MONITORING PROTOCOL AND QUALITY ASSURANCE PROJECT PLAN FOR CONDUCTING METEOROLOGICAL MONITORING FOR THE RESOLUTION COPPER COMPANY RESOLUTION MINE NEAR SUPERIOR, ARIZONA

May 6, 2009

Prepared for:

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FOR THE
RESOLUTION COPPER COMPANY
RESOLUTION MINE
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Approved by:

Louis C. Thanukos, Ph.D.
Manager, Environmental Projects
Applied Environmental Consultants, Inc.

Louis C. Thanukos

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1. INTRODUCTION

1.1 PROJECT DESCRIPTION

This document presents the monitoring and quality assurance project plan for a meteorological monitoring program to be implemented for Resolution Copper Company (Resolution) for a copper mine in Pinal County, Arizona. The planned monitoring program includes meteorological monitoring for wind speed, wind direction, standard deviation of the horizontal wind direction (sigma theta), barometric pressure, precipitation, relative humidity, solar radiation, evaporation, temperature at 2 meters, and differential temperature between 10 meters and 2 meters. Monitoring will be conducted at two sites: East Met Site (KC1) and West Met Site (KC2).

The objectives of the monitoring program are to provide the measurements necessary to establish meteorological conditions that affect the transport and dispersion of emissions from potential sources at the future Resolution facility. The data will be used as inputs to applicable dispersion models in order to quantify potential off-site impacts for inclusion in applications for air quality permits. The monitoring program is conducted in accordance to EPA's Meteorological Monitoring Guidance for Regulatory Applications (EPA-454/R-99-005) and meets Prevention of Significant Deterioration (PSD) guidelines.

1.2 DESCRIPTION OF RESOLUTION MINE AND MONITORING SITE

1.2.1 Facility Location

The property encompassing the Resolution Mine is located approximately 50 miles west of Phoenix, Arizona in Pinal County and 75 miles north of Tucson, Arizona (Figure 1.1). More specifically, the East Met Site (KC1) site is in the southwest corner of Township 1S, Range 13E. The West Met Site (KC2) site is located in the southeast corner of Township 1S, Range 12E.

The Resolution Project is located in the historic Pioneer Mining District three miles East of Superior, Arizona. Elevations in the area range from to 2,763 feet above sea level in the town of Superior, while nearby Apache Leap Mountain reaches over 4,700 feet above sea level. Terrain East of the property is highly mountainous. Terrain to the West is less mountainous and becomes relatively flat approximately 10 miles west of Superior and into Phoenix.

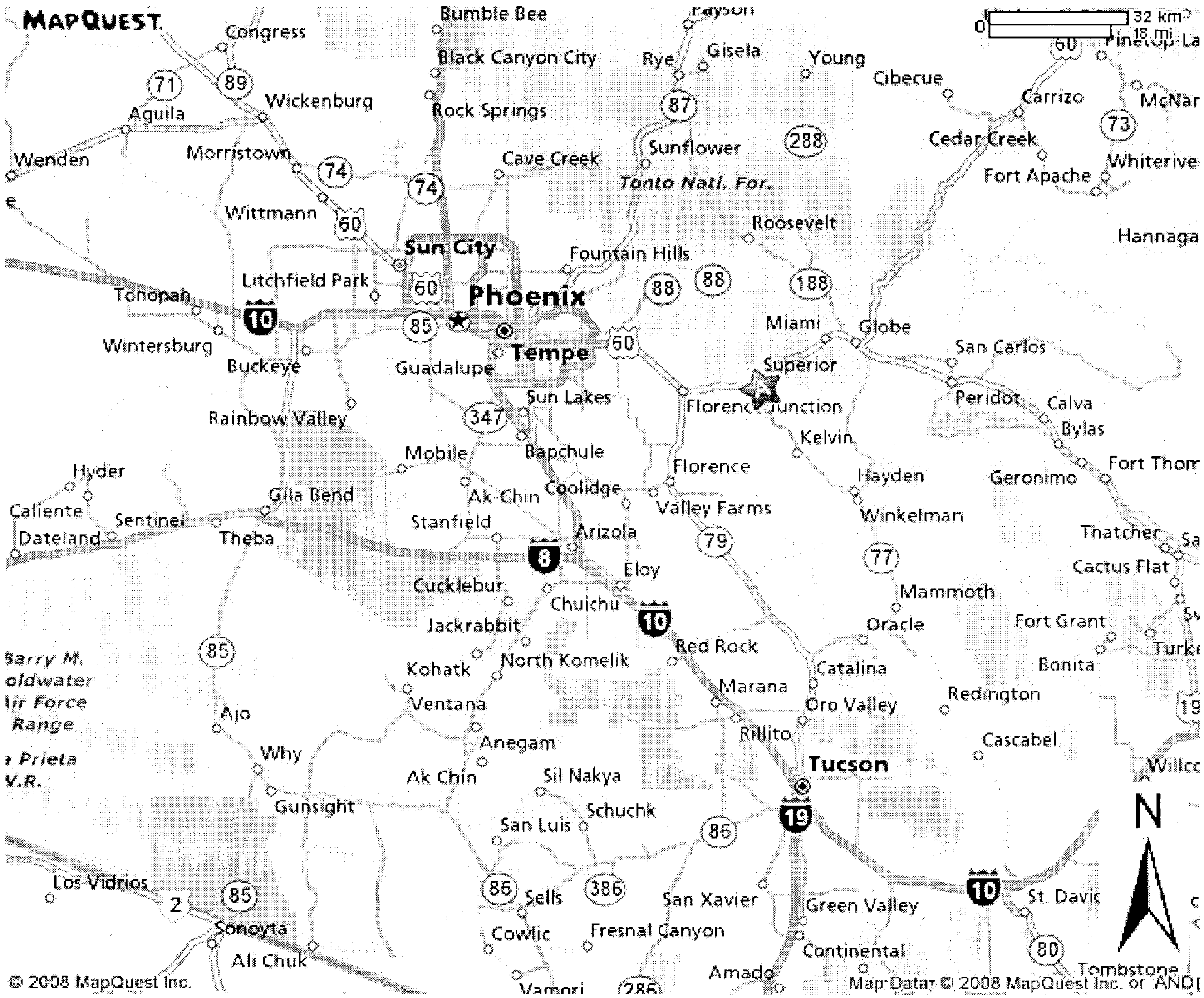

Figure 1.1 Map showing the location of the Resolution Mine in Pinal County, Arizona.

The Resolution facility is located in the Sonoran Desert. Temperatures peak over 100 °F in the summer but cool considerably at night. Winter days are usually mild with night temperatures just above freezing in the lower elevations. Snowfall is rare, and most rainfall occurs between July and October. Cooler temperatures are found at higher elevations in the area.

1.2.2 Facility Description

The Resolution facility includes an underground mine located about three miles east of Superior and the former magma mine located in Superior. The underground mine is still in the prefeasibility phase. The work scheduled for the next several years also includes dewatering the former Magma mine.

Mine plans have not been developed for the Resolution facility. Consequently a description of operations is not available. Emissions from the facility, however, are expected to consist primarily of particulate matter generated from the ore processing operations that take place outside the mine and from ventilation of operations in the underground mine; and gaseous emissions from fuel combustion sources. All emissions are anticipated to have low level release elevations, less than 100 feet above ground.

1.2.3 Monitoring Site Selection

Resolution Copper Company previously operated two 10-meter meteorological towers (with wind speed, wind direction, temperature, solar radiation, relative humidity, barometric pressure, precipitation, and evaporation) at the sites shown in Figure 1.2. The new meteorological systems represent upgrades with additional instruments, and are designed to collect the parameters necessary to more accurately predict the dispersion of emissions from the point of origin.

Since operations at the Resolution Mine will be conducted at two distinctly different areas with different terrain, separate monitoring sites have been established at each area. The KC1 site is located near the #9 Shaft where mining will take place, and will collect data representative of an elevated and mountainous region. The KC2 site is located near the base of elevated terrain in the relatively flat region around the town of Superior.

The meteorological monitoring locations are shown in Figures 1.2 and 1.3. The proposed monitoring sites should capture the localized diurnal wind patterns that transport pollutants in the immediate area, while also capturing the regional wind patterns.

The coordinates of the KC1 monitoring site are 33°18'16.81" N, 111°4'3.61" W (UTM 493714E, 3685076N, Zone 12S, NAD83), and elevation of 4,160 feet. The KC1 monitoring site is located at the perimeter of the #9 Mine Shaft activity. Photographs showing monitoring systems and panoramic views of the terrain surrounding the KC1 site are presented in Figures 1.4 and 1.5.

The coordinates of the KC2 monitoring site are at 33°17'58.12" N, 111°6'7.01" W (UTM 490506E, 3684491N, Zone 12S, NAD83), and elevation of 2,920 feet. Photographs showing panoramic views of the terrain surrounding the KC2 site are presented in Figures 1.6 and 1.7.

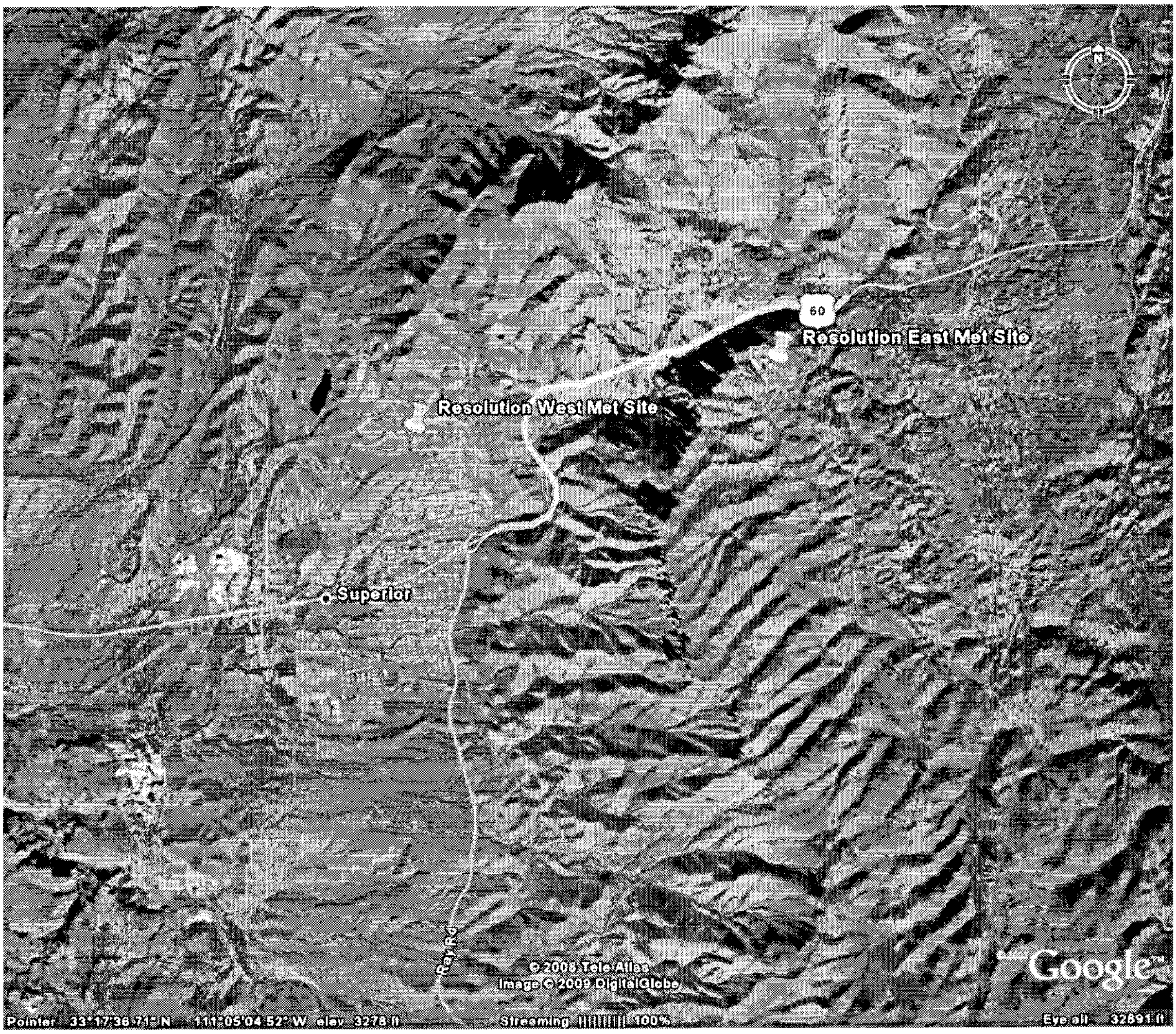

Figure 1.2 Aerial Photo showing the location of the meteorological monitoring sites (East and West) in relation to the surrounding area.

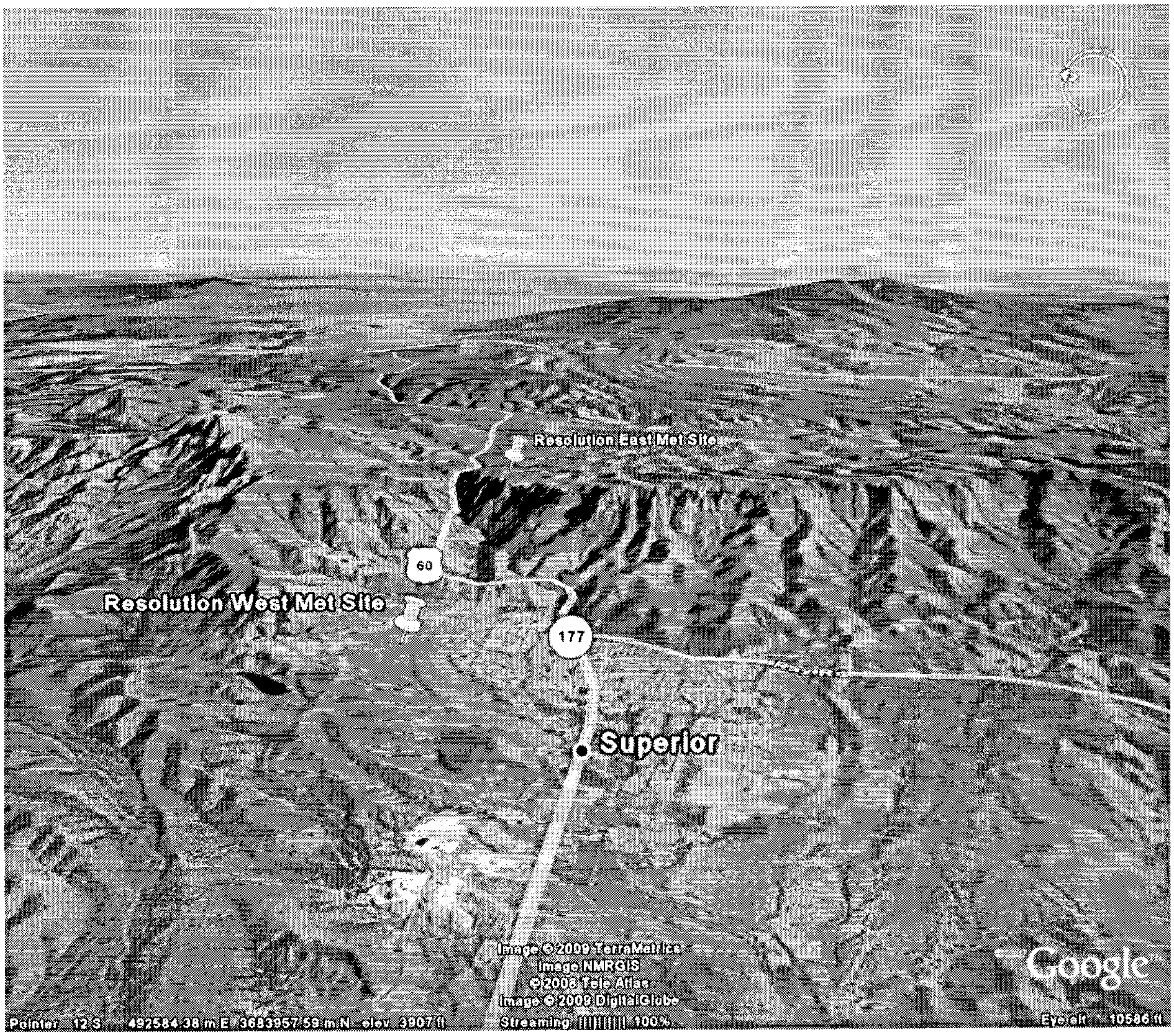

Figure 1.3 Three-dimensional photographic view showing the locations of the meteorological monitoring sites in relation to the plant and # 9 Shaft.

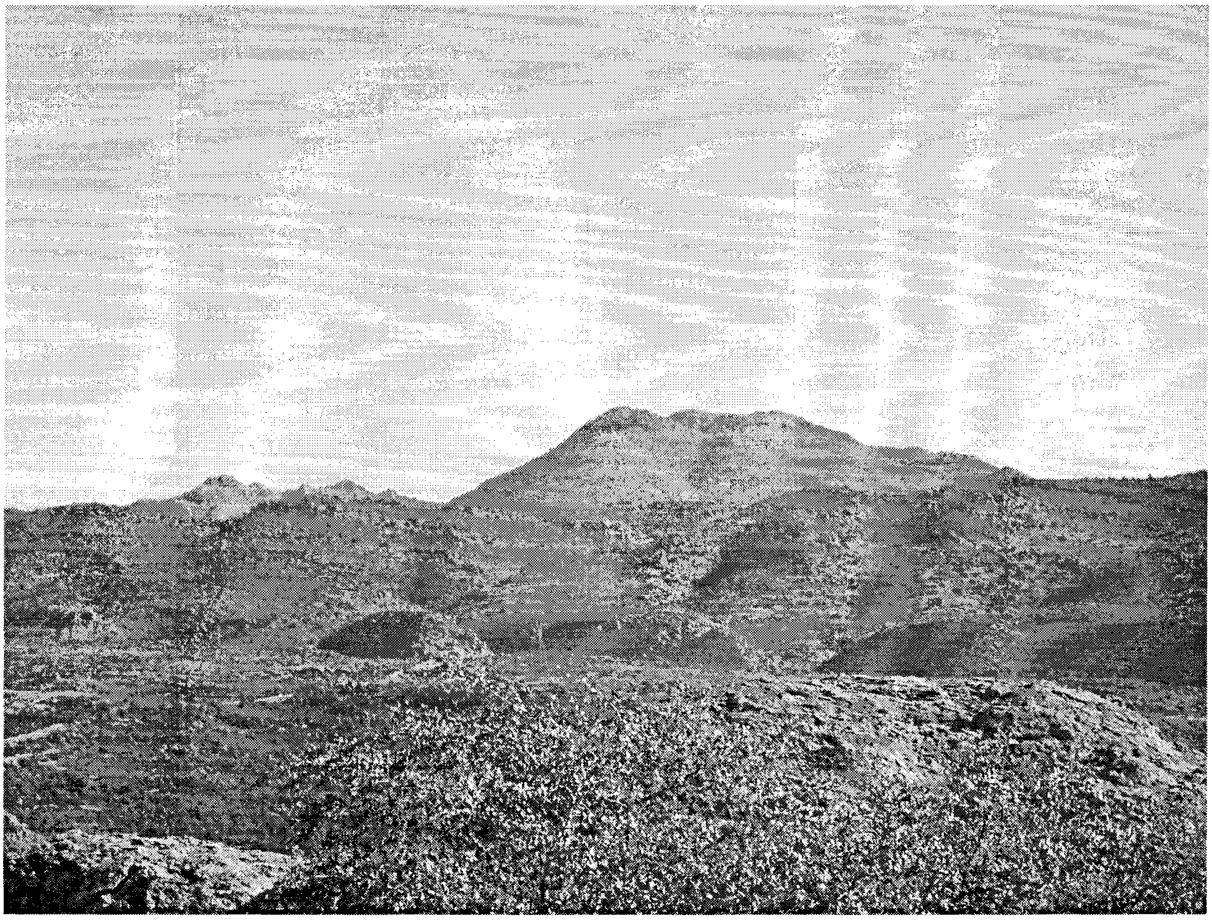

Figure 1.4 Photograph from monitoring site KC1 showing terrain to the East.

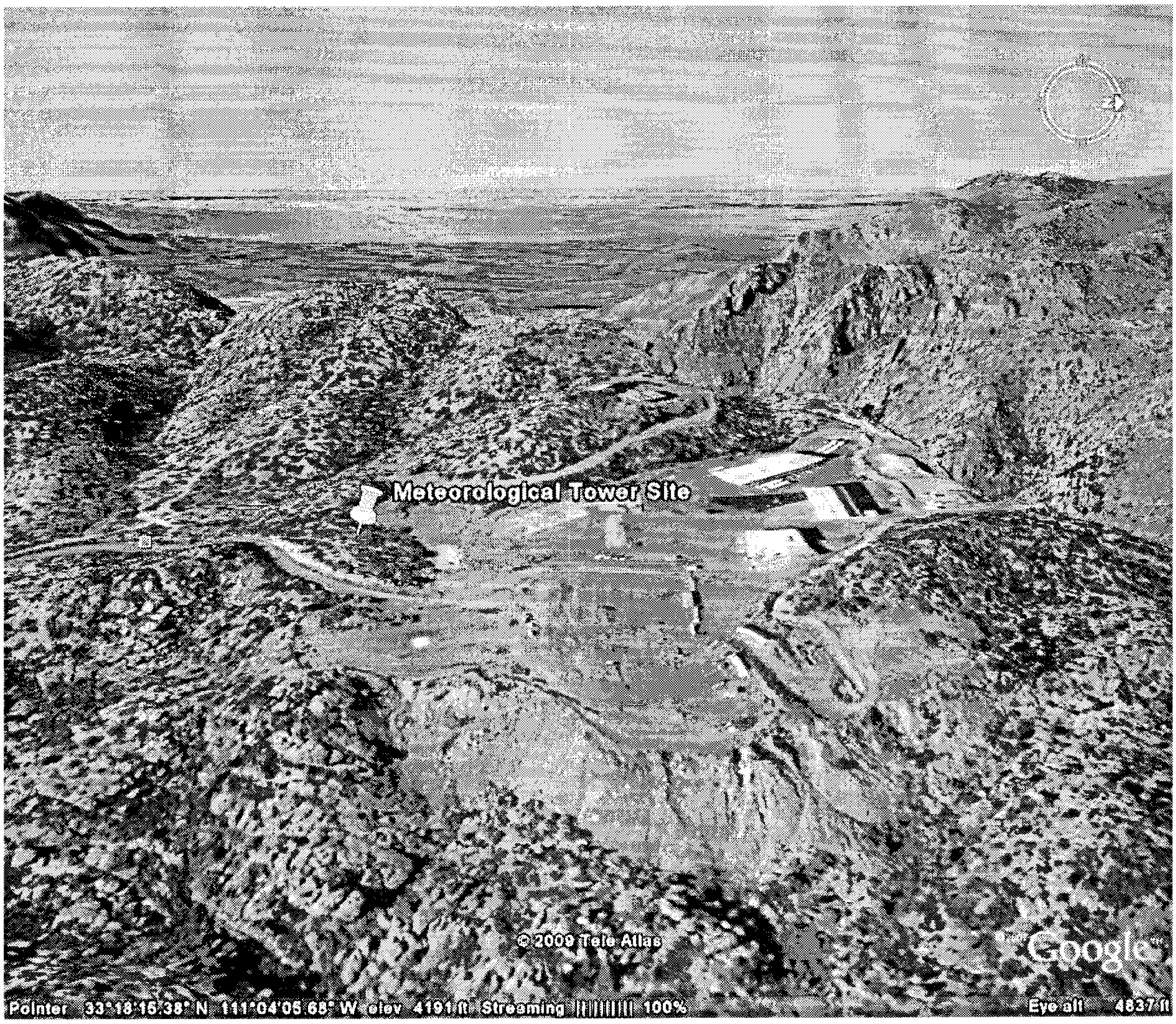

Figure 1.5 Photograph from monitoring site KC1 showing terrain to the West.

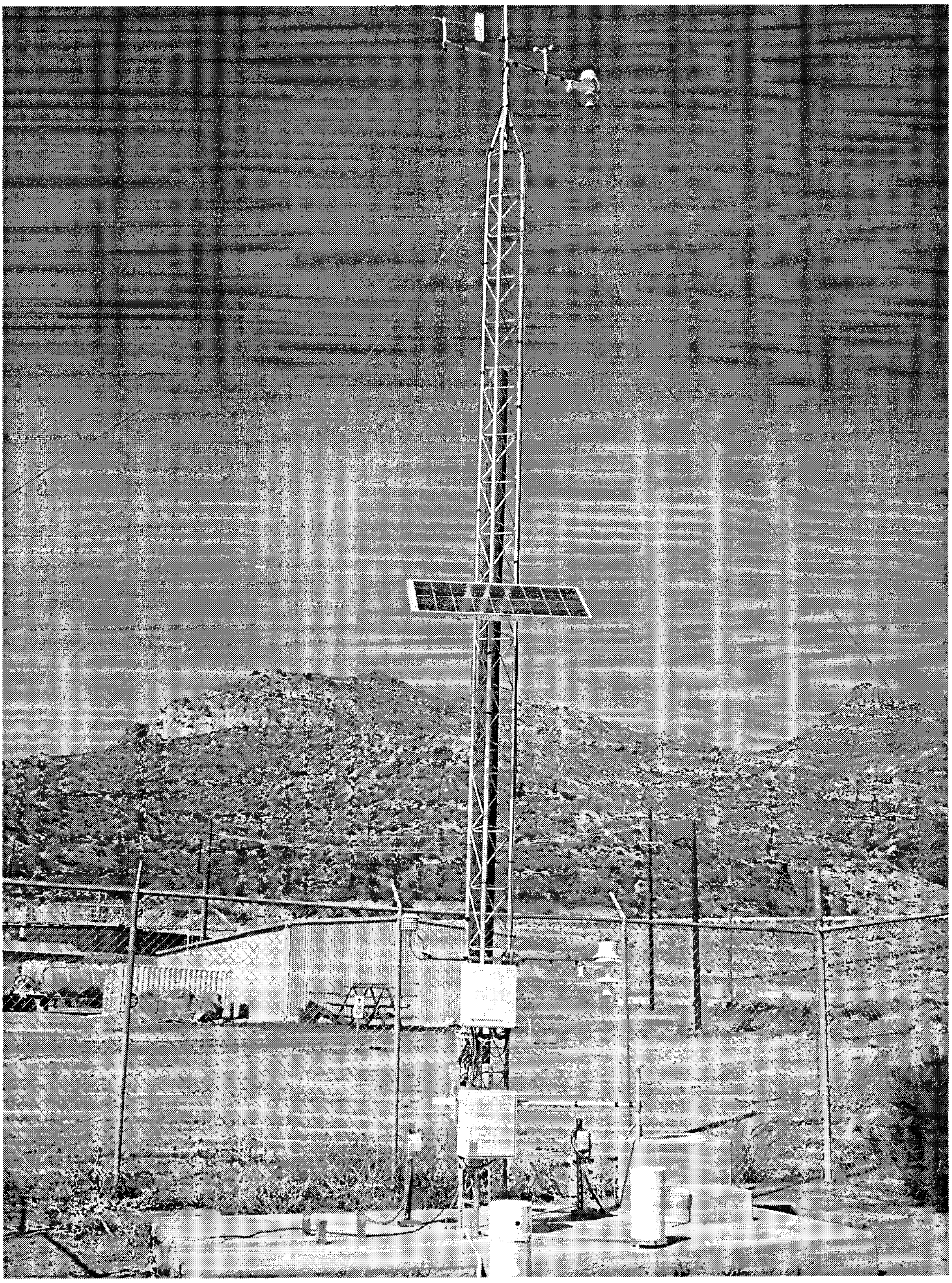

Figure 1.6 Photograph from monitoring site KC2 showing terrain to the North.

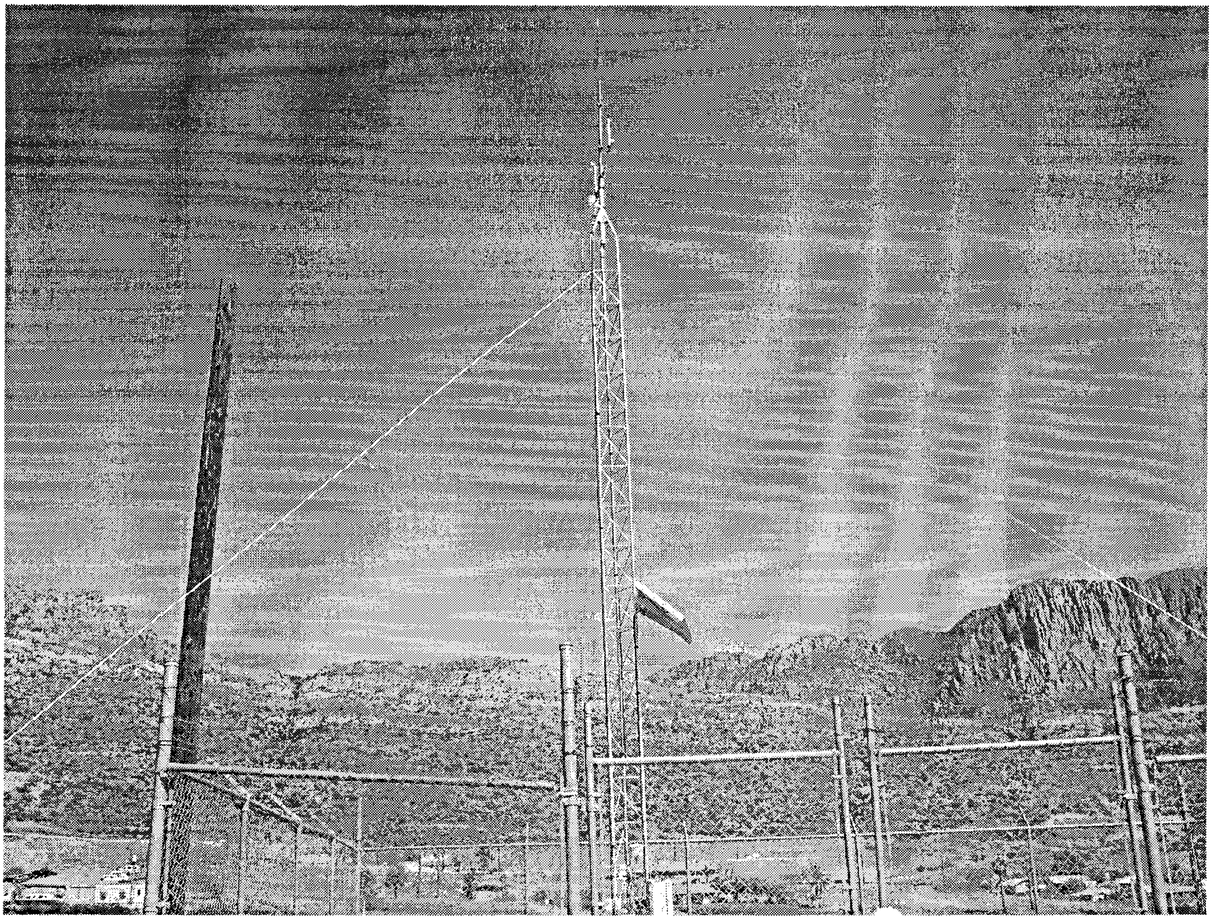

Figure 1.7 Photograph from monitoring site KC2 showing terrain to the East.

1.3 PROJECT ORGANIZATION AND RESPONSIBILITY

The meteorological monitoring program will be operated by Applied Environmental Consultants, Inc. (AEC), 1553 W. Elna Rae, Tempe, Arizona, 85281 with assistance by Resolution personnel in downloading and forwarding data to AEC. The individuals involved in the project and their responsibilities in assuring the quality of the measurements are listed in Table 1.1.

1.4 OBJECTIVES OF MONITORING AND QUALITY ASSURANCE PROGRAMS

The objectives of the monitoring and quality assurance (QA) programs are to provide representative meteorological measurements for use in conducting air impact analyses for future operations. All elements of the monitoring program conform to the guidelines established in: (a) *Meteorological Monitoring Guidance for Regulatory Modeling Application*, EPA-454/R-99-005, Feb 2000 and (b) *Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD)*, EPA-450/4-87-007, May 1987, (*PSD Monitoring Guidelines*). Specific quality control limits for the meteorological instruments are presented in Table 1.2.

1.5 DOCUMENTATION AND TECHNICAL REVIEW

1.5.1 Documentation

All procedures for implementing the monitoring program follow AEC's Standard Operating Procedures (SOPs). These procedures are referenced throughout this document. The applicable SOPs for the monitoring program are listed in Table 1.3 and copies of the complete SOPs are included in Appendix A.

Upon each site visit, an entry is made into the site log book at the meteorological site. Each entry describes the conditions of the site as found, and any equipment servicing, maintenance, or repair that may have been conducted. Each entry is signed and dated.

1.5.2 Technical Review

Audits and calculations are selectively reviewed by the Quality Assurance Officer to ensure that:

- the quality assurance procedures have been followed;
- the performance of all equipment falls within the limits specified in this document;
- all calculations have been properly performed; and
- all data are reasonable and technically consistent.

Table 1.1 Project Personnel and Responsibilities

Name	Entity	Title	Responsibilities
Bruce Marsh	Resolution Copper	Project Manager	Project Manager responsible for implementation of the project.
Louis C. Thanukos, Ph.D.	Applied Environmental Consultants	Principal Scientist	1. Coordination with Resolution to ensure that project goals are fulfilled. 2. Project Manager for Applied Environmental Consultants 3. Ensure that independent audits are performed.
Thitipong Chindavijak	Applied Environmental Consultants	Scientist II	1. Perform six-month meteorological performance audits. 2. Verify that QA procedures are followed. 3. Follow-up audit results and ensure that corrective action is implemented. 4. Certify the integrity of measurements and operations.
Jonathan Marrufo	Applied Environmental Consultants	Technician	1. Ensure field operation and maintenance of all measurement equipment. 2. Initiate corrective action for all measurement equipment when audits indicate malfunctions.
Mike Sonenberg	Applied Environmental Consultants	Scientist/Permit Engineer	1. Reduction and quality control of all data. 2. Routine on-site data collection.
Site Technicians	Resolution Copper	Technician	1. Perform meteorological data collection. 2. Forward all data to AEC in timely manner. 3. Perform routine site checks to ensure site security and proper equipment operation and inform AEC of any problems.

Table 1.2 Quality Control Limits for the Meteorological Monitoring

Parameter	Reference	Experimental Conditions	Accuracy	Completeness (Quarterly Basis)
Wind Speed	EPA-454/R-99-005 and EPA Quality Assurance Handbook, Volume 4	Physical Challenge	Response: ± 0.25 m/s (at horizontal speeds < 5.0 m/s, all vertical speeds) ≤5.0% (at speeds > 5.0 m/s) Starting Torque:* 0.30 gm-cm	90%
Wind Direction	EPA-454/R-99-005 and EPA Quality Assurance Handbook, Volume 4	Physical Challenge	Response: ± 3.0° Starting Torque:* 9.0 gm-cm Vane Alignment: ± 5.0°	90%
Temperature	EPA-454/R-99-005 and EPA Quality Assurance Handbook, Volume 4	Ice Bath, Ambient Bath, and Warm Bath Physical Challenge	± 0.5°C	90%
Differential Temperature	EPA-454/R-99-005 and EPA Quality Assurance Handbook, Volume 4	Ice Bath, Ambient Bath, and Warm Bath Physical Challenge	± 0.05°C for Probe to Stds. Comparison ± 0.1°C for Probe to Probe Comparison	90%
Solar Radiation	EPA-454/R-99-005 and EPA Quality Assurance Handbook, Volume 4	Comparison with calibrated pyranometer	± 5% error	90%
Precipitation	EPA-454/R-99-005 and EPA Quality Assurance Handbook, Volume 4	Introduction of known amounts of water	± 10% of recorded value	90%
Relative Humidity	EPA-454/R-99-005 and EPA Quality Assurance Handbook, Volume 4	Collocated Transfer Standard	± 7% RH	90%
Evaporation	National Weather Service Observing Handbook No. 2, Section 5 (1989)	Introduction of known amounts of water	± 10% of recorded value	90%
Barometric Pressure	EPA-454/R-99-005 and EPA Quality Assurance Handbook, Volume 4	Comparison with calibrated barometer	± 3 mb	90%

* The starting torques listed are the maximum allowable to maintain the starting threshold of < 0.5 m/s.

Table 1.3 Applicable AEC Standard Operating Procedures			
Number	Revision	Date	Title
200	1	September 1, 1991	Operation of Campbell Scientific Dataloggers
214.1	0	December 4, 2008	Operation of Campbell Scientific CS215 Temperature and Relative Humidity Sensors
221	3	November 27, 1994	Operation of Met One 024A Wind Direction Sensors
220	3	November 27, 1994	Operation of Met One 014A Wind Speed Sensors
240.1	0	December 4, 2008	Operation of Model LI200X Pyranometers
250	0	June 1, 1999	Operation of Tipping Bucket Rain Gauges
270	0	April 13, 2009	Operation of NovaLynx 255-100 Evaporation Pan
260	0	August 22, 2008	Operation of Setra 278 Barometric Pressure Sensors
212	0	November 7, 1995	Operation of RM Young Models 41342/43347 Platinum Temperature Probes

2. METEOROLOGICAL MEASUREMENT PROCEDURES AND QUALITY ASSURANCE

2.1 MEASUREMENT PROCEDURES

Emissions from the Resolution Mine are anticipated to occur at relatively low levels, less than 100 feet above ground. Consequently, meteorological measurements collected at 10 meters should capture conditions that will affect the transport and dispersion of near-ground level emission releases. Meteorological measurements include ambient temperature at 2 meters, differential temperature between 2 meters and 10 meters, horizontal wind speed, wind direction, the standard deviation of the horizontal wind direction (sigma theta), solar radiation, precipitation, evaporation, relative humidity, and barometric pressure.

The meteorological instrumentation that are used at the KC1 and KC2 sites are listed in Table 2.1. Each site has identical instruments. All meteorological instruments comply with the EPA criteria outlined in the *PSD Monitoring Guidelines*. The sensor specifications and EPA criteria are listed in Table 2.2.

Measurement procedures are in accordance with the *PSD Monitoring Guidelines* and AEC SOPs. Standard operating procedures include:

- site visits at a minimum of twice per month;
- visual observation during each site visit of the meteorological equipment, sensor responses, and battery voltage;
- data reduction, screening and validation twice per month to allow quick response to potential problems; and
- independent performance audits once every six months.

Table 2.1 Listing of Meteorological Equipment at KC1 and KC2

Instrument Description	Parameter Measured
Campbell Scientific CR1000 Data Logger with Compact Flash Module and Enclosure	Data Acquisition and Storage
Met One 024A Wind Direction Sensor	Wind Direction
Met One 014A Wind Speed Sensor	Horizontal Wind Speed
RM Young 43347 Differential Temperature Sensor with Radiation Shield	Differential Temperature
Li-Cor LI-200 Silicon Pyranometer	Solar Radiation
Campbell Scientific CS215 Relative Humidity Sensor	Relative Humidity and Temperature
Setra 278 Barometric Pressure Sensor	Barometric Pressure
Met One 370 Precipitation Gauge	Precipitation
NovaLynx 255-100 Evaporation Pan	Evaporation

Table 2.2 Meteorological Instrument Specifications and EPA Acceptance Criteria

Parameter	EPA Criteria	Instrument Specification
Solar Radiation		
Accuracy	± 5%	± 5% max, ± 3% typical
Time Constant	10 µs	5 s
Dew Point (Relative Humidity)		
Accuracy (non-fog areas)	± 1.5 °C	± 0.8 °C
Time Constant (temp)	N/A	120 s
Time Constant (RH)	N/A	< 10 s
Overall Time Constant	≤ 30 min	< 30 min[1]
Precipitation		
Accuracy	± 10%	± 3.5%
Barometric Pressure		
Accuracy	± 10 hPa (1%)	± 2 hPa
Ambient Temperature		
Accuracy	± 0.5 °C	± 0.3 °C
Time Constant	≤ 1 minute	30-60 s @ 5 m/s wind speed
Differential Temperature		
Accuracy	± 0.1 °C	± 0.05 °C
Time Constant	≤ 1 minute	42 s
Wind Speed		
Starting Threshold	≤ 0.5 m/s	0.4 m/s
Accuracy	± 5%	± 0.5% fs
Distance Constant	≤ 5m	2.1m
Wind Direction		
Starting Threshold	≤ 0.5 m/s	0.5 m/s
Accuracy	$\pm 5.0^{o}$	$\pm 3.0^{o}$
Delay Distance	≤ 5m	1.2m
Damping Ratio	0.4 - 0.65	0.45
Evaporation		
Accuracy	± 10%	± 3.5%

[1] Dew Point is a function of Temperature and RH. As such, the time constant for Dew Point is dependent on the time constants of the Temperature sensor (120 s) and the RH sensor (<10 s).

[2] Criteria for Evaporation was taken from National Weather Service Observing Handbook No. 2, Section 5 (1989).

The monitoring system meets all instrument siting criteria outlined in EPA's *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (EPA-454/R-99-005) except the wind sensor locations at KC1. The specific siting criteria and the instrument compliance status with these criteria are as follows:

- *Wind Instruments*: the standard exposure height of wind instruments over level, open terrain is 10 m above the ground. Open terrain is defined as an area where the distance between the instrument and any obstruction is at least ten times the height of that obstruction.

  The KC1 site is located in very rugged terrain. Some elevated terrain features located approximately a quarter mile distant were at a distance that was only 8 times the height difference between the instruments and the terrain elevation. Because of the sloping terrain, however, a site that could meet the "ten times the height" criteria and still capture the wind conditions at the site was not practical. A photograph of KC1 showing the location of the meteorological tower and the complexity of the terrain is presented in Figure 1.5.

- *Temperature and Humidity Sensors*: ambient temperature should be measured at 2 m and the sensor should be located over an open area of at least 9 m in diameter, and should be located at a distance of at least four times the height of any nearby obstruction. The surface should be covered by short grass, or, where grass does not grow, the natural earth surface. Instruments should be protected from thermal radiation (from the earth, sun, sky, and any surrounding objects) and adequately ventilated using aspirated shields. The Resolution ambient and differential temperature sensors meet these criteria.

- *Delta-T Sensors*: probe placement for temperature difference measurements (delta-T) depend on the application. Recommended heights for temperature gradient measurements in the surface layer are 2 m and 10 m. The Resolution differential temperature sensors meet these criteria.

- *Precipitation*: a rain gauge should be sited on level ground so that the mouth is horizontal and open to the sky. The underlying surface should be covered with short grass or gravel. The height of the opening should be as low as possible, but high enough to avoid splashing in from the ground (minimum 30 cm). The Resolution rain gauges meet these criteria.

- *Pressure:* manufacturer's siting guidance should be used. The placement of the Resolution barometers meet the manufacturers siting criteria.

- *Radiation:* pyranometers should be located with an unrestricted view of the sky in all directions during all seasons, with the lowest solar elevation angle possible. A tall platform or rooftop is desirable. Obstructions that cast a shadow on the sensor should be avoided. Light colored walls and artificial sources of radiation should also be avoided. The Resolution pyranometers meet these criteria.

- *Evaporation:* There is no guidance for evaporation pans in EPA's *Meteorological Monitoring Guidance for Regulatory Modeling Applications.* Therefore, the manufacturer's siting guidance is used.

2.1.1 System Operation and Maintenance

The meteorological monitoring system is operated in accordance with AEC SOPs which follow the guidelines specified in the *EPA Quality Assurance Handbook*, *Volume IV.* Periodic maintenance will follow the schedule recommended by the manufacturer and include:

- replacement of flange (wind speed) and vertical shaft (wind direction) bearings at least once per year, or more frequently if needed;
- reconditioning of the wind direction potentiometer as needed; and
- cleaning of the temperature sensor radiation shield as needed at least once every six months.

2.2 POWER SUPPLY

Power requirements for the entire system have been determined and a solar power system has been designed to meet the demand. The system includes a 70 watt solar panel and three 110AH, 12 volt batteries and a 10 amp charge control. The system provides the necessary power for the meteorological instruments.

2.3 CALIBRATION PROCEDURES

The meteorological sensors are fully calibrated by the manufacturer at the time of purchase. Continued sensor stability is assessed through bi-monthly data validation techniques and through independent performance audits.

2.4 PERFORMANCE AND SYSTEM AUDITS

The monitoring program includes independent six month performance audits that employ physical challenges to sensor performance as described in the *EPA Quality Assurance Handbook*, *Volume IV.* An initial audit is performed within 30-days following installation of the site.

Audit reports are reviewed by the project Quality Assurance Officer and the Technician. Corrective action will be implemented by the Technician in consultation with the Quality Assurance Officer if necessary.

2.5 DATA REDUCTION, QUALITY ASSURANCE, VALIDATION AND REPORTING

2.5.1 Data Reduction

Data are gathered from the on-site datalogger and processed twice per month in order to allow quality control checks to be effective. Data are reduced by the on-site datalogger into 15 minute and hourly averages. Wind direction vectors and values of sigma theta are calculated using the Yamartino method as described in the EPA's *Meteorological Monitoring Guidance for Regulatory Modeling Applications.*

2.5.2 Routine Quality Assurance Procedures

Quality assurance begins with the site visits twice per month and documentation in the site log book of the condition of the meteorological monitoring system. Any system maintenance or repair will also be documented in the site log book. Data screening and validation comprise the largest component of the routine quality assurance procedures. Any discrepancies in the data will be brought to the attention of the QA Officer, and corrective action will be implemented.

2.5.3 Data Validation

The data validation procedures begin with the field technician's site visits. Any instrument peculiarities or failures will be reported to the QA Officer and the affected data will be examined. The validity of all data is regularly evaluated. Individual meteorological observations are screened according to the criteria listed in Table 2.3. Any data outside of the quality control limits will be investigated by the Technician and the QA Officer for possible invalidation. The final determination on validity will be made after comparing the suspect data with other data to determine whether the data are invalid or whether an unusual meteorological event occurred.

2.5.4 Data Reporting

Hourly averages for temperature, differential temperature, wind direction, wind speed, sigma theta, relative humidity, precipitation, pressure, and radiation are segregated by month for summary reporting. Frequency distributions of wind speed/direction along with a quarterly wind rose will be generated for monthly and quarterly reporting. The total number of valid observations, total possible observations, and percent data recovery will also be reported for each meteorological variable.

Upon completion of the monitoring project, a complete report of the monitoring activities, monitoring results, audit results, all quality assurance documentation, and a technical evaluation of the data will be prepared.

Table 2.3 Meteorological Data Screening Criteria

Meteorological Variable	Screening Criteria - Flag the data if the value:
Ambient Temperature	- is greater than the local historical monthly maximum - is less than the local historical monthly minimum - is greater than a 5 °C change from the previous hour - does not vary by more than 0.5 °C for 12 consecutive hours
Differential Temperature	- is greater than 0.1 °C/m during the daytime - is less than 0.1 °C/m during the nighttime - is greater than a 5 °C change from the previous hour
Wind Speed	- is less than zero or greater than 25 m/s - does not vary by more than 0.1 m/s for 3 consecutive hours - does not vary by more than 0.5 m/s for 12 consecutive hours
Wind Direction	- is less than 0° or greater than 360° - does not vary by more than 1° for 3 consecutive hours - does not vary by more than 10° for 18 consecutive hours
Sigma Theta	- is less than 0° or greater than 90°
Dew Point Temperature	- is greater than the ambient temperature for the given time period - is greater than a 5 °C change from the previous hour - does not vary by more than 0.5 °C for 12 consecutive hours - equals the ambient temperature for 12 consecutive hours
Precipitation	- is greater than 1 inch in one hour - is greater than 3 inches in 24 hours
Pressure	- is greater than 1060 mb (sea level) - is less than 940 mb (sea level) (the above values can be adjusted for other elevations)
Radiation	- is greater than zero at night - is greater than the maximum possible for the date and latitude
Evaporation	- is less than 2 inches in one month - is greater than 16 inches in one month

APPENDIX A

APPLICABLE AEC STANDARD OPERATING PROCEDURES

STANDARD OPERATING PROCEDURE
Applied Environmental Consultants, Inc.

Number: 200

Title: Operation of Campbell Scientific Dataloggers

Date: September 1, 1991

Approvals

Author(s)		date: 9-1-91
		date:
QA Officer		date: 9-1-91
Principal Scientist		date: 9-1-91

Revisions

Revision #	Date	Changes	Authorization

1.0 INTRODUCTION

This document describes the standard operating procedures for the use of Campbell Scientific dataloggers. Since the proper use of the dataloggers is complicated, this document will not provide all of the information necessary to operate them. Instead, the user is directed to the datalogger manual for detailed instructions on programming and general use. This SOP highlights the general procedures to be followed when using the Campbell CR21X or CR10 dataloggers in field operations.

2.0 INSTALLATION AND CALIBRATION

2.1 Installation

The installation of the datalogger is highly dependent upon the individual site characteristics and the goal of the monitoring program. The following points must be considered in every monitoring program.

1. The datalogger must be wired to a reliable earth ground. This connection provides the only protection available against the datalogger and the sensors taking a direct lighting strike. It also helps eliminate ground potential differences between the datalogger and the sensors (as long as the sensors are grounded properly).

2. The shield or drain wires of all sensors should be grounded at the same place as the datalogger ground to prevent ground potential differences which would affect sensor readings.

3. The datalogger and related peripherals must be placed in a weatherproof enclosure that will minimize moisture contact with the datalogger. If necessary, place packets of desiccant in the enclosure with the datalogger. When using rechargeable lead-acid batteries as a datalogger power source, be careful not to completely seal the datalogger enclosure. Lead-acid batteries give off hydrogen gas which could accumulate in a sealed enclosure and could lead to an explosion hazard.

4. Provide the datalogger with a reliable source of 12 VDC power. This may be accomplished in several ways depending upon the site characteristics. If lead-acid batteries are used, be sure to provide a stable charging source (AC power or solar panel) and check the battery voltage frequently. If alkaline batteries are used, schedule frequent site visits for battery changes. If AC line voltage alone is used, be aware that power spikes and/or failures will cause the CR21X to lose

its program and thus the data. More information on power sources can be found in the datalogger manual.

2.2 Calibration

The Campbell dataloggers are very stable measurement systems. Periodic calibrations are not required, and are beyond the capabilities of AEC. Datalogger calibrations should be made by Campbell Scientific, Inc..

3.0 OPERATION

The Campbell dataloggers are automated data collection systems. There are no routine operation procedures aside from proper installation and maintenance. The following system checks, however, should be performed during each site visit.

1. Make an entry in the site log book. This entry should include the technician's initials, the date, the time, and any other pertinent information about the site condition.

2. Verify that the datalogger is clean and dry, and that all sensor connections are tight. Change desiccant packages if necessary.

3. Monitor the sensor output and verify that the readings "make sense".

4. Check the datalogger battery voltage (if used) and verify that the power supply system is operating properly.

4.0 ROUTINE MAINTENANCE

Routine maintenance of Campbell dataloggers is minimal, but necessary for proper operation of the datalogger. Routine maintenance should include:

1. All periodic system checks as described in section 3.0 above.

2. Replacement of batteries on a regular interval if needed.

3. Cleaning of the solar panel (if used) at least once every two months; more frequently if needed.

4. Cleaning of the face of the datalogger (CR21X only) to remove dust and dirt from the display and keyboard. Use only dry air, or a damp, soft, cloth. Be sure not to use too much water, as water will run beneath the keyboard and damage the circuitry.

5. If moisture buildup is noticed around the datalogger, replace the desiccant packages inside the datalogger case (CR21X) or in the enclosure (CR10).

5.0 DOCUMENTATION

Use of Campbell dataloggers, requires proper documentation of all procedures performed with the datalogger and on the datalogger. Minimum documentation required shall include:

1. A site log in which all activities at the site are recorded.

2. Complete documentation of any factory service or calibrations.

3. Complete documentation of all routine maintenance performed on the datalogger.

4. Complete documentation of the datalogger program and accompanying multipliers and sampling intervals.

Additional documentation may be required by the Quality Assurance Plan.

STANDARD OPERATING PROCEDURE
Applied Environmental Consultants, Inc.

Number: 214.1

Title: Operation of Campbell Scientific Model CS215 Temperature and RH Probe

Date: December 4, 2008

Approvals

Author(s) ______________________ date: 12/4/08

______________________ date: ______

QA Officer ______________________ date: 12/4/08

Principal Scientist ______________________ date: 12-04-08

Revisions

Revision #	Date	Changes	Authorization

1.0 INTRODUCTION

This document describes the standard operating procedures for the use of the Campbell Scientific Model CS215 Temperature and Relative Humidity Probe.

2.0 INSTALLATION, CALIBRATION AND PERFORMANCE AUDITS

2.1 Installation

The installation of the sensor should follow the guidelines specified in the project Quality Assurance Plan (eg. PSD siting criteria). It is assumed that the sensor will be connected to a Campbell Scientific CR21X, CR10, CR1000 or CR3000 datalogger. Other data acquisition systems will require different installation procedures.

2.1.1 Electrical Connections

The CS215 probe utilizes a single chip element that incorporates both a temperature and RH sensor. Each element is individually calibrated with the calibration stored on the chip. Low power electronics within the CS215 controls the measurement made by the sensor element, applies temperature and linearization corrections to the readings, and presents the data via an SDI-12 compatible interface to a datalogger. The following are the electrical connections used with this sensor.

Red Wire -	12V
White Wire -	Power Ground
Black Wire -	Power Ground
Green Wire -	SDI-12 Signal
Clear Wire -	Shield

2.1.2 Datalogger Programming

The following is an example CRBasic program for a CR3000 datalogger measuring one sensor every 10 seconds with data stored every 60 minutes. The instructions are different if other dataloggers are used.

```
'Declare Variables and Units to be used.
Public TRHData(2)

Alias TRHData(1)=AirTC
Alias TRHData(2)=RH

Units AirTC=Deg C
Units RH=%

'Define Data Tables to store data.
DataTable(Table1,True,-1)
        DataInterval(0,60,Min,10)
        Average(1,AirTC,FP2,False)
        Sample(1,RH,FP2)
EndTable

'Main Program
BeginProg
Scan(10,Sec,1,0)
        SDI12Recorder(AirRC,7,"0","M!",1,0)
        CallTable(Table1)
        NextScan
EndProg
```

2.1.3 Mounting

The CS215 sensor should be located over an open, level area at least 9 meters in diameter. The sensors should be located at a distance of at least four times the height of any nearby obstruction, and at least 30 meters from large paved areas. It is important that a proper radiation shield is provided to prevent solar radiation loading on the probe that would cause inflated temperature readings. A mechanically aspirated radiation shield is recommended. Any shelter should be adequately ventilated to inhibit heat buildup.

2.2 Calibration and Performance Audits

The life of the humidity chip element is quoted as many years with a typical drift of less than 1% per year when used in "clean" environments. It is recommended that the sensor element be replaced annually. Replacement effectively brings the probe back to a factory calibration state both for the temperature and RH. Therefore, it is not necessary to perform any calibrations on the probe. Performance audits, however, should be performed upon initial installation of the sensor and at a minimum of once every six months or more frequently if so specified in the project Quality Assurance Plan. The following subsection describes the procedures for conducting a performance audit. These procedures are compatible with those described in the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV, Meteorological Measurements* (March 1995).

2.2.1 Performance Audits

Performance audits on the CS215 probe involve collocated transfer standard. The following items are necessary to conduct a performance audit:

To conduct a performance audit with a digital psychrometer, perform the following steps.

1. Reinstall the primary sensor on its mounting platform.

2. Locate the psychrometer so that it will experience similar ambient conditions as the primary sensor.

3. Record the wet/dry-bulb temperature and relative humidity readings from the psychrometer to obtain measurements of the dew point temperatures.

4. Record temperature and relative humidity readings from the CS215 humidity field sensor, along with the local barometric pressure to calculate the equivalent dew point temperature.

5. Calculate the mean difference between the paired observations as:

$$\overline{d} = \frac{1}{n}\sum_{i=1}^{n}(T_{PS_i} - T_{CS_i})$$

where: n = the number of paired observations,
T_{PS} = the dew point temperature measured by the primary sensor, and
T_{CS} = the dew point temperature measured by the collocated sensor

6. Compare the mean difference in equivalent dew point temperatures to the quality control limits specified in the project Quality Assurance Plan to determine if the sensor is operating within acceptable limits.

3.0 PERIODIC MAINTENANCE

The following procedures should be followed to ensure proper sensor operation:

1. Every site visit, verify proper sensor output on the datalogger, and visually inspect the sensor, its radiation shield, and wires for any signs of damage.

2. At least once every 6 months, inspect the sensor and conduct a performance audit as described in section 2.2.1 above.

4.0 DOCUMENTATION

It is necessary for proper sensor operation to maintain complete documentation on each sensor. Minimum documentation required shall be:

1. A site log in which all activities at the site are documented.
2. Complete documentation of all sensor performance audits, including raw data, collocated sensor specifications (if applicable), and results.
3. A complete record of all sensor maintenance.

Additional documentation may be required by the project Quality Assurance Plan.

STANDARD OPERATING PROCEDURE
Applied Environmental Consultants, Inc.

Number: 221

Title: Operation of Met-One Model 024A Wind Direction Sensors

Date: September 1, 1991

Approvals

Author(s)	[signature]	date: 9-1-91
		date:
QA Officer	[signature]	date: 9-1-91
Principal Scientist	[signature]	date: 9-1-91

Revisions

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2	3-3-92	Corrected equation # 2	[signature]
3	9-27-94	Renumbered document and added new sections (3.1.1, 3.1.2) to incorporate physical challenges. Revised audit form	[signature]

1.0 INTRODUCTION

This document describes the standard operating procedures for the use of the Met-One Model 024A Wind Speed Sensor.

2.0 INSTALLATION AND CALIBRATION

2.1 Installation

The installation of the sensor should follow the guidelines specified in the project Quality Assurance Plan (eg. PSD siting criteria). Specific installation procedures appear in the ensuing subsections. It is assumed that the sensor will be connected to a Campbell Scientific CR21X, or CR10 datalogger. Other data acquisition systems will require different installation procedures.

2.1.1 Initial Checkout

Before installing the sensor, check the following items:

1. Inspect the wind vane, and counterbalance to verify that there are no cracks or loose parts.

2. Check that the vane turns freely about the base, verifying smooth unimpeded operation.

3. Check all cabling for signs of wear or damage.

4. Verify that the sensor outputs one-half of full scale voltage while the shoulder screw is inserted. If it does not, then:

    a. loosen the two set screws on the side of the sensor head;

    b. poke a hole in the sticker on top of the sensor to expose the top of the potentiometer shaft;

    c. using a screwdriver, turn the shaft until one-half of full scale voltage is produced, then tighten the two set screws; and

    e. re-cover the hole in the top of the sensor.

5. Verify that the wind vane is balanced by performing the following:

    a. Remove the shoulder screw from the side of the wind vane;

b. lay the direction sensor on a table, on its side, with the rotating vane extending over the edge of the table, so that the vane can turn freely;

c. if the fin end and the counterbalance end are not balanced, loosen the set screw on the counterbalance and slide the counterbalance until the unit is balanced, then tighten the set screw.

2.1.2 Electrical Connections

The 024A sensor uses a potentiometer to vary resistance linearly from a high at 0 degrees to a low at 359 degrees. The sensor is read by the datalogger by providing it a precise excitation voltage, and then measuring the return voltage. The wind direction is then related to the return voltage by a linear relationship. The following are the electrical connections used with this sensor.

Black Wire -	Excitation Channel
Red Wire -	Single-ended Voltage Channel
White Wire -	Analog Ground (Ground on CR21X, AG on CR10)
Clear Wire -	Earth Ground (Ground on CR21X, G on CR10)

2.1.3 Datalogger Programming

The wind direction is sampled using the datalogger excite-delay-single-ended instruction. The offset for the instrument is zero, and the multiplier varies by instrument, and wire length. To determine the proper multiplier, start with a multiplier of 1.0, then follow the calibration instructions given in section 2.2. The following are sample program fragments which can be adapted for use with the 024A sensor.

CR21X Datalogger

Program Step	You Enter	Description
1	4	Excite-Delay-SE
	1	Repetitions
	14	Range Code (500 mV, fast)
	1	Input Channel#
	1	Excitation Channel
	2	Delay (.02 sec)
	1000	Excitation (mV)
	1	Storage Location
	1.0	Multiplier (**Calibrate in field**)
	0.0	Offset

CR10 Datalogger

Program Step	You Enter	Description
1	4	Excite-Delay-SE
	1	Repetitions
	14	Range Code (250 mV, fast)
	1	Input Channel#
	1	Excitation Channel
	2	Delay (.02 sec)
	500	Excitation (mV)
	1	Storage Location
	1.0	Multiplier (**Calibrate in field**)
	0.0	Offset

2.1.4 Mounting

Mount the sensor on an appropriate mount using an alignment orientation collar. Make sure that the sensor is perfectly level to ensure proper operation. The orientation of the sensor is the most critical component of the installation process. All effort should be made to orient the sensor to within ± 1 degree of TRUE north. To orient the sensor, perform the following steps:

1. From a topographic map or other reliable source, determine the magnetic declination for the site.

2. With an accurate compass, locate a position on the horizon which is directly TRUE north of the instrument tower. Do not forget to incorporate the magnetic declination in this process.

3. Make sure that the shoulder screw is installed on the wind direction sensor. This locks the sensor into a 180 degree orientation. Also ensure that the orientation collar is attached to the sensor.

4. Loosen the mounting screws on the orientation collar so that the entire sensor/collar assembly can be rotated.

5. With the counterbalance pointing at you, sight down the shaft of the wind vane and line the shaft up with the point on the horizon which represents TRUE north. Tighten the mounting screws.

6. Using the compass, determine the TRUE direction to at least three prominent objects (preferably in different quadrants). Write a description of these objects and

their TRUE directions in the site log book. These will later be used to verify proper sensor orientation and response.

2.2 Calibration

A calibration of the sensor is required upon initial installation, and at any time that performance audits indicate that the sensor is not operating properly. The following steps describe the procedures used to calibrate the sensor. Although the procedures are the same for both the CR21X datalogger and the CR10 datalogger, the excitation voltages vary. These differences are noted where they occur. The calibration procedure is best performed by two people, after the instrument has been installed.

1. Install the sensor and program the datalogger according to the instructions in this document.

2. Set the datalogger to display the wind direction sensor output. This display will be used to determine the full scale input voltage (FSIV).

3. Locate one person at the datalogger location, and the other with the sensor.

4. If still installed, remove the shoulder screw from the sensor.

5. The person with the sensor should turn the wind vane slowly back and forth around the direction of TRUE north. As this is done, the datalogger display should show input voltages changing from full-scale values to near zero as the sensor passes the north orientation. During this, the second person should note the highest value on the datalogger display (FSIV).

6. If the FSIV is greater than the range limit set on the datalogger (500 mV for the CR21X, 250 mV for the CR10), then the excitation voltage must be reduced. Change the datalogger excitation voltage to 90% of its initial value. Repeat step 5 until the FSIV is lower than the maximum range.

7. Once the FSIV is within the range limit, calculate the sensor multiplier as:

$$M = \frac{360}{FSIV} \tag{1}$$

8. Record this multiplier in the site log book, and on the sensor calibration sheet.

9. Change the multiplier on the datalogger from 1.0 to the value of M. The datalogger display should now be reading degrees from TRUE north.

10. To verify proper alignment, perform an alignment check on the sensor as described in section 3.1.2.

3.0 PERFORMANCE AUDITS

In regular field operations, AEC will conduct performance audits using physical sensor challenges, a collocated sensor, or both. The following subsections describe the procedures for performing these precision checks. These procedures are compatible with those described in the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV, Meteorological Measurements* (April 1989).

3.1 Physical Challenge

Physical challenges of the wind direction sensor will include a series of tests to verify the proper sensor operation. These tests include:

1. Check of the sensor starting torque (which is related to starting threshold);

2. Verification of the vane alignment by orienting the sensor toward known directions at the site; and

3. Check of the sensor internal response through the use of an alignment gauge.

3.1.1 Starting Torque Measurements

AEC will check the condition of the wind vane bearings on each sensor before installation and at periodic intervals by measuring the starting torque of the vane. The R.M. Young model 18331 Vane Torque Gauge will be used to perform the measurements. To obtain a measurement of actual vane starting torque do the following:

1. The vane torque gauge should be attached to the top of the wind vane using double-sided foam tape. The gauge should be attached to the vane so that the tip of the leaf spring is 6 cm from the center of the vertical shaft of the vane.

2. With the instrument on a level surface with no air movement, apply a constant force to the end of the leaf spring so that the vane just rotates through 360 degrees. Note the amount of force applied as indicated on the gauge.

3. The force applied in grams multiplied by the distance of 6 cm will give the amount of torque that was needed to bring about rotation. The maximum allowable torque to maintain a 0.5 m/s starting threshold is 8.64 gm-cm. Since measurement of the torque is only accurate to at best 0.1 gm-cm, any torque of 9.0 gm-cm or less is considered acceptable. If a greater torque is needed to rotate the vane, corrective action should be implemented.

Alternate torque measurements using other torque measurement devices such as a torque watch are acceptable. Specific procedures for such measurements will depend upon the measurement device.

3.1.2 Wind Vane Alignment Tests

The wind vane alignment tests consist of a check of the vane orientation to known objects, and a verification of the sensor operation as compared to a known standard (the vane alignment gauge). As with the sensor installation, the alignment tests are best performed with two people; one to manipulate the sensor and the other to record the datalogger responses.

To check the sensor alignment:

1. Locate the prominent objects which were sighted on in the initial installation. Record the TRUE direction to these objects on the data form.

2. Point the sensor at each of these objects by sighting down the sensor tail fin and record the datalogger response for each object in the "as found" column on the data form.

3. Compare the known direction and the sensor response for each object. Calculate the difference between sensor response and the known direction for each object. Calculate the mean absolute difference using the absolute values of the differences. Compare the mean absolute difference with the criteria established for the monitoring program. If the mean absolute difference is greater than the quality control criteria, repeat the test. If the same result is obtained, corrective action should be implemented.

To verify the sensor response:

1. Check the vane alignment as described above.

2. Remove the wind vane from its mount and place it on the vane alignment gauge. Be sure that only the sensor is removed from the mount and not the orientation

collar. Place the shoulder screw in the sensor to lock the vane at 180°. Rotate the alignment gauge so that the pointer indicates 180°.

3. Remove the shoulder screw from the sensor. Using the scale on the alignment gauge, orient the sensor to known directions from 10° to 340° in increments of 30°. Record the sensor response for each direction on the data form.

4. Calculate the difference between the sensor response and each known direction. Calculate the mean absolute difference using the absolute values of the individual differences. Compare the mean absolute difference with the criteria established for the monitoring program. If the mean absolute difference is greater than the quality control criteria, repeat the test. If the same result is obtained, corrective action should be implemented.

5. Reinstall the sensor and perform an alignment check as described earlier in this section. Record the alignment check data in the "as left" column on the data worksheet.

<u>3.2 Collocated Sensor Method</u>

The following procedures should be used when conducting a performance audit using a collocated sensor (CS):

1. Locate the CS so that it will experience similar wind patterns as the primary sensor. The CS must be within 10 m horizontally, and 1 m vertically of the primary sensor.

2. The most accurate performance audits are made when the same datalogger is used to read both the primary sensor and the CS. If this is not possible, synchronize the two datalogger clocks, and use the same scan intervals and output instructions.

3. Conduct the audit over a period of at least 8 hours (preferably 24 hours), or long enough to generate a minimum of 30 paired observations, whichever is longer.

4. Following the sampling period, edit the data to eliminate any data pairs where the wind direction was such that mutual interference between the sensors occurred.

5. Calculate the comparability of the measurements as:

$$C = \pm\sqrt{\frac{1}{n}\sum_{i=1}^{n}(\theta_{PS_i} - \theta_{CS_i})^2} \qquad \textbf{(2)}$$

where: n = the number of paired observations
θ_{PS} = the wind direction measured by the primary sensor
θ_{CS} = the wind direction measured by the collocated sensor

6. Calculate the mean difference between the paired observations as:

$$\bar{d} = \frac{1}{n}\sum_{i=1}^{n}(\theta_{PS_i} - \theta_{CS_i}) \qquad \textbf{(3)}$$

7. Calculate the estimated standard deviation of the difference as:

$$s = \pm\sqrt{C^2 - \bar{d}^2} \qquad \textbf{(4)}$$

8. Perform a linear regression between the paired measurements in the form:

$$\theta_{PS} = a + b(\theta_{CS}) \qquad \textbf{(5)}$$

where: a = the intercept of the regression line (bias)
b = the slope of the regression line

9. Record each of the above calculations as part of the documentation process.

10. Compare the appropriate values to the quality control limits specified in the project Quality Assurance Plan to determine if the sensor is operating within acceptable limits.

4.0 MAINTENANCE

The following procedures should be followed to ensure proper sensor operation:

1. Every site visit, verify proper sensor output on the datalogger, and visually inspect the sensor for any signs of damage.

2. At least once every 6 months, inspect the sensor and conduct a performance audit as described in section 3 above.

3. At least once every three years, replace the sensor potentiometer according to manufacturer's instructions.

5.0 DOCUMENTATION

It is necessary for proper sensor operation to maintain complete documentation on each sensor. Minimum documentation required shall be:

1. A site log in which all activities at the site are documented.

2. Complete documentation of all performance audits, including raw data, collocated sensor specifications (if appropriate), and results.

3. A complete record of all sensor maintenance including cleaning and bearing replacement.

Additional documentation may be required by the project Quality Assurance Plan.

APPLIED ENVIRONMENTAL CONSULTANTS, INC.

WIND DIRECTION SENSOR AUDIT FORM

General Information	
Project:	Site:
Date:	Auditor:
Start Time:	End Time:
Sensor Make:	Starting Torque (gm-cm):
Sensor Model:	Starting Threshold (m/s):
Sensor Serial #:	Sensor Visual Condition:

Alignment Information				
Known Direction (degrees TRUE)	As Found		As Left	
	Sensor Response (°)	Difference (Response - Known) (°)	Sensor Response (°)	Difference (Response - Known) (°)
	Absolute Mean		Absolute Mean	

Sensor Response Test		
True Direction (degrees) [X]	Sensor Response (degrees) [Y]	Difference (Sensor - True) (degrees)
10		
40		
70		
100		
130		
160		
190		
220		
250		
280		
310		
340		
	Absolute Mean	
Regression Results: a=	b=	r^2=

Revision: 9/27/94

STANDARD OPERATING PROCEDURE
Applied Environmental Consultants, Inc.

Number: 220

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Date: September 1, 1991

Approvals

Author(s)	[signature]	date: 9-1-91
		date:
QA Officer	[signature]	date: 9-1-91
Principal Scientist	Louis C. Thanukos	date: 9-1-91

Revisions

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2	3-3-92	corrected equation # 1	[signature]
3	9-27-94	Revised section 2.2 to incorporate physical challenges (added sections 2.2.1, 2.2.1.1, 2.2.1.2). Renumbered section 2.2 as 2.2.2. Revised audit form.	[signature]

1.0 INTRODUCTION

This document describes the standard operating procedures for the use of the Met One, Inc., Model 014A Wind Speed Sensor.

2.0 INSTALLATION, CALIBRATION AND PERFORMANCE AUDITS

2.1 Installation

The installation of the sensor should follow the guidelines specified in the project Quality Assurance Plan (eg. PSD siting criteria). Specific installation procedures appear in the ensuing subsections. It is assumed that the sensor will be connected to a Campbell Scientific CR21X, or CR10 datalogger. Other data acquisition systems will require different installation procedures.

2.1.1 Initial Checkout

Before installing the sensor, check the following items:

1. Inspect the anemometer cups for signs of cracks or other damage.
2. Check the bearings and verify smooth, unimpeded operation.
3. Check all cabling for signs of wear or damage.

2.1.2 Electrical Connections

The 014A sensor produces two switch closures upon each revolution of the cup assembly. The switch closures are caused when a small magnet mounted on the bottom of the anemometer shaft passes over a fixed reed switch. The following are the electrical connection used with this sensor.

Black Wire -	Pulse Input Channel
White Wire -	Analog Ground (Ground on CR21X, AG on CR10)
Clear Wire -	Earth Ground (Ground on CR21X, G on CR10)

2.1.3 Datalogger Programming

The wind speed sensor is sampled using the datalogger pulse instruction with a switch closure option. Since the sensor has a minimum starting speed of 0.447 m/s, a series of instructions are issued to convert this wind speed (0.447) to zero when it is found. The proper offset is always 0.447, and the multiplier can be found by:

$$\text{Multiplier} = 0.800/t$$

where t is the scan interval of the datalogger program.

The following are sample program fragments which can be adapted for use with the 014A sensor.

CR21X Datalogger

Program Step	You Enter	Description
1	3	Pulse Count
	1	Repetitions
	1	Pulse Input Channel
	12	Config. Code (Switch closure)
	1	Storage Location
	0.8000	Multiplier
	0.447	Offset
2	89	If X = F (check 0 speed)
	1	X Location (wind speed)
	1	Comparison Code (=)
	0.447	F value
	30	Then DO
3	30	X = F (convert to zero)
	0	F value
	1	Storage Location
4	95	End (finishes DO)

CR10 Datalogger

Program Step	You Enter	Description
1	3	Pulse Count
	1	Repetitions
	1	Pulse Input Channel
	12	Config. Code (Switch closure)
	1	Storage Location
	0.8000	Multiplier
	0.447	Offset
2	89	If X = F (check 0 speed)
	1	X Location (wind speed)
	1	Comparison Code (=)
	0.447	F value
	30	Then DO
3	30	Z = F (convert to zero)
	0	F value
	0	Exponent
	1	Storage Location
4	95	End (finishes DO)

2.1.4 Mounting

Mount the sensor on an appropriate mount. Make sure that the sensor cups are perfectly level to ensure proper readings. When mounting, be sure not to cover the vent hole near the bottom of the sensor.

2.2 Calibration and Performance Audits

Calibration of the wind speed sensor is dictated by the design of the sensor, and thus the transfer equation relating rates of rotation to wind speed is fixed. Regular calibration of the sensor is thus not required as long as the data acquisition system and sensor are operating properly. To verify proper operation and the validity of the transfer equation, periodic performance audits of the sensor should be performed. In regular field operations, AEC will conduct performance audits using physical challenges, collocated sensors, or both. The following subsections describe the procedures for conducting performance audits. These procedures are compatible with those described in the EPA Quality Assurance Handbook for Air Pollution *Measurement Systems, Volume IV, Meteorological Measurements* (April 1989).

2.2.1 Physical Challenge Method

Physical challenges to the wind speed sensor involve testing the sensor starting torque (which is related to starting threshold), and testing the validity of the sensor transfer equation by actively rotating the sensor at known rates of rotation and comparing these rates to the anemometer response. The following subsections describe these physical challenges.

2.2.1.1 Starting Torque Measurements

AEC will check the condition of the anemometer before installation and at periodic intervals by measuring the starting torque of the propeller shaft. The R.M. Young model 18310 Propeller Torque Disc will be used to perform the measurements. The propeller torque disc is used as follows:

1. Remove the anemometer cup assembly and slide the torque disk over the anemometer shaft. Place the anemometer on a flat surface with the torque disk hanging over the edge of the surface so that it is free to rotate.

2. Apply a known torque to the disc by attaching weights (screws) at different radii in a line on the disc. Attach the screws weighing 0.1 gm (black screws), or 1.0 gm (silver screws) in holes which are spaced at 1 cm intervals to yield the desired starting torque (for example: a 0.1 gm weight at the 3 cm mark = 0.3 gm-cm of torque).

3. With the disc weights held in a horizontal position release the disc and the disc should rotate downward. Failure to rotate indicates the need to add additional torque. Continue incrementally adding torque until the disc rotates. Check the rotation in both the clockwise and counter-clockwise directions. Record the measured starting torque. The maximum allowable torque to maintain the 0.5 m/s starting threshold is 0.28 gm-cm. Since measurement of the torque is only accurate to 0.1 gm-cm, any torque of 0.3 gm-cm or less is considered acceptable. If the torque is greater than 0.3 gm-cm, replace the sensor bearings.

Alternate torque measurements using other torque measurement devices such as a torque watch are acceptable. Specific procedures for such measurements will depend upon the measurement device.

2.2.1.2 Wind Speed Rotation Test

To verify the sensor response to known wind speeds, the anemometer shaft is rotated at rates which correspond to known wind speeds using the RM Young anemometer drive unit. Wind speeds throughout the sensor range should be simulated.

To perform the active rotation test:

1. Remove the anemometer cup assembly from the sensor shaft.

2. Attach the anemometer drive unit to the anemometer shaft. Be sure to align the motor with the shaft to ensure that the mechanism will not wobble when the motor is on.

3. Set the desired rate of revolution of the motor (rpm) on the anemometer drive control unit to match a known wind speed.

4. Allow the anemometer drive and anemometer response to stabilize, and record the anemometer response on the data form.

5. Repeat steps 3 and 4 for at least five different rates of rotation over the full range of the anemometer. At least one rotation rate should simulate a wind speed ≤ 5.0 m/s. For each response calculate the difference and percent difference between the sensor response and the simulated wind speed. Calculate the mean absolute difference for all wind speeds ≤ 5.0 m/s and the mean absolute percent difference for wind speeds > 5.0 m/s. When calculating the means, be sure to use the absolute values of the difference measurements.

   Compare the calculated mean absolute difference and mean absolute percent difference to the quality control guidelines established for the monitoring project. If any response is outside of these limits, retest the sensor. If the same results are obtained, corrective action should be implemented.

2.2.2 Collocated Sensor Method

The following procedures should be used when conducting a performance audit using a collocated sensor (CS):

1. Locate the CS so that it will experience similar wind patterns as the primary sensor. The CS must be within 10 m horizontally, and 1 m vertically of the primary sensor.

2. The most accurate performance audits are made when the same datalogger is used to read both the primary sensor and the CS. If this is not possible,

synchronize the two datalogger clocks, and use the same scan intervals and output instructions.

3. Conduct the audit over a period of at least 8 hours (preferably 24 hours), or long enough to generate a minimum of 30 paired observations, whichever is longer.

4. Following the sampling period, edit the data to eliminate any data pairs where the wind direction was such that mutual interference between the sensors occurred.

5. Calculate the comparability of the measurements as:

$$C = \pm\sqrt{\frac{1}{n}\sum_{i=1}^{n}(U_{PS_i} - U_{CS_i})^2} \qquad (1)$$

where: n = the number of paired observations
U_{PS} = the wind speed measured by the primary sensor
U_{CS} = the wind speed measured by the collocated sensor

6. Calculate the mean difference between the paired observations as:

$$\bar{d} = \frac{1}{n}\sum_{i=1}^{n}(U_{PS_i} - U_{CS_i}) \qquad (2)$$

7. Calculate the estimated standard deviation of the difference as:

$$s = \pm\sqrt{C^2 - \bar{d}^2} \qquad (3)$$

8. Perform a linear regression between the paired measurements in the form:

$$U_{PS} = a + b(U_{CS}) \quad \textbf{(4)}$$

where: a = the intercept of the regression line (bias)
b = the slope of the regression line

9. Record each of the above calculations as part of the documentation process.

10. Compare the appropriate values to the quality control limits specified in the project Quality Assurance Plan to determine if the sensor is operating within acceptable limits.

3.0 PERIODIC MAINTENANCE

The following procedures should be followed to ensure proper sensor operation:

1. Every site visit, verify proper sensor output on the datalogger, and visually inspect the sensor for any signs of damage.

2. At least once every 6 months, inspect the sensor and conduct a performance audit as described in section 2.2 above.

3. At least once per year, replace the sensor bearings according to manufacturer's instructions.

4.0 DOCUMENTATION

It is necessary for proper sensor operation to maintain complete documentation on each sensor. Minimum documentation required shall be:

1. A site log in which all activities at the site are documented.

2. Complete documentation of all sensor performance audits, including raw data, collocated sensor specifications (if applicable), and results.

3. A complete record of all sensor maintenance including cleaning and bearing replacement.

Additional documentation may be required by the project Quality Assurance Plan.

APPLIED ENVIRONMENTAL CONSULTANTS, INC.

WIND SPEED SENSOR AUDIT FORM

General Information	
Project:	Site:
Date:	Auditor:
Start Time:	End Time:

Sensor Information	
Sensor Make:	Multiplier (rpm to m/s):
Sensor Model:	Offset (rpm to m/s):
Sensor Serial #:	Starting Torque (gm-cm):
Sensor Visual Condition:	Starting Threshold (m/s):

Active Rotation Test					
Simulated Rotation (rpm)	Simulated Wind Speed (m/s) [X]	Sensor Response (m/s) [Y]	Sensor Response (mph)	Difference (Response - Simulated) (m/s)	Percent Difference (Diff/Simul.)*100
Mean Absolute Difference (m/s) (for simulated speeds ≤ 5.0 m/s)					
Mean Absolute Percent Difference (for simulated speeds > 5.0 m/s)					
Regression Results	a=	b=	r^2=		

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Applied Environmental Consultants, Inc.

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Approvals

Author(s)	[signature]	date: 4/10/09
		date:
QA Officer	[signature]	date: 4/10/09
Principal Scientist	Louis C. Thanukos	date: 4-10-09

Revisions

Revision #	Date	Changes	Authorization

1.0 INTRODUCTION

This document describes the standard operating procedures for the use of the Campbell Scientific Model LI200X Pyranometers or equivalent.

2.0 INSTALLATION, CALIBRATION AND PERFORMANCE AUDITS

2.1 Installation

The installation of the sensor should follow the guidelines specified in the project Quality Assurance Plan (eg. PSD siting criteria) and the U.S. Environmental Protection Agency (EPA) *On-Site Meteorological Program Guidance for Regulatory Modeling Applications.* Specific installation procedures appear in the ensuing subsections.

2.1.1 Electrical Connections

The Model LI200X is a temperature compensated, silicon photovoltaic type pyranometer. The detector outputs current; a shunt resistor in the sensor cable converts the signal from current to voltage. The difference in voltage between the hot and cold junctions is a function of incident radiation. The following are the electrical connections used with this sensor.

Red Wire -Differential Voltage (Hi) Channel
Black Wire -Differential Voltage (Low) Channel
White Wire -Signal Ground
Clear Wire-Shield

2.1.2 Mounting

The Model LI200X sensor must be mounted on a solid base in accordance with the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems,* section 4.6.3.1. The Model LI200X should be mounted such that it is never shaded and should be mounted with the cable pointed towards the nearest magnetic pole. It is important that the sensor be level to ensure proper sensor response and to guarantee a complete hemi-spherical view of the sky. A spirit level is built into the base of the unit along with securing screws to prevent the sensor from moving after leveling.

2.2 Calibration and Performance Audits

2.2.1 Calibration

Calibration of the pyranometer should be conducted prior to or upon initial installation of the sensor and at a minimum of once per year or more frequently if so specified in the project Quality Assurance Plan. The unit should be calibrated against a calibration pyranometer whose calibration is traceable to the Absolute Radiation Scale. The calibration should be performed in accordance with ASTM E824-81.

2.2.2 Performance Audits

Performance audits, should be performed upon initial installation of the sensor and at a minimum of once every six months or more frequently if so specified in the project Quality Assurance Plan. The following subsection describes the procedures for conducting a performance audit. These procedures are compatible with those described in the EPA *QA Handbook*. Performance audits on the Model LI200X pyranometer involve collocated sensor methods. Either of two methods may be used to audit the sensor: complete diurnal cycle method or incomplete diurnal cycle. The former method is preferred if time permits. The following items are necessary to conduct a performance audit:

1. A reference standard pyranometer with spectral and cosine responses comparable to those of the pyranometer to be audited. This reference standard must be traceable to the Absolute Radiation Scale and must have been recalibrated within a year of the audit.

2.2.2.1 Complete Diurnal Cycle Method

To conduct a performance audit with a collocated sensor (CS) when a complete diurnal cycle is afforded, perform the following steps.

1. Inspect both sensors for damage, condensation within the dome and chipping or flaking of the thermopile surface. If any of these conditions are found, the sensor should be replaced.

2. Locate the CS so that it will experience ambient conditions similar to those subjected to the primary sensor.

3. Ensure that both sensors are level, with clean sensor domes.

4. The most accurate performance audits are made when the same datalogger is used to read both the primary sensor and the CS. If this is not possible, synchronize the two datalogger clocks, and use the same scan intervals and output processing.

5. Conduct the audit over a period of at least 24 hours and long enough to capture one complete sunrise to sunset cycle. If possible, cloud-free days should be chosen for the audit.

6. Calculate the comparability of the measurements as:

$$C = \pm\sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_{PS_i}-X_{CS_i})^2}$$

where: n= the number of paired observations,
X_{PS}= the incoming solar radiation measured by the primary sensor, and
X_{CS}= the incoming solar radiation measured by the collocated sensor.

7. Calculate the mean difference between the paired observations as:

$$d = \frac{1}{n}\sum_{i=1}^{n}(X_{PS_i}-X_{CS_i})\ .$$

8. Calculate the estimated standard deviation of the difference as:

$$s = \pm\sqrt{C^2-d^2}\ .$$

9. Perform a linear regression between the paired measurements in the form:

$$X_{PS} = a + b \bullet X_{CS}\ .$$

10. Record each of the above calculations as part of the documentation process.

11. Compare the appropriate values to the quality control limits specified in the project Quality Assurance Plan to determine if the sensor is operating within acceptable limits.

2.2.2.2 Incomplete Diurnal Cycle Method

To conduct a performance audit with a collocated sensor (CS) when a complete diurnal cycle is not available, perform the following steps.

1. Inspect both sensors for damage, condensation within the dome and chipping or flaking of the thermopile surface. If any of these conditions are found, the sensor should be replaced.

2. Locate the CS so that it will experience ambient conditions similar to those subjected to the primary sensor.

3. Ensure that both sensors are level, with clean sensor domes.

4. The most accurate performance audits are made when the same datalogger is used to read both the primary sensor and the CS. If this is not possible, synchronize the two datalogger clocks, and use the same scan intervals and output processing.

5. Conduct the audit over at least five averaging/totalizing periods (i.e. 5 × 1 hour, or 5 × 15 minutes).

6. Calculate the mean absolute percent difference between the sensors:

$$\overline{\%\Delta} = \frac{1}{n}\sum_{i=1}^{n}\frac{|X_{PS_i} - X_{CS_i}|}{X_{PS_i}} \bullet 100 .$$

7. Record each of the above calculations as part of the documentation process.

8. Compare the appropriate values to the quality control limits specified in the project Quality Assurance Plan to determine if the sensor is operating within acceptable limits.

3.0 PERIODIC MAINTENANCE

The following procedures should be followed to ensure proper sensor operation:

1. Every site visit, verify proper sensor output on the datalogger, and visually inspect the sensor, its leveling, and wires for any signs of damage. Check the color of the sensor desiccant. If the desiccant is mostly or totally pink, replace the desiccant.

2. At least once every 6 months, inspect the sensor and conduct a performance audit as described in section 2.2.2 above.

4.0 DOCUMENTATION

It is necessary for proper sensor operation to maintain complete documentation on each sensor. Minimum documentation required shall be:

1. A site log in which all activities at the site are documented.

2. Complete documentation of all sensor performance audits, including raw data, collocated sensor specifications (if applicable), and results.

3. A complete record of all sensor maintenance.

Additional documentation may be required by the project Quality Assurance Plan.

STANDARD OPERATING PROCEDURE
Applied Environmental Consultants, Inc.

Number:	250
Title:	Operation of Tipping Bucket Rain Gauges
Date:	June 1, 1999

Approvals

Author(s)		date: 6/1/99
		date: ______
QA Officer		date: 6/1/99
Principal Scientist		date: 6/1/99

Revisions

Revision #	Date	Changes	Authorization

1.0 INTRODUCTION

This document describes the standard operating procedures for the use of tipping bucket rain gauges. The procedures herein are applicable to most tipping bucket rain gauges. In the event that certain operational procedures differ between this SOP and a manufacturer's instructions, the manufacturer's instruction should take precedence.

2.0 INSTALLATION, CALIBRATION AND PERFORMANCE AUDITS

2.1 Installation

The installation of the rain gauge should follow the guidelines specified in the project Quality Assurance Plan (e.g. PSD siting criteria). Specific installation procedures appear in the ensuing subsections. It is assumed that the sensor will be connected to a Campbell datalogger. Some variation in the setup may be necessary for other data acquisition systems.

2.1.1 Electrical Connections

Tipping bucket rain gauges usually activate a switch closure (either a magnetic or mercury switch) upon each bucket tip. The following are the electrical connections used with this sensor (polarity of the connections is unimportant).

Wire # 1 -	Pulse Input Channel
Wire # 2 -	Analog Ground (AG)

2.1.2 Datalogger Programming

The Campbell datalogger Instruction 3 records the pulses generated by bucket tips. The number of tips is multiplied by the bucket capacity in engineering units (i.e. one tip equals 0.01 inches).

Table 2.1 shows a sample program fragment that might be used with tipping bucket rain gauges. The instruction is the same for both the CR21X and the CR10X dataloggers:

Table 2.1 Sample Program for use with Tipping Bucket Rain Gauges

Program Step	You Enter	Description
Measure the Sensor and Convert to Engineering Units		
1	3	Pulse Measurement
	1	Repetitions
	1	Pulse Input Channel
	2	Switch Closure
	1	Input Storage Location
	0.01	Multiplier (assuming one tip = 0.01 in)
	0	Offset

2.1.3 Mounting

Tipping Bucket Rain Gauges must be mounted according to *On-Site Meteorological Program Guidance for Regulatory Modeling Applications* (EPA 450/4-87-013), Section 3. The gauge should be mounted at least 30 cm above the ground or high enough to be above the average anticipated snow depth (whichever is greater). Ensure that the lip of the rain gauge is level and that the body of the rain gauge is plumb.

2.2 Calibration and Performance Audits

Most tipping bucket rain gauges are factory calibrated. The procedures for field calibration and for performance audits are the same. If routine performance audits indicate that the gauge is performing with quality assurance guidelines, no calibration of the gauge is required. If calibration is required, make adjustments in accordance with the manufacturer's instructions.

Performance audits should be conducted upon initial installation of the gauge and at a minimum of once every six months or more frequently if so specified in the project Quality Assurance Plan. The following subsection describes the procedures for conducting a performance audit. These procedures are compatible with those described in the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV, Meteorological Measurements* (Revised March 1995).

2.2.1 Performance Audits

Performance audits on tipping bucket rain gauges involve the use of a physical challenge to the instrument. The nature and frequency of precipitation events in most regions precludes the use of a collocated transfer standard.

2.2.1.1 Physical Challenge

Perform the following steps to conduct a physical challenge to the sensor.

1. Construct or purchase a container that will hold enough water to generate at least 10 tips of the tipping bucket. Create a small hole in the container that will allow water to slowly escape at a rate of no more than one inch of simulated precipitation per hour. The minimum amount of water to use can be calculated using the following equation:

$$V = \pi\left(\frac{d}{2}\right)^2 (16.387)(P)$$

where: V = the required volume of water (ml)
d = the diameter of the rain gauge opening (in)
P = the desired simulated precipitation amount (in) (at least 10 times the bucket capacity)

2. Measure the amount of water to be used as accurately as possible.

3. Configure the data acquisition system to record the number of bucket tips (or amount of recorded precipitation) during the performance audit period.

4. Fill the container with the desired amount of water. Place the container over the rain gauge collector and allow the water to drip into the rain gauge.

5. Allow all of the water to drain from the container. Retrieve the number of bucket tips (or recorded precipitation amount) from the data acquisition system.

6. Calculate the difference in recorded vs. simulated precipitation as a percentage of the simulated precipitation. Compare the audit result with the quality assurance limits for the project.

3.0 PERIODIC MAINTENANCE

The following procedures should be followed to ensure proper sensor operation:

1. Every site visit, visually inspect the gauge for signs of damage. Check for and remove any foreign matter, dusts, insects, etc. from the rain gauge opening, tipping bucket and drain hole. Verify that the sensor is level and plumb.

2. At least once every 6 months inspect the sensor and conduct a performance audit as described in section 2.2.1 above.

4.0 DOCUMENTATION

It is necessary for proper sensor operation to maintain complete documentation on each sensor. Minimum documentation required shall be:

1. A site log in which all activities at the site are documented.

2. Complete documentation of all sensor performance audits, including raw data, collocated sensor specifications (if applicable), and results.

3. A complete record of all sensor maintenance.

Additional documentation may be required by the project Quality Assurance Plan.

STANDARD OPERATING PROCEDURE
Applied Environmental Consultants, Inc.

Number:	270
Title:	Operation of NovaLynx Evaporation Gauges
Date:	April 13, 2009

Approvals

Author(s)	[signature]	date: 4/13/09
		date:
QA Officer	[signature]	date: 4/13/09
Principal Scientist	Louis C. Thanukos	date: 4-13-09

Revisions

Revision #	Date	Changes	Authorization

1.0 INTRODUCTION

This document describes the standard operating procedures for the use of the NovaLynx 255-100 Evaporation Gauge. In the event that certain operational procedures differ between this SOP and a manufacturer's instructions, the manufacturer's instruction should take precedence.

2.0 INSTALLATION, CALIBRATION AND PERFORMANCE AUDITS

2.1 Installation

The installation of the evaporation gauge and pan should follow the guidelines specified in the project Quality Assurance Plan (eg. PSD siting criteria). Specific installation procedures appear in the ensuing subsections. It is assumed that the sensor will be connected to a Campbell Scientific datalogger. Other data acquisition systems will require different installation procedures.

2.1.1 Electrical Connections

The evaporation gauge is equipped with a potentiometer that exhibits a varying resistance in response to the motion of the float. A datalogger can monitor the gauge by measuring voltage across the potentiometer. The output signal of the potentiometer can be configured to give an increasing or decreasing voltage as the water level changes. The following are the electrical connections used with this sensor.

Evaporation Gauge Output Signal Connections

Power Input	5 vdc (typical)	**RED**	TB PIN 1 ~ TOP
Evap Signal	0~5 vdc (wiper)	**WHITE**	TB PIN 2 ~ MIDDLE
Power Ground	GND	**BLACK**	TB PIN 3 ~ BOTTOM

2.1.2 Datalogger Programming

The instruction below shows a sample program for the CR1000 datalogger:

```
'Evaporation Gauge measurement Evap_in:
BrHalf (Evap,1,mV2500,7,Vx3,1,2500,False,20000,250,9.425,0)
```

2.1.3 Siting

The Evaporation Gauge should be sited with the evaporation pan with a ½" diameter pipe. Either rigid or flexible tubing may be used, provided it does not deteriorate in outdoor weather conditions.

The gauge should be placed to the north of the pan and far enough away to avoid casting shadows on to the pan. The pan should also be placed away from any structures or vegetation that could cast shadows onto it.

The evaporation pan and gauge should be as level as possible to get an accurate reading.

2.2 Calibration and Performance Audits

Proper calibration is critical to the accuracy of the data and correct operation of the evaporation gauge. The gauge should be calibrated upon initial installation and whenever the gauge is removed from its platform. The evaporation gauge must be calibrated in order to set the operating range of the potentiometer and to determine the zero point of the float motion. Refer to page 5 of the instruction manual for the calibration procedure.

Performance audits should be performed upon initial installation of the sensor and at a minimum of once every six months or more frequently if so specified in the project Quality Assurance Plan. The following subsection describes the procedures for conducting a performance audit.

2.2.1 Performance Audits

Performance audits on the NovaLynx Evaporation Gauge involve a physical sensor challenge. The nature of evaporation precludes the use of a collocated transfer standard. The following items are necessary to conduct a performance audit:

1. 7.6 Gallons of water
2. Laptop computer connected to the data logger

2.2.1.1 Physical Challenge

Perform the following steps to conduct a physical challenge to the sensor.

1. Use the laptop to read the water level that is being reported by the gauge.
2. SLOWLY, pour 7.6 gallons into the evaporation pan.

3. Use the laptop to read the water level that is being reported by the gauge. It should be 1" greater than the previous reading (7.6 gal= 1 in).

4. Compare the difference of the expected reading and actual reading to the quality control limits specified in the project Quality Assurance Plan to determine if the gauge is operating within acceptable limits.

3.0 PERIODIC MAINTENANCE

The following procedures should be followed to ensure proper sensor operation:

1. Keep the evaporation pan free of algae.

2. Plants must not be allowed to grow up over the edges of the pan.

3. Dirt and dust must not be allowed to accumulate inside the pan.

4. During months when freezing conditions are likely, empty, clean, and store the pan. The pan should be stored indoors, or turned bottom side up at the site if it must be left at the site

4.0 DOCUMENTATION

It is necessary for proper sensor operation to maintain complete documentation on each sensor. Minimum documentation required shall be:

1. A site log in which all activities at the site are documented.

2. Complete documentation of all sensor performance audits, including raw data, collocated sensor specifications (if applicable), and results.

3. A complete record of all sensor maintenance.

Additional documentation may be required by the project Quality Assurance Plan.

STANDARD OPERATING PROCEDURE
Applied Environmental Consultants, Inc.

Number: 260

Title: Operation of CS100 Barometric Pressure Sensor

Date: August 22, 2008

Approvals

Author(s)	Chitipong C.	date: 8/22/08
		date:
QA Officer	Chitipong C.	date: 8/22/08
Principal Scientist	Louis C. Thanukos	date: 8-22-08

Revisions

Revision #	Date	Changes	Authorization

1.0 INTRODUCTION

This document describes the standard operating procedures for the use of the CS100 Barometric Pressure Sensor or equivalent.

2.0 INSTALLATION, CALIBRATION AND PERFORMANCE AUDITS

2.1 Installation

The installation of the sensor should follow the guidelines specified in the project Quality Assurance Plan (eg. PSD siting criteria) and the U.S. Environmental Protection Agency (EPA) *On-Site Meteorological Program Guidance for Regulatory Modeling Applications.* Specific installation procedures appear in the ensuing subsections.

2.1.1 Electrical Connections

The CS100 is a capacitive pressure transducer over the 600 to 1,100 millibar range. The following are the electrical connections used with this sensor.

Red Wire -	Differential Voltage (Hi) Channel
Black Wire -	Differential Voltage (Low) Channel
White/Brown Wire -	Earth Ground
Clear Wire -	Earth Ground
Black Wire -	Earth Ground
Blue Wire -	Single-Ended Voltage Channel
Yellow Wire -	Analog Ground
Green Wire -	Control Channel
Red Wire -	12V

2.1.2 Mounting

The CS100 pressure sensor can be mounted on an enclosure. It is important that the sensor with the pneumatic connector pointing vertically downwards to prevent condensation collecting in the pressure cavity. Additionally, ensure that water cannot enter the sensor.

2.2 Calibration and Performance Audits

2.2.1 Calibration

Calibration of the pressure sensor should be conducted prior to or upon initial installation of the sensor. The unit should be calibrated against N.I.S.T. traceable primary standard. The calibration should be performed in accordance with ANSI/NSCL Z540-1-1994.

2.2.2 Performance Audits

Performance audits should be performed upon initial installation of the sensor and at a minimum of once every six months or more frequently if so specified in the project Quality Assurance Plan. The following subsection describes the procedures for conducting a performance audit. These procedures are compatible with those described in the EPA *QA Handbook.* Performance audits on the CS100 pressure sensor involve collocated sensor method. The audit pressure sensor can be as a simple as a portable pressure indicator which has been calibrated against N.I.S.T traceable primary standard.

To conduct a performance audit with a collocated sensor (CS), perform the following steps.

1. Inspect both sensors for damage.

2. Locate the CS so that it will experience ambient conditions similar to those subjected to the primary sensor.

3. Calculate the mean difference between the paired observations as:

$$d = \frac{1}{n}\sum_{i=1}^{n}(X_{PS_i} - X_{CS_i}) .$$

4. Record each of the above calculations as part of the documentation process.

5. Compare the mean difference to the quality control limits specified in the project Quality Assurance Plan to determine if the sensor is operating within acceptable limits.

3.0 PERIODIC MAINTENANCE

The following procedures should be followed to ensure proper sensor operation:

1. Every site visit, verify proper sensor output on the datalogger, and visually inspect the sensor, its pneumatic connection, and wires for any signs of damage.

2. At least once every 6 months, inspect the sensor and conduct a performance audit as described in section 2.2.2 above.

4.0 DOCUMENTATION

It is necessary for proper sensor operation to maintain complete documentation on each sensor. Minimum documentation required shall be:

1. A site log in which all activities at the site are documented.

2. Complete documentation of all sensor performance audits, including raw data, collocated sensor specifications (if applicable), and results.

3. A complete record of all sensor maintenance.

Additional documentation may be required by the project Quality Assurance Plan.

STANDARD OPERATING PROCEDURE
Applied Environmental Consultants, Inc.

Number: 212

Title: Operation of RM Young Models 41342/43347 Platinum Temperature Probes

Date: November 7, 1995

Approvals

Author(s)	Robert J Siverson	date: 11/7/95
		date:
QA Officer	Herbert J Neville	date: 11/7/95
Principal Scientist	Louis C. Thanukos	date: 11-7-95

Revisions

Revision #	Date	Changes	Authorization

1.0 INTRODUCTION

This document describes the standard operating procedures for the use of the RM Young Models 41342 and 43347 Platinum RTD Temperature Probes.

2.0 INSTALLATION, CALIBRATION AND PERFORMANCE AUDITS

2.1 Installation

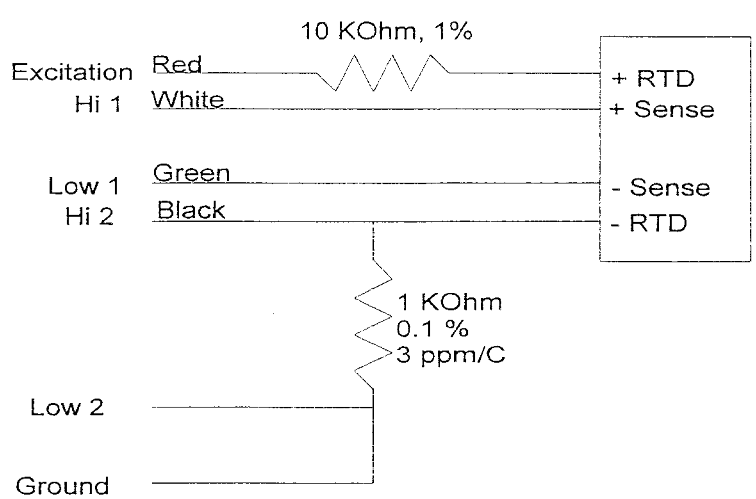
The installation of the sensor should follow the guidelines specified in the project Quality Assurance Plan (eg. PSD siting criteria). Specific installation procedures appear in the ensuing subsections. It is assumed that the sensor will be connected to a Campbell datalogger. Some variation in the setup may be necessary for other data acquisition systems.

2.1.1 Electrical Connections

The 41342/43347 temperature probes are 1 KΩ RTD resistive type sensors that show changes in resistance as a function of temperature. The following are the electrical connections used with this sensor.

Red Wire - Excitation Voltage Channel (with 10 KΩ, 1% resistor in series)
White Wire - Differential Input Channel (Hi)
Green Wire - Differential Input Channel (Low)
Black Wire - 2nd Differential Input Channel (Hi) [contiguous with the first differential channel]

In addition to the above wiring scheme, place a 1 KΩ, 0.1%, 3 ppm/°C resistor across the 2nd differential input "Hi" and "Low" channels. Tie the 2nd differential input channel (Low) to ground.



2.1.2 Datalogger Programming

The Campbell datalogger Instruction 9 applies an excitation voltage and makes two differential measurements. The first measurement is made across the 1 KΩ resistor and the second is made across the RTD, resulting in a ratio of the two resistances. Instruction 55 converts the ratio to a temperature. Coefficients for instruction 55 are specific to each sensor and are supplied by the manufacturer. Any necessary offset is also supplied by the manufacturer and added to the program as Instruction 34.

Table 2.1 shows a sample program fragment which might be used with the 41342/43347 sensors. The instruction is the same for both the CR21X and the CR10 dataloggers:

2.1.3 Mounting

The 41342/43347 sensors must be mounted according to *On-Site Meteorological Program Guidance for Regulatory Modeling Applications* (EPA 450/4-87-013), Section 3. The sensor should be mounted in an aspirated shield with the tip of the sensor being no more than 30 mm from the bottom of the shield.

2.2 Calibration and Performance Audits

The 141342/43347 temperature probes are factory calibrated and their transfer functions are:

$$^\circ C = -251.1326 + 2.3985\times10^{-1} R + 1.1279\times10^{-5} R^2$$

and

$$^\circ F = -420.0387 + 4.3174\times10^{-1} R + 2.0302\times10^{-5} R^2 \; .$$

These coefficients, supplied by RM Young, should be used unless the supplier submits new coefficients generated by their own calibration. Performance audits, however, should be performed upon initial installation of the sensor and at a minimum of once every six months or more frequently if so specified in the project Quality Assurance Plan. The following subsection describes the procedures for conducting a performance audit. These procedures are compatible with those described in the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV* (March 1995).

2.2.1 Performance Audits

Performance audits on the 41342/43347 temperature probes involve either physical sensor challenges, collocated sensor methods or both. The following items are suggested to conduct a performance audit:

Table 2.1 Sample Program for use with the 41342/43347 Temperature Probe

Program Step	You Enter	Description
Measure the Sensor		
1	9	Full BR w/Compensation
	1	Rep
	24	250 mV, 60 Hz rejection, EX Range
	24	250 mV, 60 Hz rejection, BR Range
	1	IN Chan
	1	Excite all reps w/EXchan 1
	2500	mV Excitation
	1	Loc
	1	Mult
	0	Offset
Convert the measurement result to temperature in °C		
2	55	Polynomial
	1	Rep
	1	X Loc
	1	F(X) Loc
	-251.13*	C0
	239.85*	C1
	11.279*	C2
	0.0000	C3
	0.0000	C4
	0.0000	C5
Subtract Offset		
3	34	Z=X+F
	1	X Loc
	-0.00813*	F
	1	Z Loc

* These are sample values and may be different for each sensor. Actual values will be generated by the manufacturer or the supplier.

1. Three insulated containers to hold an ice bath, an ambient temperature bath and an upscale temperature bath. The container tops should have holes to accommodate the sensor and a thermometer.

2. A precise mercury-in-glass thermometer with 0.1 °C (0.2 °F) or finer graduations, which is traceable to NIST standards.

3. Ice.

4. A small immersible heater or equivalent to heat the upscale bath.

5. A second electronic temperature sensor and (if necessary) a second datalogger to act as the collocated sensor, if collocated sensor tests are to be performed.

2.2.1.1 *Physical Challenge*

Perform the following steps to conduct a physical challenge to the sensor:

1. Fill one insulated container with water and allow the water to reach ambient temperature.

2. Fill the second container with a mixture of ice and water and allow enough time for the mixture to approach 0 °C.

3. Submerse the primary temperature probe and the mercury thermometer in the ice bath. Stir the container slightly to ensure that the entire bath is at uniform temperature. Record the temperature response of all instruments on the audit worksheet.

4. Wait for several minutes, stir the container, and take a second reading. Repeat this procedure until 5 measurements have been recorded.

5. Repeat steps 3 and 4, but substitute the ambient temperature bath for the ice bath. Be sure to give the sensors time to equilibrate before taking any readings.

6. Fill the third container with hot water near the upper end of the temperature probe range (approx. 45°C). If hot water is unavailable, an immersible heater can be used to heat the water to the necessary temperature. Repeat steps 3 and 4 using the upscale bath.

7. For each of the measurements taken above, calculate the temperature difference between the electronic sensor(s) and the mercury thermometer. Compute the mean absolute difference for each electronic sensor using the absolute values of the temperature differences.

8. Compare the mean absolute difference values to the quality control limits specified in the project Quality Assurance Plan to determine if the sensor is operating within acceptable limits. Typical limits are ± 1°C.

2.2.1.2 *Collocated Sensor Test*

To conduct a performance audit with a collocated sensor (CS) perform the following steps.

1. Locate the CS so that it will experience conditions similar to those experienced by the primary sensor.

2. The most accurate performance audits are made when the same datalogger is used to read both the primary sensor and the CS. If this is not possible, synchronize the two datalogger clocks and use the same scan intervals and output instructions.

3. Conduct the audit over a period of at least 8 hours (preferably 24 hours), or long enough to generate a minimum of 30 paired observations, whichever is longer.

4. Calculate the comparability (C) of the measurements as:

$$C = \pm\sqrt{\frac{1}{n}\sum_{i=1}^{n}(T_{PS_i} - T_{CS_i})^2}$$

where: n = the number of paired observations,
T_{PS} = the temperature measured by the primary sensor, and
T_{CS} = the temperature measured by the collocated sensor.

5. Calculate the mean difference ($\bar{d}$) between the paired observations as:

$$\bar{d} = \frac{1}{n}\sum_{i=1}^{n}(T_{PS_i} - T_{CS_i}) \ .$$

6. Calculate the estimated standard deviation (s) of the difference as:

$$s = \pm\sqrt{C^2 - \bar{d}^2} \ .$$

7. Perform a linear regression between the paired measurements in the form:

$$T_{PS} = a + b(T_{CS}) \ .$$

8. Record each of the above calculations as part of the documentation process.

9. Compare the appropriate values to the quality control limits specified in the project Quality Assurance Plan to determine if the sensor is operating within acceptable limits.

3.0 PERIODIC MAINTENANCE

The following procedures should be followed to ensure proper sensor operation:

1. Every site visit, verify proper sensor output on the datalogger, and visually inspect the sensor, its radiation shield, and wires for any signs of damage.

2. At least once every 6 months, inspect the sensor and conduct a performance audit as described in section 2.2.1 above.

4.0 DOCUMENTATION

It is necessary for proper sensor operation to maintain complete documentation on each sensor. Minimum documentation required shall be:

1. A site log in which all activities at the site are documented.

2. Complete documentation of all sensor performance audits, including raw data, collocated sensor specifications (if applicable), and results.

3. A complete record of all sensor maintenance.

Additional documentation may be required by the project Quality Assurance Plan.