calibration and after bearing replacement.

3.6.2 Sensor bearings will be replaced whenever torque tests indicate starting thresholds above instrument specifications or at least every six months.

3.6.3 Sensor alignment will be checked in reference to the sensor crossarm. Crossarm alignment will be measured with a sighting compass or theodolite.

3.6.4 Refer to SOP 300-200 for detailed procedures.

3.7 Temperature

3.7.1 Calibration of temperature sensor will consist of the submersion of the thermistor in a temperature controlled water bath and comparison with a transfer standard thermometer.

3.7.2 The thermistor will be calibrated at a minimum of three temperatures, including an ice point.

3.7.3 Refer to SOP 300-300 for detailed procedures.

3.8 Barometric Pressure

3.8.1 A barometer or absolute manometer calibrated to standards traceable to NIST standards will be used to calibrate the barometric pressure sensor.

3.8.2 The pressure range checked will be dependent on the barometric pressure on the day of calibration.

3.8.3 Refer to SOP 300-800 for detailed procedures.

3.9 Precipitation

3.9.1 The precipitation gage will be calibrated by the measuring the volume of water necessary to produce one tip of each side of the tipping bucket, and then running a volume of water equal to a known amount of precipitation.

3.9.2 The test volumes introduced will be corrected for the ambient temperature.

3.9.3 Refer to SOP 300-450 for detailed procedures.

4.0 DOCUMENTATION

4.1 Calibration field forms shall contain:

- a complete list of test equipment and reference units used;
- both "end-of-period" and "beginning-of-period" conditions, including the total system error (sum or individual component errors);
- tolerance limits for each critical measurement;
- serial numbers of each sensor and component calibrated.

4.2 Site log shall contain:

- names or initials of each member of the meteorological team;
- personnel time in and out each day;
- brief description of activities, including parameters calibration, problems, and out-of-specification conditions found, corrective action taken, and recommend future action.

4.3 The site log or applicable calibration field form will be annotated such that all non-valid data will be clearly identified.

4.4 A copy of each calibration field form shall be submitted to the quality control manager for review. The original must remain on site.

STANDARD OPERATING PROCEDURE

NUMBER 700-190
Revision 1 - 04/27/10

DATA COLLECTION, REDUCTION, AND VALIDATION PROCEDURES

CWM METEOROLOGICAL NETWORK

1.0 APPLICABILITY

This document provides information on procedures for routine collection, reduction, and validation of meteorological data from the CWM meteorological network. The purpose is to assess the status of the monitoring system, evaluate the quality of data, and document reasons for missing data.

This procedure describes methods that do not adjust data based on calibration or audit results. Beginning in Spring 2008, all hourly data are reported in local time (standard time in the winter and daylight savings time in the summer) and as the ending hour (i.e., 0200 hourly value is the average of readings from 1:00 to 2:00 AM).

2.0 SUPPORTING DOCUMENTATION

2.1 SOP 400-710 - Field Calibration Control Plan

2.2 All instrument-specific SOPs contain sections on documentation.

2.3 Data Editing and Missing Data Form (attached)

3.0 DATA COLLECTION

3.1 All meteorological data are collected with a digital data logger. The data logger uses 1-hour averaged data as the primary collection method and 1-minute averaged data for backup and verification.

3.2 The data logger obtains input signals from each instrument at a rate of once every one to ten seconds. The input signals are averaged into 1- minute and 1-hour intervals. The averages are stored in the data logger internal memory. Once every ten minutes the 1-minute averages are automatically polled by a personal computer. The 1-hour averaged data is polled once per hour.

3.3 When polled, the 1-minute averaged data is appended to an existing file named YYYY-MM – 1 min.csv. The 1-hour averaged data is appended to an existing file named YYYY-MM – 1 hour.csv.

3.4 At the end of each month, a data package including 1-minute and 1-hour averaged data electronic csv files, copies of check lists, site logs, and calibration forms is assembled and delivered to the individual in charge of data validation.

4.0 DATA REDUCTION

4.1 Raw data files are imported to a supplemental data management system (Microsoft Excel). Excel spreadsheets are then used to sort, flag, and compare 1-hour and 1-minute averaged data and to generate reports and graphs.

4.2 Data missing from 60-minute files are investigated to determine whether data can be retrieved from 1-minute averaged data. If possible, 1-minute averages are summarized into 1-hour averages and written on Data Editing Forms. Information from these forms is then entered into the Excel spreadsheet data management systems (see Section 5.0 for data averaging procedures).

5.0 DATA REDUCTION FROM 1-MINUTE AVERAGES

5.1 It is necessary to verify that sufficient data is available by verifying that there are at least 30 valid one-minute data records in the 1-hour time period..

5.2 Averaging 1-minute data into hourly data is accomplished by first importing the 1-minute data into an Excel workbook for processing. The data should be imported as separate worksheets for each day. Each worksheet can then be set up to calculate the 1-minute data into hourly averaged data.

5.3 Hourly averages for 1-minute data will be computed arithmetically for all parameters except precipitation and wind direction. Precipitation will be computed as the sum of the differences between the totalized data from each 1-minute data point. Wind direction averaging will take into account the 360 degree/0 degree cross-over by computing average wind direction using the following polar–coodinate equation:

Hourly Average Wind Direction = atan2[{-sin(avgWD)}, {-cos(avgWD)}] + Flow

where avgWD = 1-hour arithmetic average of 1-minute wind directions
Flow = +180 for atan2[{-sin(avgWD)}, {-cos(avgWD)}] <180
Flow = -180 for atan2[{-sin(avgWD)}, {-cos(avgWD)}] >180

5.3 Prepare the appropriate Data Editing and Missing Data Form that contains entry blocks to note all pertinent information (i.e., day, hour, hourly averaged values and whether the values have been entered into the Excel spreadsheet..

6.0 DATA VALIDATION

6.1 Initial Data Review

6.1.1 Following receipt of the data package, the hourly and 1-minute averaged .csv files are imported into Microsoft Excel for quality assurance and reporting purposes. An initial review of all raw data and field materials is made to identify specific periods for which data are obviously erroneous and must be removed from the spreadsheet.

6.1.2 Data values for calibration sequences, maintenance periods, or other obvious instrument malfunctions are removed during this preliminary review to save time during the more intensive quality assurance review of the final data report.

6.1.3 Data removed from the spreadsheet are entered on the Data Editing and Missing Data Forms along with the reason for removal.

6.2 Database Management Flags

6.2.1 An automated screening level of validation will be performed on hourly data as it is imported to the Excel spreadsheet to ensure that the instruments are operating properly. A summary of the screening criteria is as follows for each parameter:

<u>Wind Speed</u>: is less than 0.27 m/s or greater than 25 m/s, does not vary by more than 0.1 m/s for 3 consecutive hours, or does not vary by more than 0.5 m/s for 12 consecutive hours.

<u>Wind Direction</u>: is less than or equal to 0 degrees or greater than 360 degrees, does not vary by more than 1 degree for more than 3 consecutive hours, and does not vary by more than 10 degrees for 18 consecutive hours.

<u>Temperature</u>: is greater than a 5 degree change from the previous hour and does not vary by more than 0.5 degrees C for 12 consecutive hours.

<u>Sigma Theta</u>: is less than 1 degree or greater than 100 degrees and does not vary by more than 0.1 degrees for 3 consecutive hours.

<u>Barometric Pressure</u>: is greater than 1049 mmHg, is less than 929 mmHg, and changes by more than 4.5 mmHg in three hours.

<u>Precipitation</u>: is greater than 1 inch per hour, is greater than 4 inches per 24-hour period, is less than 2 inches per 3 months.

6.2.2 Data that fails the screening test will be flagged for further review under the manual review. Quality control flags will be assigned to data, as appropriate, to indicate suspect and missing data.

6.3 One-Minute Data Review

6.3.1 A key step in the data validation process is examination of the character of the continuous graphical trace of 1-minute averaged data. This will be done for all parameters each month by graphing the data using Microsoft Excel.

6.3.2 An unusual trace is the first indication that a component in the monitoring system may have been malfunctioning. There are several characteristics of the trace that may indicate potential problems such as:

- A flat or seemingly non-varying recorder trace,
- Abrupt spikes up or down,
- A trace that shows excessive drifting,
- A trace that is running along zero, full scale or some constant value for long periods of time.

6.3.3 If any of these characteristics is noted, immediate additional checks of all operational status checks and calibration information for the parameter and period in question will be made. This is to determine whether the recorded data are actually valid or not. The Field Technician will also be notified and requested to fully check the on-site operation of the system.

6.3.4 If a problem is confirmed, the affected data will either have to be completely discarded or corrected if sufficient information exists to make appropriate adjustments.

6.3.5 It will also be necessary to determine the beginning and end times of the total period of questionable data. If both primary and back-up data recording systems are employed, determine if both records are affected.

6.4 Calibration Review

6.4.1 Another step of the data validation process is to review the routine analyzer calibration responses and the field sensor calibration results.

6.4.2 During this process the data should again be reviewed for potential problems and invalid data.

6.5 Documentation Review

6.5.1 All log notes and field calibration sheets should be similarly reviewed for indications of potential equipment problems that could affect the data, and a determination made whether any such conditions must be corrected.

6.5.2 During this review, all the information and the computations listed in the field documentation should be re-checked for accuracy.

6.6 Missing or Edited Data

6.6.1 All data that are deemed missing or unretrievable by the validation processes discussed above are edited as missing.

6.6.2 Data Editing and Missing Data Forms must be completed for every hour of missing data.

6.6.3 Hourly data that are retrievable from 1-minute average data and still considered valid can be edited in the Excel spreadsheet along with the proper documentation using the Data Editing and Missing Data Form.

6.6.4 All missing data is reported in monthly data reports. Dates, hours, and reasons of missing data are obtained from the Data Editing and Missing Data Form, which is completed during data validation.

6.7 Quality Assurance Review

6.7.1 The quality assurance review of the database is the final step before the data are reported. It is a subjective overall interpretation and assessment of the monitoring conditions, instrument performance, and calibration results and validity of the final database.

6.7.2 The person responsible for the quality assurance review of the data will be familiar with all aspects of the monitoring operations and capable of interpreting the many variables that will affect the data.

6.7.3 One hour or more per day for wind speed and wind direction is summarized into hourly averages from the 1-minute average files and compared to the corresponding hourly averaged value.

6.7.4 The results of data comparisons should be within ±5% or further verification must be performed before the data are reported.

6.7.5 The final review of the database should verify that the data are reasonably representative of actual conditions. This is a subjective interpretation of the data and applies the reviewer's familiarity with the monitoring system and the parameters being examined.

7.0 DATA VALIDATION CRITERIA

7.1 For hourly data to be a valid data point, 30 minutes out of the hour must be valid.

STANDARD OPERATING PROCEDURE

NUMBER 700-600
Revision 5 - 04/30/10

SYSTEM AUDIT PROCEDURES

CWM METEOROLOGICAL NETWORK

1.0 APPLICABILITY

This document outlines the procedure for a system audit, be it third-party or in-house. The system audit assesses a monitoring program's compliance with established regulations governing the collection, analysis, validation and reporting of ambient air quality data. This protocol serves as a suggested guideline and is not intended to be a detailed step-by-step instruction. Auditors should feel free to ask as many questions as necessary to evaluate the quality of a program.

This procedure has been designed primarily for Prevention of Significant Deterioration (PSD) field monitoring programs, and verification of compliance with Quality Assurance Program Plans (QAPPs), regulations, and permit requirements appropriate to the program.

2.0 AUDITOR RESPONSIBILITIES

2.1 Review the QAPP, if available, to become familiar with the system design, the purpose of the monitoring, and applicable operating procedures.

2.2 (Optional) Review at least a month of data from the site to be audited (or one representative site) to determine data- capture history, presence of any operational problems, and reasonableness of data, given the site location and prevailing climatological conditions. If data are not available before the audit, the auditor may request from the agency collecting the data that it be available during or after the audit.

2.3 The auditor should be familiar with the calibration equipment to be used in the field. Certification of the auditor on the operation of the calibrators used is highly recommended.

2.4 Assure that all calibration equipment used at the site has been verified within required time limits specified in the QAPP, and that all test equipment is in current calibration.

3.0 SYSTEM AUDIT

3.1 Verify that the site location and configuration match those in the QAPP. Document any variances and note whether required approvals were granted.

3.2 Verify that all probes are located at the proper heights and exposures (for PSD, they must meet the probe siting criteria as contained in 40 CFR 58, Appendix E). If any probe is not properly sited, it should be determined whether there is documentation of an approved variance.

3.3 Verify that meteorological instruments are located at appropriate heights and distances from obstacles for the surrounding terrain (see Ambient Monitoring Guidelines for PSD, Section 4.2). If meteorological instruments are not properly sited, determine whether there is documentation of an approved variance.

3.4 Note tower and wire conditions and observe (when possible) whether tower instruments appear to be operating properly.

3.5 Inspect the shelter and surrounding area, noting accessibility (road conditions), cleanliness, orderliness, shelter temperature control, and OSHA safety standards pertaining to electrical connections, ladders, railings, and storage of combustible and/or hazardous gases.

3.6 Inspect the normal sampling line for leaks, kinks, and visible contamination and moisture. Assure that all ports of the sampling manifold are used or capped off.

3.7 (Optional) Estimate volume of the sampling manifold and blower capacity, and if possible calculate an approximate flow through the manifold. Include in the report a description of the manifold and whether it meets EPA QA guidelines (EPA Quality Assurance Handbook for Air Pollution Measurements Systems, Vol. II, 2.0).

3.8 (Optional) Inventory all monitoring and recording equipment by manufacturer, model number, serial number, age (if available), and date of last calibration, where appropriate.

3.9 Determine that all air quality monitors in use are certified as reference or equivalent instruments (if required by program) and that they are being operated as such with respect to range, time constant, etc. If they are not, there should be documentation of an approved variance.

3.10 Verify that the meteorological system meets the minimum accuracy requirements as indicated by manufacturer and/or applicable guideline specifications; also that each met sensor meets the appropriate specification (PSD, see Ambient Monitoring Guidelines for PSD, Section 5.2, and references therein).

3.11 Verify that all instruments are in current calibration. There should be documentary evidence showing that all calibrations are traceable to NBS or equivalent standards.

3.12 Ascertain whether the site is operated under written or oral procedures. Written procedures should be available on site for the technician's reference. The written procedures should be adequate to ensure data validity. The technician may be evaluated as to his or her knowledge of correct procedures.

3.13 Review site documentation (logs, maintenance schedules, calibration documents, calibration stickers) to assure that procedures (whether written or not) are being followed.

3.14 Determine if procedures exist (written or oral) for the reduction of raw data to reporting format. These procedures should be adequate to ensure data validity and should cover Quality Control criteria, methods, and documentation. The following questions should be asked:

- What averaging method is used (e.g., 1 min, 60 min)?
- How many values are included in the average?
- Is start, center, or end of average interval used to report data?
- What kind of spot checking, if any, is done?

3.15 Determine whether calibration documents are used in the validation process, if data are ever adjusted for any reason, and if so, what methods are used and how they are documented.

3.16 Determine under what conditions the periodic zero and span checks are done (automatic or manual), whether the span values are plotted or logged, and how the span data are used in data reduction.

4.0 AUDIT REPORT

4.1 Audit reports will contain the results of the system audit and may also include a checklist with notations made at the site(s), and an evaluation of the overall effectiveness of the agency's data collection activities.

4.2 Issue audit reports promptly and address to the division manager of the audited area, or to the program manager in the case of program-specific audits. Also send copies to those involved in the audited function, to those with profit and loss responsibility, and to the corporate quality assurance officer.

STANDARD OPERATING PROCEDURE

NUMBER 700-670
Revision 3 - 04/27/10

PERFORMANCE AUDIT PROCEDURES

METEOROLOGICAL INSTRUMENTATION

CWM METEOROLOGICAL NETWORK

1.0 APPLICABILITY

This document details methods and considerations applicable in conducting performance audits of meteorological monitoring instrumentation, consisting of Climatronics sensors measuring wind speed, and wind direction.

2.0 EQUIPMENT REQUIRED

2.1 See specific calibration SOP.

3.0 SUPPORTING DOCUMENTATION

3.1 *Quality Assurance Handbook of Air Pollution Measurement Systems, Volume IV, Section 4.2.7.*

3.2 *On-Site Meteorological Program Guidance for Regulatory Modeling Applications, Section 8.4.*

3.2 *SOP 300-200. Field Calibrations: Climatronics F460 Wind Speed and Wind Direction Sensors*

4.0 AUDIT PROCEDURES

4.1 Audit of each parameter will be performed using the same procedures as used in a calibration. See the appropriate calibration SOP for each procedure.

4.2 Audits will be performed using calibration equipment independent of the equipment used for calibrations.

4.3 Audits will be performed or directed by personnel independent of the calibration and operation personnel.

4.4 If sensor accuracy exceeds specified tolerance, the program manager will be notified within 24-hours.

5.0 DOCUMENTATION

5.1 Audit forms must be completed in their entirety with no empty blanks.

5.2 The site log entry must contain a brief chronology of your actions.

5.3 Audit reports shall contain results of the performance audit and copies of the audit data sheets. Reports shall be submitted in a timely manner (within 30 days) to the program manager.

STANDARD OPERATING PROCEDURE

NUMBER 900-110
Revision 4 - 10/21/13

PC SYSTEM START-UP AND SHUTDOWN

CAMPBELL SCIENTIFIC LOGGERNET SOFTWARE
WITHIN WINDOWS 7 SOFTWARE ENVIRONMENT

CWM METEOROLOGICAL NETWORK

1.0 APPLICABILITY

This SOP provides step-by-step procedures for the Microsoft Windows 7multitasking environment software, and the ENVICOM data acquisition and data logger control software in their application in the CWM Meteorological Network. This SOP covers system start-up and shutdown procedures, and power failure.

2.0 START-UP

2.1 Power up the PC system. This starts Windows 7.

2.2 After Windows 7 boots up, verify correct time and date. Correct if necessary.

2.3 On the desktop, select the ”Loggernet” icon to start the Loggernet software. Once open, Loggernet will automatically poll data from the data logger using the current schedule and filename/path configuration settings.

2.4 On the Loggernet toolbar, under “Data”, select “RTMC Run Time” to bring up CWM's custom data view screen.

3.0 SYSTEM SHUTDOWN

3.1 To power off the PC, close RTMC Run Time and then close Loggernet. The PC will stop polling data from the data logger.

STANDARD OPERATING PROCEDURE

NUMBER 900-121
Revision 0 – 4/27/10

DATA ANALYSIS AND REPORTING

CWM METEOROLOGICAL NETWORK

1.0 APPLICABILITY

This SOP provides procedures for the generation of daily and monthly data reports, and wind roses. If hard copies are desired, be sure printer is properly connected and configured. Daily and monthly data reports will be generated using commercially available spreadsheet software such as Microsoft Excel. Wind roses will be generated using specialized wind rose analysis software.

2.0 DAILY DATA REPORTS

2.1 Daily reports will be generated using Microsoft Excel. Pre-validated data for each day will be imported from comma separated value (csv) files to a Microsoft Excel spreadsheet that will allow for printing of a daily data summary report. The daily report will include hourly data for all parameters.

3.0 MONTHLY DATA REPORTS

3.1 Once data have been validated, they can be saved to a monthly validated Microsoft Excel spreadsheet. The spreadsheet will summarize the data into monthly reports for each parameter that can be readily printed. Monthly reports will present the data at beginning times of each 1-hour period, and will also present the number of valid hours, total hours and data capture for the month.

4.0 WIND ROSE GENERATION

4.1 Wind roses, if required, will be generated using Windrose Pro Software by Enviroware. Alternately, other commercially available programs may also be used including Oriana (by Kovach) or WRPlot View (by Lakes Environmental).

4.2 Wind roses will be generated by compiling the desired periods of validated wind speed and wind direction data into one spreadsheet using Microsoft Excel. The Windrose Pro Software will be used to select the data suitable for processing by the program.