Appendix A

Quality Assurance Project Plan for the National Air Emissions Monitoring Study (Open Source Emissions Component)
QAPP Category #1

Prepared by

Purdue Applied Meteorology Laboratory

Department of Agronomy, Purdue University

Quality Assurance Project Plan[1,2]
for the
National Air Emissions Monitoring Study
(Open Source Emissions Component)

QAPP Category #1

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Purdue Applied Meteorology Laboratory
Department of Agronomy, Purdue University

A. Project management

1. Approvals

Richard Grant, Purdue University Project Manager	Date
Albert Heber, Purdue University Science Advisor	Date
Juan Carlos Ramirez, Purdue University Quality Assurance Manager	Date
William Schrock, USEPA OAQPS Project Manager	Date
Joseph Elkins, USEPA OAQPS QA Manager	Date

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[1] This QAPP was drafted according to:
USEPA. 2002. *EPA Guidance for Quality Assurance Project Plans*. Office of Research and Development, United States Environmental Protection Agency, Washington, D.C. EPA QA/G-5, and
USEPA. 2001. *EPA Requirements for Quality Assurance Project Plans*. Office of Research and Development, United States Environmental Protection Agency, Washington, D.C. EPA QA/R-5.

[2] Principal author: Richard H Grant, Purdue University, West Lafayette, IN 47907-2054.

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Acronyms and Abbreviations

AARC	Agricultural Air Research Council
ABE	Agricultural and Biological Engineering Department
abl	Above berm level
ACA	Air Consent Agreement
AFOs	Animal Feeding Operations
agl	Above ground level
AGRY	Agronomy Department
ARM	Atmospheric Radiation Measurement Program
ASOS	Automated Surface Observation Stations
ASTM	American Society for Testing and Materials
AWOS	Automated Weather Observation Stations
bLS	Backward Lagrangian Stochastic method
CAA	Clean Air Act
CCF	Concordance correlation factor
CD	Compact disk
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Chain of custody
C_6H_6	Benzene
CH_4	Methane
DM	Data Manager
DOAS	Differential optical absorption spectrometer
DQI	Data Quality Indicators
DQO	Data Quality Objectives
DVD	Digital Video Disk
EA	Explained absorbance
FA	Filtered absorbance
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EtOH	Ethanol
FT-IR	Fourier Transform Infrared
FOS	Field Operations Staff
GC/MS	Gas Chromatography combined with a Mass Spectrometer
GPS	Global Positioning System
GSS	Gas Sampling System
HAc	Acetic Acid
H_2S	Hydrogen sulfide
HD	Computer hard drive
Hg	Mercury
hPa	Hectopascal
IHF	Integrated Horizontal Flux
IR	Infrared waveband
LAN server	Local Area Network server computer

m	Meter
mb	Millibar
MDL	Minimum Detectable Limit
MeOH	Methanol
MQO	Measurement Quality Objective
mV	Millivolt
NA	Not Applicable
NAEMS	National Air Emissions Monitoring Study
NAS	National Academy of Sciences
NELAP	National Environmental Laboratory Accreditation Program
NH_3	Ammonia
NIST	National Institute of Standards and Technology
NMi	Netherlands Measurement Institute
nm	Nanometer
NMHC	Non-Methane Hydrocarbons
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
N_2	Nitrogen
OP	Optical path
PAAQL	Purdue Agricultural Air Quality Lab
PAML	Purdue Applied Meteorology Lab
PAS	Photoacoustic IR Spectroscopy
PC	Personal computer
PDC	Path length-defining components
PDM	Project Data Manager
pH	Measure of activity of hydrogen
PF	Pulsed Fluorescence
PI	Principle investigator
PI-ORS	Path integrated optical remote sensing
PIC	Path integrated concentration
PM	Program manager
ppm	Parts per million
PP	Pull plug
PPR	Pull plug with recharge
PQAM	Project Quality Assurance Manager
QA/QC	Quality Assurance/Quality Control
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan
RH	Relative humidity
RMS	Root mean square
RMSE	Root Mean Square Error
RPM	Radial plume mapping method
SA	Science advisor
SBFM	Smooth Basis Function Minimization

SMP	Site Monitoring Plan
SSE	Sum of squared errors.
S-OPS	Synthetic Open-Path System
SOP	Standard operating procedures
SO_2	Sulfur dioxide
SPS	Sponsored Program Services
SVD	Singular Value Decomposition
TBD	To be determined
TDLAS	Tunable Diode-Laser Absorption Spectroscopy
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UV	Ultraviolet waveband
UV-DOAS	Ultraviolet Differential Optical Absorption Spectrometer
VOC	Volatile Organic Compounds
WAAS	Wide Area Augmentation System
WMO	World Meteorological Organization

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Complete copies of the QAPP will be stored in the computers at the PAML and PAAQL and at each mobile instrument trailer for ready access at any time. Paper copies will be provided to any future field operator or analyst associated with the project but not listed above. In addition, copies of the EPA-approved QAPP will be made available to any organization or individual upon request. Any changes to the QAPP will be reported to all participants listed above via email.

4. Project/Task Organization and Schedule

4.1. Personnel and agencies involved

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Confidential	Producer- Farm 2	Confidential
Confidential	Producer- Farm 3	Confidential
Confidential	Producer- Farm 4	Confidential
Confidential	Producer- Farm 5	Confidential
Confidential	Producer- Farm 6	Confidential
Confidential	Producer- Farm 7	Confidential
Confidential	Producer- Farm 8	Confidential
Confidential	Producer- Farm 9	Confidential
Confidential	Producer- Farm 10	Confidential

4.2. Personnel responsibilities/ Project organization

Roles of each individual or group of individuals in the project follow:

- The Science Advisor (SA) has overall supervision of all aspects of the National Air Emissions Monitory Study (NAEMS) and has final approval authority for the release of study data and reports of scientific results. The SA is responsible for selecting the external corral PI and implementing the subcontract with the PI's university, comprehensive NAEMS study design, selecting measurement locations, and overseeing all extensive technical aspects of the Barns Component of the NAEMS. The SA is the primary point of contact with the commercial laboratory.

- The Project Manager (PM) is responsible for the development of standard operating procedures (SOPs) and establishment of all measurement sites as well as ensuring that staff members are trained in site operation and sample handling. The PM assists the SA in the selection of Open Source emissions measurement locations. The PM is responsible for the specification and selection of all project instrumentation and equipment. The PM manages all aspects of the NAEMS Open Source Emissions Component, has the overall responsibility of field operations and activities, instrument calibrations, data validation, and ensures successful outcomes. All Open Source Emissions staff report to the Project Manager. The Project Manager reports to the SA. The PM is also responsible for all internal audits of measurement systems and instrument/ sensor performance.
- The Quality Assurance Manager (QAM) is responsible for the quality assurance of both the Barn and Open Source components of the NAEMS. The QAM will perform 'external' system and performance audits, document the adherence to measurement quality objectives (MQOs) and data quality indices (DQIs), and manage data quality assessment.
- The Data Manager (DM) is responsible for the data management of both the Barn and Open Source components of the NAEMS and will review and archive data reported from the PDM. The Data Manager also assists in the data reviews and preparation of periodic reports.
- The Data Analysis Manager (DAM) is responsible for the combined data analysis of both the Barn and Open Source components of the NAEMS and will correlate the data reported from the DM and PDM and develop linkages between the measured emissions and farm characteristics.
- The Project Data Manager (PDM) assists in the development and revision of SOPs for data processing and management and is responsible for the data management of the reported compound concentrations, emissions, and meteorological data from all monitoring locations in this project. The PDM receives and archives all data transferred from the field (by ftp download and physical delivery of electronic media) and the commercial laboratory, assists in the data reviews and with the PM evaluates the evidence for data invalidation, and preparation of periodic reports.
- The Project Quality Assurance Manager (PQAM) assists in the development and revising of SOPs, development and validation of automated quality assurance programs and documents the adherence to measurement quality objectives (MQOs) and data quality indices (DQIs), and is responsible for reviewing the accuracy of automatically invalided data, coordinates the routine assessment of data quality, and with the PM evaluates the evidence for data invalidation. The PQAM assist in the preparation of periodic reports. The PQAM is responsible for verifying and documenting the acceptance of all instruments and equipment.

- The Field Operations Staff (FOS) are responsible for on-site quality assurance checks, collecting and deploying samples, and retrieving open path analyzer, lagoon/ basin and meteorological data at each non-corral monitoring location. Manure samples collected at the swine basin location will be collected by the FOS and shipped by them to the designated commercial laboratory for analysis. When not at a measurement location, they also are involved in the data validation checks (coordinated by the PQAM) and data analysis for all locations.

Because the supported project staff is limited, some individuals have multiple roles. The individuals assigned to each role are indicated in Table 4.1.

Table 4.1 Roles of key personnel in the study.

Position	**Location**	**Training**	**Name**
Science Advisor (SA)	ABE	PhD	A Heber
Project Manager (PM)	AGRY	PhD	R Grant
Quality Assurance Manager (QAM)	ABE	PhD	J C Ramirez
Data Manager (DM)	ABE	PhD	J-Q Ni
Project Data Manager (PDM)	AGRY	PhD	A Lawrence
Project Quality Assurance Manager (PQAM)	AGRY	PhD	M Boehm
Field Operations Staff (FOS)	AGRY	PhD	M Boehm A Lawrence

The FOS will consist of two mobile teams and an additional technician. The 'East' team, consisting of a technician and scientist, will travel between eastern and Midwestern US monitoring locations, and a 'West' team of a technician and scientist will travel between Midwestern and western US monitoring locations. An additional technician will be responsible for maintenance of a continuous measurement location. An organizational chart of the staffing for this project is illustrated in Figs. 4.1 and 4.2.

Purdue University, the Agricultural Air Research Council (AARC), the US Environmental Protection Agency (EPA), and producers/farm managers have specific responsibilities:

- Purdue University will have specific fiduciary, communications and technical responsibilities. Purdue will oversee the expenditures of project funds and equipment purchases to ensure that federal check-off funding requirements and applicable tax laws are followed. Purdue University will report on the conduct of the study to the EPA and AARC. Purdue University will establish a project-specific website for the public dissemination of project progress and results.

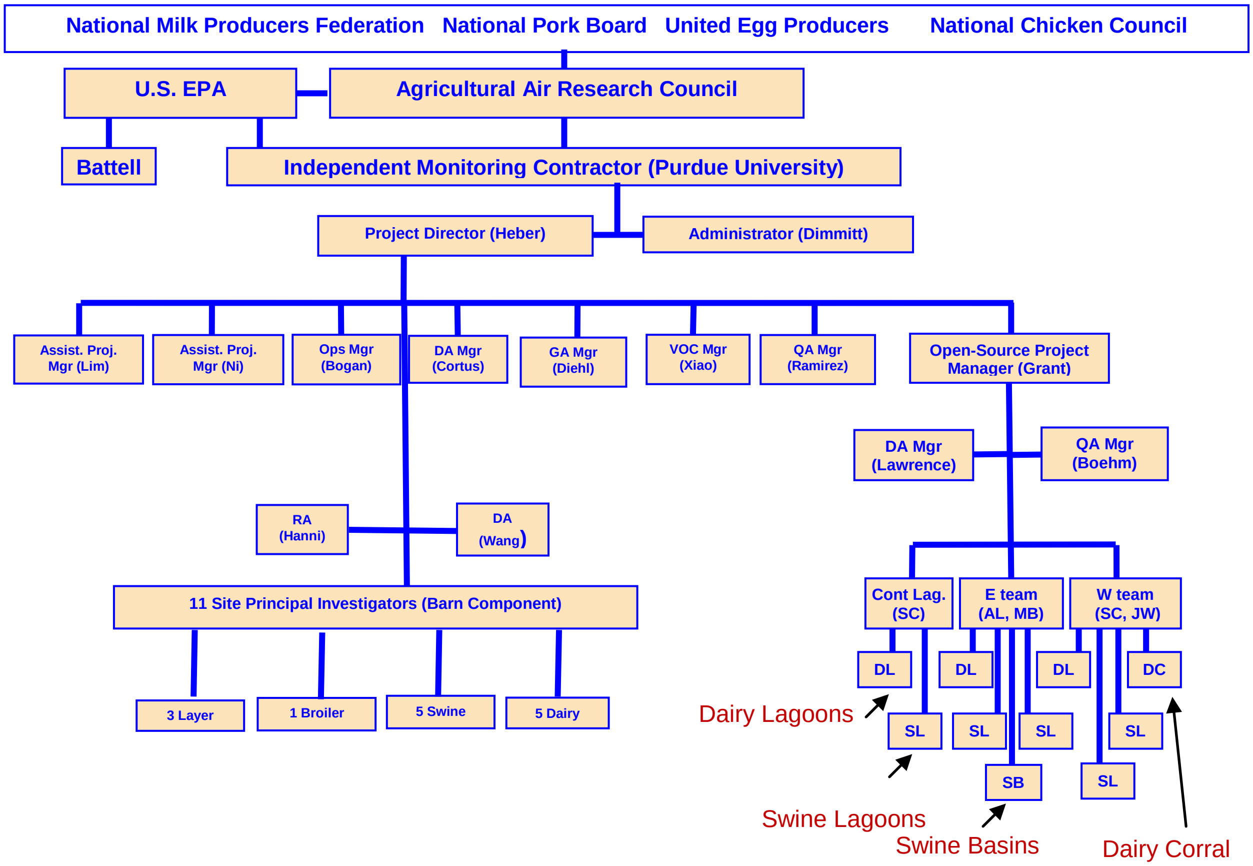

Figure 4.1 Responsibility & Authority Flow Chart for the NAEMS.
(GA = Gas Analyzer; RA = Research Assistant; DA = Data Analyst; DL = Dairy Lagoon; SL = Swine Lagoon; SB = Swine Basin; DC = Dairy Corral)

- The AARC will fund the study and receive regular progress reports on the project. The AARC is responsible for the holding and dispersing to Purdue University the funds necessary for the completion of the project. The AARC will approve the budget and review expenditures. The AARC also will provide the communication mechanism between the project personnel, Purdue University, and the livestock producers, media, and other interested parties (Fig. 4.1).
- The EPA will oversee the scientific issues of the project and provide external quality assurance that the approved protocols are being used throughout the study. EPA will receive regular interim reports including validated data and data summaries (Fig. 4.1).
- Producers/farm managers providing measurement locations for the project must be willing to: 1) attend a training session, 2) make minor changes in normal operating procedures to accommodate the project, and 3) maintain and share certain production and other records to facilitate data analysis and interpretation.

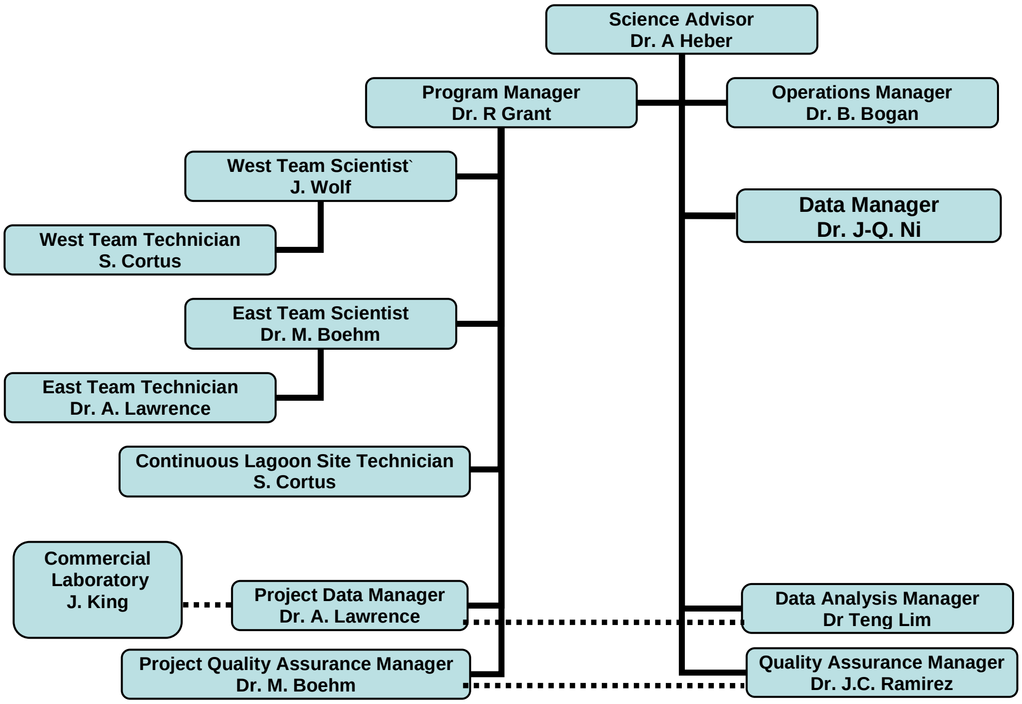

Figure 4.2 Organizational chart- Open Source Component

Non-authoritative communication linkages are indicated by dashed lines

4.3. Project schedule 2006-2009

The project schedule is partially defined by the Air Consent Agreement (EPA, 2005). There is a six-month spin-up time to establish the continuous monitoring locations, the permanent fixtures at all measurement locations, train the staff, and accept and prepare the equipment. Measurements will continue for 2 years. Subsequent to the measurement period, there will be a three month period for closing locations and writing the final reports. A general timeline follows (Quarters are indicated by boxes):

In the six months prior to beginning of data collection at any location:

- A backward Lagrangian Stochastic (bLS) emissions model validation study (described in section 10.7) will be conducted.
- A Cerex UVSentry UV-DOAS H_2S measurement characterization and validation study (described in section 10.8) will be conducted.
- A synthetic open-path sampling system validation study (described in Section 10.9) will be conducted.
- The infrastructure necessary for the conduct of the project for most locations will be established by the FOS in cooperation with each producer (rotating and continuous measurement locations). This includes the establishment of electricity, phone (where applicable), fixed measurement towers, and locations for all portable masts, and tripods.

- Training for operational staff, the FOS, PM, PDM, and PQAM will be conducted.
- All equipment and instruments will be ordered, received, accepted, configured, and integrated in the measurement systems for the project data collection.

Table 4.2 Project schedule

Year	2006	2007										
Month	D	J	F	M	A	M	J	J	A	S	O	N
Equipment procurement and testing	X	X	X									
Complete personnel hiring, conduct training	X	X	X	X					X			
Establish measurement locations	X	X	X	X	X	X	X					
UV-DOAS H_2S validation study					X	X						
Collect measurement data							X	X	X	X	X	X
Analyses						X	X	X	X	X	X	X
Interim reports										X		

Year	2007	2008										
Month	D	J	F	M	A	M	J	J	A	S	O	N
Establish measurement location					X	X						
Collect measurement data	X	X	X	X	X	X	X	X	X	X	X	X
bLS validation study							X	X				
Analyses	X	X	X	X	X	X	X	X	X	X	X	X
Interim reports	X			X			X			X		

Year	2008	2009									
Month	D	J	F	M	A	M	J	J	A	S	O
Collect measurement data	X	X	X	X	X	X					
Analyses	X	X	X	X	X	X	X	X	X	X	X
Interim reports	X			X			X				
Publish study results								X	X	X	X
Close measurement locations							X	X	X	X	

Given the relatively severe conditions during the winter months for the establishment of the measurement infrastructure at many farms, it is anticipated that the establishment of infrastructure at some locations will occur after the beginning of the routine measurement data collection at the previously established locations.

During the measurement data collection phase, the FOS will rotate between eight measurement locations each quarter for two years, spending between eight and twenty days at a location. One corral location will be monitored continuously for the entire two years. Two measurement locations will each be monitored for one year continuously. In the three months after the end of data collection:

- Infrastructure at the measurement locations will be dismantled unless follow-on studies are to be conducted.
- Data analysis will be completed and final report written

References

Environmental Protection Agency, 2005. Animal Feeding Operations Consent Agreement and Final Order: Notice, Part IV, Environmental Protection Agency, Federal Register 70(19):4958-4877.

5. Problem Definition/Background

Air pollutants emitted from livestock manure storages may represent a significant source of pollution to the wider environment. Aerial pollutants of particular interest are ammonia (NH_3) and hydrogen sulfide (H_2S). At present, however, insufficient data exists to accurately model exactly how much pollution is emitted by livestock facilities, and how much emissions may be influenced by local climate, animal species, facility configuration, and/or management practices.

The NAEMS was developed in response to a 2003 National Academy of Sciences (NAS) report which highlighted potential air pollution problems arising from animal feeding operations (AFOs), and discussed the insufficiency of existing data. The study was designed by the Air Quality Group of the USDA's Natural Resources Conservation Service (NRCS) to address the issues in the NAS report, and to determine whether AFOs were likely to have compliance issues regarding the Clean Air Act and/or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The EPA offered AFOs in the swine, dairy, broiler chicken, egg, and turkey industries a one-time opportunity to participate in a legal agreement that would provide protection from prosecution from past federal law violations which may have occurred at those operations. In return, those industries would agree to participate in an extensive nationwide study which would generate data for determining emissions from major types of farms in geographic areas where they are located. NAEMS is the culmination of that agreement.

The goals of this component of NAEMS are:

- Determine whether individual farms are likely to emit volatile organic compounds (VOCs) in excess of applicable Clean Air Act (CAA) thresholds.
- Determine whether individual farms are likely to emit NH_3 and/or H_2S in excess of applicable CERCLA and Emergency Planning and Community Right-to-Know Act (EPCRA) reporting requirements.
- Form a database with which additional studies of air emissions and effectiveness of control technologies can be compared, and from which emission factors can be developed.
- Promote a national consensus on methods and procedures for estimating emissions from livestock operations.

In addition, it is expected that this project will result in a database with which additional studies of air emissions and effectiveness of control technologies can be compared and from which emission factors can be developed. As such, the results of this project will be useful to state and federal regulatory agencies, the livestock industry, researchers, consultants, and the general public.

NAEMS consists of two components: a barn component and an open source component. This QAPP addresses the details of the open source component only. A separate QAPP documents the details of the barn component. To meet the goals of the open source project, micrometeorological techniques in combination with open-path gas measurements will be used to estimate the emissions of ammonia (NH_3) from open sources of swine and dairy lagoons or basins and dairy corrals. Emissions of VOCs will be estimated based on synthetic open-path sampling and either micrometeorological techniques or the relationship of the VOC to NH_3 concentrations measured near the open sources. Fundamentally, the emission calculations of NH_3 will use absorption spectroscopy of the air along an open path of at least 100 m length downwind and upwind of the open source (a path-integrated concentration or PIC) in conjunction with one to three (depending on emissions calculation method) 3-dimensional (3D) wind velocity measurements near the source. The emission of H_2S will use either direct open path absorption spectroscopy or a synthetic open-path system (S-OPS) in conjunction with a gas sampling system (GSS), analyzer, and one to three 3D wind velocity measurements near the surface. The emission of VOCs will use a synthetic open-path system (S-OPS) in conjunction with a gas sampling system (GSS), photoacoustic spectroscopy (PAS), and one to three 3D wind velocity measurements near the surface.

None of the gas concentration or emissions calculation methods are EPA-approved. The methods used in the project are however likely to result in defensible concentration measurements and emissions calculations through careful quality assurance and control.

Assessment of the capabilities of the TDLAS gas measurement system and bLS method in determining emissions from the lagoon/basin environment: Several studies have used TDLAS concentration measurements in combination with backward Lagrangian stochastic (bLS) modeling to calculate the emission rates for a variety of gases. Although this particular combination will not be used in our measurements, these studies demonstrate the validity of both the TDLAS measurement system and the bLS method inverse dispersion technique. There have been several studies of methane (CH_4) emissions from open sources using an open-path TDLAS measurement system in combination with bLS modeling. An evaluation of CH_4 emissions from a defined 6 m x 6 m area source made over 11 roughly two hour periods over 6 d indicated the bLS method error for a given 15-min period varied with stability; with a mean 12% overestimation under near neutral conditions, 13% underestimation under unstable conditions, and 38% overestimation under stable conditions (Flesch et al., 2004). The standard deviation of the bLS-estimated emission was 20%. A problem with this study was the low CH_4 signal/noise ratio of only 2 to 4, which probably resulted in high emission estimation errors. Another evaluation of the combination of TDLAS and bLS inverse dispersion modeling was made using CH_4 emissions from a 3 m x 3 m grid measured by an open-path laser and turbulence data from a three dimensional sonic anemometer (McBain and Desjardins, 2005). Under conditions when Monin Obukhov similarity theory is valid, the calculated emission rate was on average within 6% of the actual value with a standard deviation of 16%. In addition, obstructions upwind from the sensors were determined to have little impact on the Q estimates, so long as the distance between the sensors and the obstructions was at least 25 times the height of the obstructions. Finally, an evaluation of CH_4 emissions from grazing dairy cows over a 3 week period in winter and summer indicated the bLS method overestimated the emission (relative to the IHF method) by between 5% to 17% when averaging emissions estimates from five TDLAS beamlines (Laubach and Kelliher, 2005). Due to the limited validation of the bLS method of determining lagoon or basin emissions, a validation study (Section 10.7) will be conducted as part of the project.

This same combination (TDLAS and bLS) has also been used to measure emissions of NH_3. An evaluation of NH_3 emissions using TDLAS gas measurements and the backward Lagrangian Stochastic (bLS) emissions model was made from a lagoon over 6 d with 15-min measurement periods (Flesch et al. 2005). Periods with $u_* < 0.15$ m/s were excluded, and two different exclusion criteria for the Monin Obukhov length (L) were used. When periods with $|L| < 2$ m were excluded, the mean emission rate was 1.69 g/s (SD 1.23 g/s), while when periods with $|L| <$ 10 m were excluded, the mean emission rate dropped to 1.44 g/s (SD 0.57 g/s). The emission rate dropped to 1.27 g/s (SD 0.49 g/s) when actual turbulence data were used. Since there was no measure of actual emissions, the reduction in emissions estimate after excluding measurements made outside of the defined meteorological conditions may or may not have caused a greater accuracy of the estimate. The calculated NH_3 emissions from a 3.1-m diameter (1.1-m high) manure pile using the bLS emissions calculation method with five individual TDLAS beamlines and the Integrated Horizontal Flux emissions calculation method (IHF) with passive gas samplers over 24 h were within 15% (after assumption concerning the differences in sampling times) (Sommer et al., 2004). It is however important to note that the IHF method cannot be assumed to be a standard method to which all other methods should be compared.

Assessment of the capabilities of the RPM emissions calculation method in determining emissions from the lagoon/basin environment: In simulation and controlled release studies, Hashmonay and Yost (1999) and Hashmonay et al. (2001) demonstrated that the application of VRPM configuration can be used to reconstruct the smoothed concentration field in a plane. In these studies, a series of measurements were made using open-path instruments. These studies showed that the fluxes carried by the plumes reconstructed by the RPM method generally agree within 10% of the emission rates from a controlled source. The accuracy of this method will depend on the specifics of the source and measurement configuration; for the studies mentioned, it was found that results were accurate so long as the wind direction was within about 30^o of perpendicular to the measurement path. In addition, best results were obtained when several measurement periods were combined, with the dwell time for any particular PIC measurement as short as practically possible for obtaining an accurate reading above the background.

Assessment of the capability of UV-DOAS gas measurement systems to determine emissions from lagoon/basin environments: Mount et al. (2001) describe a method for using UV-DOAS in combination with a Gaussian plume model to calculate NH_3 emission rates near a lagoon. Most of the results presented are of NH_3 concentrations measured using the UV-DOAS, and not of emission rates, *per se.* They showed that the concentration measurements increase in a sensible manner with wind direction and also with time of day. Preliminary calculations of emission rate gave values of between 30 and 75 $\mu g/m^2/s$. Thoma (2006) describes use of a UV-DOAS system for measuring NO concentration near a road. These results demonstrate the ability of UV-DOAS to measure gas concentrations at high temporal resolution. Due to the lack of validation of measurements of H_2S using UV-DOAS measurement systems in lagoon environments, a validation study (Section 10.8) will be conducted as part of the project.

Assessment of the capabilities of the S-OPS/PFA gas measurement system and bLS method in determining H_2S emissions from the lagoon/basin environment: The measurement of H_2S using pulsed-fluorescence (PF) is an approved EPA method (EQSA-0486-060, EMTIC TM-006C). The synthetic open-path sampling system used to collect the air sample for analysis has not been validated. Due to the lack of validation, a validation study using a synthetic line emission of SO_2 using both the PF analyzer and a UV-DOAS measurement system (Section 10.9) will be conducted.

Assessment of emissions of NH_3 from lagoon/basins: Efforts to measure NH_3 emissions from open sources have been made. Measured emission rates of NH_3 from lagoons vary from 5.3 kg/h to 83.5 kg/h. Measurements by Aneja et al. (2000) using a dynamic chamber in the lagoon and Todd et al. (2001) showed a strong seasonal effect on emissions with emissions lower during the winter and higher during the spring and summer. An evaluation of NH_3 emissions using TDLAS gas measurements and the backward Lagrangian Stochastic (bLS) emissions model was made from a lagoon over 6 d (Flesch et al, 2005). Results indicated a mean emission rate of 1.27 g/s (SD 0.49 g/s). Considering only a 72-h period in March, the mean emission rate was 0.9 g/s corresponding to 6.5 g / (animal·d). Similar estimation during July (extrapolated from 15.5 h of measurement) resulted in a mean emission of 2.2 g/s corresponding to 16 g / (animal·d).

Assessment of emissions of VOC from lagoon/basins**:** There have been few reported measurements of VOC emissions of gases other than CH_4 from open lagoon sources. Bicudo et. al. (2001) studied VOCs on three swine production sites in Southwest Minnesota using SPME (Solid Phase Micro Extraction) methodology and found mean values equivalent to 9.0, 17.1 and 15.8 $g/(m^2\ d)$ respectively. Hobbs et. al. (1999) determined average daily and annual emissions rates for different VOCs from stirred pig slurry and found the largest emission to be acetic acid (HAc) (1.49 $g/(m^2\ d)$) over propanoic acid, 2-methyl propanoic acid, butanoic acid, 3-methyl butanoic acid, 2-methylbutanoic acid, pentanoic acid, phenol, 4-methyl phenol, and 4-ethyl phenol. The emission factor for ethanol (EtOH) was estimated at 0.89 g/(cow·d) for a dairy lagoon slurry (sorbent tubes, cold trap, GC/MS; Filipy et al., 2006). The emission factor for total VOC except volatile fatty acids and amines from dairy lagoons and storage ponds was estimated at approximately 1.0 lb/(cow·yr) (method TO-15; San Joaquin Valley APC, 2005).

References

Aneja, VP, JP Chauhan, JT Walker. 2000. Characterization of atmospheric ammonia emissions from swine waste storage and treatment lagoons. *J. Geophys. Res*. 109, 11535-11545.

Bicudo JR, DR Schmidt, CL Tengman, W Powers, CJ Clanton, LD Jacobson. 2001. Biocap^{TM} Cover field Evaluation Study. Proceeding of the International Symposium Addressing Animal Production and Environmental Issues, Oct 3-5 research Triangle park, NC

Fillipy, J, B Rumberg, G Mount, H Westberg, B Lamb. 2006. Identification and quantification of volatile organic compounds from a dairy. *Atmos. Environ.* 40: 1480-1494.

Flesch, TK, JD Wilson, LA Harper, BP Crenna, RP Sharpe. 2004. Deducing ground-to-air emissions from observed trace gas concentrations: a field trial. *J. Applied Meteorol*. 43, 487-502.

Flesch, TK, JD Wilson, LA Harper, et al. 2005. Estimating gas emissions from a farm with an inversion-dispersion technique. *Atmos. Environ.* 39:4863-4874.

Flesch TK, JD Wilson, LA Harper. 2004. Deducing ground-to-air emissions from observed trace gas concentrations: A field trial with wind disturbance. *J. Applied Meteorol*. 44:476-484.

Flesch TK, JD Wilson, LA Harper, BP Crenna, RR Sharpe. 2004. Deducing ground-to-air emissions from observed trace gas concentrations: A field trial. *J. Applied Meteorol* 43 (3): 487-502.

Hanna, SR, GA Briggs, RP Hosker Jr. 1982. *Handbook of Atmospheric Dispersion*. DOE/TIC-11223. 102 p.

Hashmonay, RA, MG Yost. 1999. Localizing Gaseous Fugitive Emission Sources by Combining Real Time Optical Remote Sensing and Wind Data. *J. Air Waste Manage. Assoc. 49*:1374.

Hashmonay, RA, DF Natschke, K Wagoner, DB Harris, EL Thompson, and MG Yost. 2001. Field evaluation of a method for estimating gaseous fluxes from area sources using open-path Fourier transform infrared, *Environ. Sci. Technol.*, 35, 2309-2313.

Laubach J, FA Kelliher. 2005. Measuring methane emission rates of a dairy cow herd (II): results from a backward-Lagrangian stochastic model. *Agricultural & Forest Meteorology. 129(3-4):137-150*

McBain, MC, RL Desjardins. 2005. The evaluation of a backward Lagrangian stochastic (bLS) model to estimate greenhouse gas emissions from agricultural sources using a synthetic tracer source. Agric. and Forest Meteorol. 135: 61-72.

Mount, GH, BP Rumburg, BL Lamb, JR Havig, H Westberg, KA Johnson, RL Kincaid. 2001. DOAS measurement of atmospheric ammonia emissions at a dairy. In 10th Annual International Emission Inventory Conference, One Atmosphere, One Inventory, Many Challenges. Adams Mark Hotel, Denver, Colorado, 1–3 May. Washington D.C. USEPA.

National Research Council, 2003.Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. Natl. Academy Press, Washington

Sommer SG, SM McGinn, TK Flesch. 2004. Simple use of the backwards Lagrangian stochastic dispersion technique for measuring ammonia emission from small field-plots. *Europ. J. Agron*. 23: 1-7

Sommer SG, SM McGinn, X Hao et al. 2004. Techniques for measuring gas emissions from a composting stockpile of cattle manure. *Atmos. Environ.* 38 (28): 4643-4652

Thoma, E. 2006. Near Road Measurements with DUV-DOAS Systems: Technique description and operating procedures. Assessment paper for US Environmental Protection Agency, Air Pollution Prevention and Control Division, Emission Characterization and Prevention Branch.

US Environmental Protection Agency, 2005. Animal Feeding Operations Consent Agreement and Final Order: Notice, Part IV, Environmental Protection Agency, Federal Register 70(19):4958-4877.

6. Project/Task Description

6.1. Project objectives

NAEMS consists of two components: emissions from open sources and emissions from barns. This QAPP addresses the open source component to NAEMS. A companion QAPP addresses the barn emissions component to NAEMS. The objectives of this component of NAEMS are to:

- Quantify aerial pollutant emissions from open source manure storage areas.
- Provide valid baseline data on aerial emissions from typical U.S. livestock open source manure storage areas to regulators, producers, researchers, students, and other stakeholders.
- Determine long-term characteristics of H_2S and NH_3 emissions from representative types of livestock manure storage areas.

6.2. Project description

Gaseous emissions of NH_3, H_2S and various volatile organic compounds (VOCs) from open sources will be measured at a number of farm operations with a range of characteristics. The emissions from open sources, including lagoons, basins, and corrals, will be measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions will be measured using models that rely on concentration and wind flow measurements. All gas measurements will be corrected for barometric pressure, temperature and humidity using measurements described in Table 6.2

At the lagoon, basin and corral sites, the atmospheric concentration of NH_3 will be measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS) with a MDL of 50 ppb for a 100 m pathlength, broad bandwidth open path ultraviolet differential optical absorption spectroscopy (UV-DOAS) systems with a MDL of 5 ppb for a 100-m pathlength (if validated) and from air sampled by a synthetic open-path manifold of inlets using photoacoustic spectroscopy with a MDL of 200 ppb (Table 6.1). Prior studies indicate ranges in NH_3 concentration of between 250 and 810 parts per billion (ppb) over a swine lagoon surface (Todd et al., 2001), 500 to 700 ppb at the berm of a swine lagoon (Childers et al., 2001), and 0.4 to 130 ppb at 100 m from the berm of a swine lagoon (McCulloch, 1998). Similar concentrations are reported for a dairy lagoon, with concentrations varying from 100 to 500 ppb NH_3 over the course of 22 d of intermittent measurements during the summer (Rumberg et al., 2004). Measurements of NH_3 concentrations 50 and 200 m from dairy corrals indicate concentrations of 300 to 400 ppb (Sheffield, unpublished). Given the range in NH_3 concentrations reported in the literature and the 50 to 150 m pathlengths to be used in this study, the concentration measurements will be at least 3 times the MDL for the UV-DOAS and TDLAS under most conditions but may frequently be below the MDL of the photoacoustic multigas analyzer.

At the lagoons, basins, and open corral measurements of H_2S concentrations (as well as NH_3 concentrations) will be made using broad bandwidth open path ultraviolet differential optical absorption spectroscopy (UV-DOAS) systems (if method validated) with a MDL of 2000 ppb-m

(Table 6.1) or using pulsed fluorescence (PF) of air sampled by a synthetic open-path manifold system (if UV-DOAS method not validated) with an MDL of 2 ppb. Prior studies have shown that H_2S concentrations vary from 5 to 700 ppb near a swine lagoon surface (Lim et al, 2003), 1000 to 5000 ppb over a swine manure tank (Chénard et al., 2003), to 23,000 ppb directly over wet manure (Chénard et al., 2003). Measurements of H_2S concentrations 50 m and 200 m from dairy corrals indicate concentrations of 20 to 40 ppb (Sheffield, unpublished). Given the range in H_2S concentrations reported in the literature and the 50 to 150 m pathlengths to be used in this study, the concentration measurements will be above the nominal MDL (20 ppb over 100 m pathlength) for the UV-DOAS under some conditions. Further characterization of the UV-DOAS system performance in the matrix of gases found near lagoons or manure basins will be made (Section 10.8) to verify the suitability of the instrument for detecting and measuring the H_2S.

At the lagoons, basins, and open corral, measurements of methane (CH_4), ethanol (EtOH), methanol (MeOH), and residual VOC concentration (as well as NH_3 and water vapor concentration and barometric pressure) will be made using photoacoustic spectroscopy (Table 6.1). The instrument MDL for the measurement of CH_4 is 20 ppb, MeOH is 80 ppb, EtOH is 60 ppb, and total hydrocarbons (THC) is 20 ppb (depending on wavelength of measurement) with corrections for barometric pressure, temperature and humidity made using measurements described in Table 6.2. Very little is known about VOC concentrations near lagoons. Prior studies indicate there are very low concentrations of total VOCs in the air around lagoons, and there have been few prior studies in which VOC concentrations have been speciated. Childers et al. (2001) measured CH_4 concentrations ranging from 2.1 ppm to 11.0 ppm near swine production facilities. Rabaud et. al. (2003) identified and quantified volatile organic compounds emitted from dairy farms in NC using sorbent tubes and thermal-desorption GC/MS and found that HAc concentrations ranged between 15 ppb and 170 ppb, EtOH between 16 ppb and 90 ppb and a number of other VOCs between 0.1 and 100 ppb. Measurements of the headspace of waste collected as it enters a dairy lagoon in Washington (Filipy et al., 2006) suggest upper bounds on the EtOH concentrations of 14.3 to 58 ppb (sorbent tubes, cold trap). Total volatile organic carbon concentrations comprised of the accumulated concentration of 26 GC/MS-speciated compounds was 3-70 ppm in swine lagoons in Colorado (Method TO-15; Walker, 2001). Given the range in HAc concentrations reported in the literature and the photoacoustic analyzer MDL, the concentration at the lagoon will often be below the MDL. Given the range in CH_4 concentrations reported in the literature and the photoacoustic analyzer MDL, the concentration at the lagoon will rarely be below MDL. Given the range in MeOH+EtOH concentrations reported in the literature and the photoacoustic analyzer MDL, the concentration at the lagoon will often be below MDL. Given the range in total VOC concentrations reported in the literature and the photoacoustic analyzer MDL, the concentration at the lagoon will rarely be below MDL.

Emissions of NH_3 will be determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems and a Gaussian plume fit approach (Radial Plume Mapping: RPM). Emissions of H_2S will be determined using UV-DOAS open-path systems or PF with synthetic open path sampling systems (if the UV-DOAS measurement H_2S is not validated) and a Lagrangian Stochastic approach.

Table 6.1 Study critical measurements.

Measurement	**Method/ Instrument**	**Reporting Units**	**Required Operating range**	**MDL**	**Locations**	**Minimum sample frequency**	**Final Data-Aggregation**	**Completeness**
Location of sensors	Garmin GPS 76 w/ WAAS	M	0-300 m	3 m	1 m	1/ meas. period	1/ meas. period	100%
Optical Pathlengths	Nikon Monarch Gold Laser 1200	M	0-300 m	0.5 m	Each optical path	1/ meas. period	1/ meas. period	100%
Ammonia and Hydrogen Sulfide Concentration Measurements								
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder2	$\mu g/m^3$	1-800 ppb	5 ppm-m	retroreflectors at 1 m abl, 7 m, 15 m agl and 0 m to 10 m from berm	0.5 s beamlines	30 min & 24 h	75% of 10 d each quarter
NH_3	INNOVA 1412 multi-gas analyzer	$\mu g/m^3$	1-800 ppb	200 ppb	1 m abl, 0-2 m from berm	60 s	30 min & 24 h	75% of 10 d each quarter
H_2S	UV-DOAS/ Cerex Inc. UV Sentry	$\mu g/m^3$	1-800 ppb	2000 ppb– m	1 m abl, 10 m from berm	100 ms integration 60 s avg	30 min & 24 h	75% of 10 d each quarter
H_2S	PF/Thermo Environmental 450i analyzer	$\mu g/m^3$	1-800 ppb	2 ppb	1 m abl, 0-2 m from berm	60 s avg	30 min & 24 h	75% of 10 d each quarter
VOC Concentration Measurements								
MeOH	PAS/ INNOVA 1412 multigas analyzer	$\mu g/m^3$	0-90+ ppb	80 ppb	1 m abl, 0-2 m from berm	60 s	30 min & 24 h	75% of 10 d each quarter
EtOH	PAS/ INNOVA 1412 multigas analyzer	$\mu g/m^3$	0-90+ ppb	60 ppb	1 m abl, 0-2 m from berm	60 s	30 min & 24 h	75% of 10 d each quarter
CH_4	PAS/ INNOVA 1412 multigas analyzer	$\mu g/m^3$	2000-11000 ppb	40 ppb	1 m abl, 0-2 m from berm	60 s	30 min & 24 h	75% of 10 d each quarter
THC (reference propane)	PAS/ INNOVA 1412 multigas analyzer	$\mu g/m^3$	3000-70000 ppb	20 ppb	1 m abl, 0-2 m from berm	60 s	30 min & 24 h	75% of 10 d each quarter
Meteorological Measurements					Tower			
Wind Speed	3D Sonic anemometer/ RM Young 81000	m/s	0-60 m/s	0.01 m/s	2 m abl, 4, 16 m agl, 0- 10 m from berm	160 Hz sampling/ 16 Hz averaging	30 min & 24 h	75% of 10 d each quarter
Wind Direction	3D Sonic anemometer/ RM Young 81000	Degrees	0^{o} -360^{o}	0.1^{o}	2 m abl, 4, 16 m agl, 0- 10 m from berm	160 Hz sampling/ 16 Hz averaging	30 min & 24 h	75% of 10 d each quarter
Lagoon Measurements								
Length	Nikon Monarch Gold Laser 1200	m	0-300 m	0.5 m	1 m	1 time	1 time	100%
Width	Nikon Monarch Gold Laser 1200	m	0-300 m	0.5 m	1 m	1 time	1 time	100%
Volume	Calculation	m^3		1 m^3		1 time	1 time	100%
Turbulence Measurements					Tower			
3D Turbulence wind components	3D Sonic anemometer/ RM Young 81000	m/s	0-40 m/s	0.01 m/s	2 m abl, 4, 16 m agl, 10 m from berm	160 Hz sampling/ 16 Hz ave.	30 min	75% of 10 d each quarter
Temperature Variability	3D Sonic anemometer/ RM Young 81000	^{o}C	-50 to +50^{o}C	0.01^{o}C	2 m abl, 4, 16 m agl, 10 m from berm	160 Hz sampling/ 16 Hz ave.	30 min	75% of 10 d each quarter

Table 6.1 Study critical measurements (cont.)

Measurement	Method/ Instrument	Reporting Units	Required Operating range	MDL	Locations	Minimum sample frequency	Final Data-Aggregation	Completeness
S-OPS/GSS Air Sampling								
Sample flow rate	GSS/SOP-S	L/min	10	0.1	GSS	30 s	30 min	75% of 10 d each quarter
Sampling manifold pressure	GSS/SOP-S	Pa	±20,000	±500	GSS	30 s	30 min	75% of 10 d each quarter
Emissions Calculations								
NH_3 emissions	Radial Plume Mapping Model	$g\ m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	~ 3 min	30 min, 24 h	75% of 10 d each quarter
H_2S emissions	Backward Lagrangian Stochastic Model	$g\ m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter
NH_3 emissions	Backward Lagrangian Stochastic Model	$g\ m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter
MeOH emissions	Ratiometric to RPM Model	$g\ m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter
EtOH emissions	Ratiometric to RPM Model	$g\ m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter
CH_4 emissions	Ratiometric to RPM Model	$g\ m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter
THC emissions	Ratiometric to RPM Model	$g\ m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter

Table 6.2 Study non-critical measurements

Measurement	Method/ Instrument	Reporting Units	Required Operating range	MDL	Locations	Minimum sample frequency	Final Data-Aggregation	Complete-ness
Meteorological Measurements					Tower			
Ambient Temperature	Thermistor/ Campbell Scientific Inc HMP45C(Vaisala)	°C	-40 to 50 ° C	0.1 ° C	1 m abl, 0-10 m from berm	5 s	5 min, 30 min & 24 h	90% of 10 d each quarter
Relative Humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	%	0-100%	5%	1 m abl, 0-10 m from berm	5 s	5 min, 30 min & 24 h	90% of 10 d each quarter
Barometric Pressure	Aneroid barometer/ Setra 278	hPa	600 to 1100 hPa	600 hPa	1 m abl, 0-10 m from berm	5 s	5 min, 30 min & 24 h	90% of 10 d each quarter
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	(binary)	<2 m abl, 0- 10 m from berm	5 min	5 min, 30 min & 24 h	90% of 10 d each quarter
Solar Radiation	Silicon pyranometer/ LiCOR 190SB	W/m^2	0- 1200 W/m^2	10 W/m^2	<2 m abl, 0- 10 m from berm	5 s	5 min, 30 min & 24 h	90% of 10 d each quarter
Atmospheric pressure	PAS/ INNOVA 1412 multigas analyzer	mbar	600 to 1100 mbar	1 mbar	2 m abl, 0-2 m from berm	1 min	30 min & 24 h	75% of 10 d each quarter
Water vapor	PAS/ INNOVA 1412 multigas analyzer	°C	0 to 40 °C	0.1 °C	2 m abl, 0-2 m from berm	1 min	30 min & 24 h	75% of 10 d each quarter

Table 6.2 Study non-critical measurements (Cont.)

Measurement	Method/ Instrument	Reporting Units	Required Operating range	MDL	Locations	Minimum sample frequency	Final Data-Aggregation	Completeness
Lagoon/ Basin Measurements								
Lagoon solids depth	Sludge level detector/ SludgeGun 10HD, Markland Specialty Eng.	m	0-10 m	0.05 m	0-10 m depth in lagoon	1/ meas. Period	1 time	75% of meas. Periods
Years in service	Questioning lagoon/ basin owner	Years	NA	NA	Farm	1 time	1 time	100%
Lat & Long	Garmin GPS 76 w/ WAAS	degrees	-90 °- +90 ° latitude -180 - +180 ° longitude	0.00005 °	100 m	1 time	1 time	100%
Lagoon/ basin pH	Campbell Scientific Inc CSIM11 (Innovative Sensors, Inc)	pH units	0-14 units	0.2 unit	0.3 m lagoon depth	5 min	30 min & 24 h	75% of 10 d each quarter
Lagoon/ basin Redox potential	Campbell Scientific Inc CSIM11-ORP (Innovative Sensors, Inc)	mV	-800 - +1100 mV	20 mV	0.3 m lagoon depth	5 min	30 min & 24 h	75% of 10 d each quarter
Lagoon/ basin Temperature	Thermistor/ Campbell Scientific Inc 107-L	°C	-35 - +50 °C	0.5 °C	0.3 m lagoon depth	5 min	30 min & 24 h	90% of 10 d each quarter
Manure NH_4	Micro Kjeldahl+ titrometric	mg/L	0.5-10 mg/L (diluted)	0.05 mg/L	Basin/ Corral	1/ meas. period or 90 d	1/ meas. period or 90 d	75%
Manure Total Kjeldahl Nitrogen	Micro Kjeldahl+ titrometric	mg/L	0.5-10 mg/L (diluted)	0.05 mg/L	Basin/ Corral	1/ meas. period or 90 d	1/ meas. period or 90 d	75%
Manure pH	KCl pH electrode	pH units	0-14 units	0.02	Basin/ Corral	1/ meas. period or 90 d	1/ meas. period or 90 d	75%
Manure total solids content	Dry at 103-105 °C	mg/L	0-50 g sample	3 mg/L	Basin/ Corral	1/ meas. period or 90 d	1/ meas. period or 90 d	75%
Manure volatile solids content	Heat to 550 °C	mg/L	0-50 g sample	7 mg/L	Basin/ Corral	1/ meas. period or 90 d	1/ meas. period or 90 d	75%
Map of topography and structures	Satellite imagery, topo-graphic maps, on-site survey, photographs	m	NA	1m elev. 10 m hor.	Farm	1 time	1 time	100%

The Gaussian plume fit approach, based on mapping of the radial shape of the plume, will be used to estimate the emissions of NH_3 from concentration measurements made using the TDLAS open path system. The approach (RPM method) uses a fitted Bi-Gaussian function and a fitted wind profile (from the three 3D sonic anemometers) to define the plume. The domain of the plume is based on PIC measurements made along two elevated paths and three horizontal paths. The Lagrangian approach, based on an inverse dispersion analysis using a backward Lagrangian stochastic method (bLS), will be used to estimate the emissions of NH_3 (using TDLAS open path systems), H_2S (using S-OPS and PF analyzer or UV-DOAS systems) and VOC (using S-OPS and PAS). The Lagrangian approach uses horizontal PIC measurements and turbulence statistics derived from the lowest (2 m height abl at lagoons/ basins and 2-m height agl at the corral) sonic anemometer.

An intercomparison between the RPM and bLS methods, with the goal of validating the bLS method using methodologies similar to EPA Method 301, will be conducted at two farms, which will each have their emissions measured continuously for one entire year.

Table 6.3 Description of sites.

Farm	Species	Phase[1]	Code	Location	Manure Collection	Source Type
1	Swine	Sow	NC4A	Duplin Co., NC	Flush	Lagoon[2]
2	Swine	Finisher	NC3A	Bladen Co., NC	Flush	Lagoon
3	Swine	Sow	IN4A	Clinton Co., IN	PPR[3]	Lagoon
4	Swine	Finisher	IA3A	Greene Co., IA	PP[4]	Basin
5	Swine	Sow	OK4A	Texas Co., OK	PPR	Lagoon
6	Swine	Finisher	OK3A	Texas Co., OK	PPR	Lagoon
7	Dairy	Lactation	WA5A	Yakima Co., WA	Flush	Lagoon
8	Dairy	Lactation	WI5A	Rock Co., WI	Flush	Lagoon[2]
9	Dairy	Lactation	IN5A	Cass Co., IN	Flush	Lagoon
10	Dairy	Lactation	TX5A	Deaf Smith Co., TX	Dry lot	Corral

[1] Characterizes type of farm.
[2] Lagoon can be single or double stage.
[3] PPR = pull plug with recharge
[4] PP= pull plug

Emissions will be measured at a total of 10 farms (Table 6.3) over the course of two years with the intent of representing the dominant manure management schemes for each animal species. Swine manure basin or lagoon emissions will be measured continuously at one farm (Farm 3) for one year and for up to 21 d each season over two years at five farms (Farms 1, 2, 4, 5, and 6). Dairy lagoon emissions will be measured continuously at one farm (Farm 9) for one year and for up to 21 d each season for two years at two farms (Farms 7 and 8). Dairy corral emissions will be measured for up to 21 d each season at one corral farm over two years (Farm 10). The duration of measurement periods designated ‘up to 21 d’ depends on the weather conditions during the 21-d interval for measurement. The DQO for completeness stipulates a 75% completeness of 10 d per quarter. By setting aside 21 d per quarter to acquire at least 7.5 d of valid data (75% of 10 d), instrumentation problems associated with unfavorable weather conditions will not prevent meeting the completeness DQO for each measurement period. This is further explained in section 7.

Sites for monitoring are selected based on the location (relative to climate and typical practice), method of manure collection, type of manure storage, availability of power and communications, and physical configuration of buildings and lagoons/ basins. A general profile of the sites is found in Table 6.3. Further details of the site selection protocol are listed in the Producer Collaborations at Area Source Monitoring Sites Standard Operating Procedure (SOP S7).

Emissions measurements on Rotation Farms. Gaseous emissions of NH_3, H_2S, THC, CH_4, MeOH, and EtOH from lagoon/ basins will be measured over up to 21-d periods at eight farms each during each season of the year (Table 6.4; Fall= September, October, November; Winter=

December, January, February; Spring= March, April, May; Summer= June, July, August). The gaseous emissions of H_2S will be measured using a PF analyzer from air continuously sampled from upwind and downwind S-OPS or UV-DOAS systems in conjunction with the bLS emission model. The gaseous emissions of NH_3 will be measured continuously using upwind and downwind TDLAS systems in conjunction with the RPM emission model from a swine manure basin during the first year of measurements. Gaseous emissions of NH_3, THC, CH_4, MeOH and EtOH will also be determined from S-OPS near each lagoon/basin using the ratio of the point measurement of NH_3 concentration to TDLAS measurement of NH_3 concentration multiplied by the RPM measured NH_3 emission. Speciation of non-methane hydrocarbon (NMHC) emissions will include only MeOH and EtOH emissions. Samples of manure will be collected at the beginning of each measurement period at the basin and analyzed for pH, total and ammoniacal nitrogen, and total and volatile solids by a commercial laboratory (Midwest Laboratories, Inc.). Lagoon/basin emissions will be related to characteristics of the atmosphere and lagoon/basin including atmospheric stability, wind direction, lagoon/ basin temperature, pH and redox status, lagoon/basin loading and sludge depth (Table 6.2).

Two FOS teams (designated ‘E’ and ‘W’ in Table 6.4), each consisting of a scientist and technician will move sequentially from farm to farm to conduct the 20-d measurement periods at each of four farms each during each season of the year (Table 6.4). Each FOS team will set up instrumentation, conduct calibrations and quality assurance checks over two days, then leave the farm for up to 16 d (residing at PAML) until at latest 19 d into the measurement period. At that time they will return to the farm, conduct final quality assurance checks and take-down the equipment at the farm. They will then travel with all equipment to the next farm to begin the routine of set up and quality assurance checks for the next measurement period. Since the completeness objective is 75% of 10 d each quarter, some of the measurement periods could be as short as 8 d. The measurement sequence for the rotation around these farms for the ‘E’ and ‘W’ measurement teams are indicated in Table 6.4. Farm 4 may be measured by the ‘E’ or ‘W’ team depending on logistics at the planned time of measurement. To reduce possible bias in the climatic conditions associated with the measurements at a given farm, the sequence of measurements is the opposite in the second year as compared with the first year. The farm being measured at the end of one season will generally be continuously measured through the beginning of the next season for a measurement period of around 4 weeks (indicated in Table 6.4 by bold type). This provides for quality assurance visits that will not interfere (adding extra days in travel) with the rotation schedule as well as a period of extended measurement at each location. For the purposes of representation of individual seasons, the extended measurement period will be broken into two periods with an unused 5-7 d period of measurements at the end of one season or the beginning of the next.

Continuous lagoon/ basin emissions measurements. Gaseous emissions of NH_3 and H_2S from lagoon/ basins will be measured continuously for one year at two locations (Table 6.4). The equipment and methodologies at the continuous measurement locations will be identical to the rotation farms. The gaseous emissions of H_2S will be measured using a PF analyzer from air continuously sampled from upwind and downwind S-OPS systems or UV-DOAS systems in conjunction with the bLS emission model. The gaseous emission of NH_3 will be measured continuously using upwind and downwind TDLAS systems in conjunction with the RPM emission model from a swine lagoon during the first year of measurements (Farm 3, Table 6.3 and Table 6.4) and from a dairy lagoon during the second year of measurements (Farm 9, Table 6.3 and Table 6.4). These continuous emissions measurements will provide information towards defining how well the annual emission is characterized by the short-duration measurement periods each quarter at the eight rotation farms. The gaseous emissions of NH_3, THC, CH_4, MeOH and EtOH will also be determined from air sampled using S-OPS upwind and downwind of the lagoon/basin using the ratio of the synthetic open-path line measurements of THC, CH_4, MeOH and EtOH to the line measurement of NH_3 concentration multiplied by the RPM-calculated NH_3 emission. Non-methane hydrocarbon (NMHC) emissions will be calculated by adding the MeOH and EtOH emissions to the THC emissions. Lagoon emissions will be related to characteristics of the atmosphere and lagoon/ basin including atmospheric stability, wind direction, lagoon/ basin temperature, pH and redox status, lagoon loading and sludge depth (Table 6.2).

Table 6.4 Project measurement and calibration schedule.

	Year	2007		2008				2009		
	Season[1]	U	F	W	S	U	F	W	S	U
Farm 1: NC4A	EAST[2]		2	3	2	3	4	1	3	
Farm 2: NC3A	EAST		3	4	1	4	3	2	4	
Farm 4: IA3A	EAST		1	2	4	1	2	4	1	
Farm 8: WI5A	EAST	1	4	1	3	2	1	3	2	
PAML calibration	EAST			X		X		X		X
Farm 5: OK4A	WEST[3]	1	3	1	3	3	4	1	3	
Farm 6: OK3A	WEST		1	3	4	1	2	2	2	
Farm 7: WA5A	WEST			4	1	4	1	4	1	
Farm 10: TX5A	WEST		2	2	2	2	3	3	4	
PAML calibration	WEST			X		X		X		X
Farm 3: IN4A	FIXED[4]			▨	▨	■	■	■	■	■
Farm 9: IN5A	FIXED	■	■	■	■				▨	▨

Notes:
1: Seasons; F=Fall (September, October, November), W=Winter (December, January, February), S=Spring (March, April, May), U=Summer (June, July, August)
2: East team
3: West team
4: Continuous operation

Rotation dairy corral emissions measurements. Gaseous emissions will also be measured over periods up to 21 d long during each season of the year from an open corral facility (Farm 10, Table 6.3 and Table 6.4). The backward Lagrangian stochastic method (bLS) will be used to estimate the emissions of NH_3 from path-integrated concentration measurements made using

TDLAS systems. The backward Lagrangian stochastic method (bLS) will also be used to estimate the emissions of H_2S from path-integrated concentration measurements made using UV-DOAS or S-OPS/PFA systems. The gaseous emissions of NH_3, THC, CH_4, MeOH, and EtOH will also be determined for synthetic open paths near each lagoon/basin using the ratio of the S-OPS line measurement of CH_4, THC, MeOH, and EtOH to line measurement of NH_3 concentration multiplied by the bLS-measured NH_3 emission. Non-methane hydrocarbon (NMHC) emissions will be calculated by adding the MeOH and EtOH emissions to the THC emissions. Samples of manure will be collected every 90 d at the corral and analyzed for pH, total and ammoniacal nitrogen, and total solids (Table 6.2) by a commercial laboratory (Midwest Laboratories, Inc.). Corral emission will be related to characteristics of the atmosphere and corral surface including atmospheric temperature, stability and humidity, and wind speed and direction (Table 6.2).

The choice of open-path gaseous concentration measurements in combination with wind measurements and emissions modeling was based on the need to use a methodology that provided for measuring the emissions with minimal measurement interference to the emission processes, measuring the emissions resulting from all transport processes from liquid/solid to ‘fenceline’ air, measuring the emissions from the entire lagoon rather than a small section of the lagoon, measuring using ‘fenceline’ and not within-lagoon equipment, measuring continuously and calculating the emissions from both unmitigated and mitigated (such as straw or other covers) lagoons. The choice of TDLAS for the NH_3 measurements was based on cost and ability to make relatively long path measurements with a monostatic system configurable with a scanner. The choice of PF for the H_2S measurements over the UV-DOAS will be based on the performance of the UV-DOAS system. The PF method for H_2S measurements is EPA approved and will be used if the UV-DOAS does not meet specifications for H_2S measurement. The S-OPS was chosen to comparably sample the air along the path of the open-path TDLAS system. The choice of the photoacoustic multi-gas analyzer for the VOC measurements was chosen based on the ability to make continuous accurate measurements of multiple VOCs in combination with NH_3,

The study is largely in line with the original protocol reported in the Federal Register Air Consent Agreement (EPA, 2005). A comparison of the agreement between the Air Consent Agreement (ACA) and the project follows:

- The ACA identified the need for the manure storage at six swine facilities to be monitored. This matches the designated project monitoring locations.
- The ACA identified the need for the manure storage at four dairy facilities to be monitored. This matches the designated project monitoring locations.
- The ACA proposed the use of open-path Fourier Transform Infrared Spectrometers and the RPM model for the measurement of NH_3 emissions. The project is now using TDLAS systems in conjunction with the RPM model for this measurement.
- The ACA proposed the use of open-path UV-DOAS systems for the measurement of NH_3 and H_2S with emissions measured using the bLS model. A validation study of the UV-DOAS H_2S measurements will be conducted to determine if the measurement method meets the desired accuracy and MDL. If the UV-DOAS method does not meet the

performance criteria, the UV-DOAS will not be used to measure H_2S and the EPA-approved PF method of measuring H_2S will be used.

- The ACA proposed the use of water analyses and the WATER9 model for the measurement of VOC emissions. Due to difficulties in validating the WATER9 model, the project is using PAS in conjunction with a ratiometric VOC to NH_3 concentration and NH_3 emissions at that time to measure the VOC emissions.

Since the methods indicated in the ACA and adopted or changed for the project are not EPA standard methods, the project will provide an opportunity to evaluate the methods for possible future designation as Standard Methods. Efforts are currently underway to approve the RPM emissions measurement method as a Standard Method. The validation study of the bLS model that will occur before the routine data collection begins is an effort to determine if the method has promise of becoming a Standard Method for open path emissions calculation. A similar UV-DOAS measurement system has been evaluated and a draft standard operating procedure developed by the EPA ORD for the measurement of nitric oxide (USEPA, 2006). The TDLAS measurement system less the scanner has been evaluated by the Environmental Technology Verification Program for the measurement of NH_3 (Meyers et al., 2000).

6.3. Biosecurity

The movement of bacteria and viruses from farm to farm is a major issue. Biosecurity at each farm will be maintained by procedures outlined in SOP S7. The overarching biosecurity procedures are to be defined by each participating producer. These procedures may include:

- Using disposable boot covers and overalls if needing to meet with the farmer in his building.
- Avoiding contact with livestock and areas that the farmer has designated as off-limits.
- Avoiding driving across feed delivery lanes to reach the lagoon/ basin.
- Parking vehicle away from buildings.
- Avoiding contact with dead animals.
- Washing vehicle and trailer in a car wash between farms.

References

Aneja, VP, JP Chauhan, JT Walker. 2000. Characterization of atmospheric ammonia emissions from swine waste storage and treatment lagoons. *J. Geophys. Res*. 109, 11535-11545.

Boreal Laser, Inc. 2003. GasFinder2.0 Portable System Operation Manual. Ver 0.39, Boreal Laser, Inc, Spruce Grove, Alberta, Canada, 38 p.

Cerex Environmental Services Inc. 2006. UV Sentry Open-path Air Monitor End-User Manual, Version 2006329, Cerex Environmental Services, Inc, Atlanta, GA

Chénard, SP Lemay, C Lague. 2003. Hydrogen sulfide assessment in shallow-pit swine housing and outside manure storage. J. Agric. Safety and Health 9, 285-302.

Childers, JW, EL Thompson, DB Harris, DA Kirchgessner, M Clayton, DF Natschke, WJ Phillips. 2001. Multi-pollutant concentration measurements around a concentrated swine production facility using open-path FTIR spectroscopy. *Atmos. Environ.* 35, 1923-1936.

Fillipy, J, B Rumberg, G Mount, H Westberg, B Lamb. 2006. Identification and quantification of volatile organic compounds from a dairy. *Atmos. Environ.* 40: 1480-1494.

Hobbs PJ, TH Misselbrook., TR Cumby. 1999. Production and Emission of Odours and Gases from Ageing Pig Waste. *J. Agric. Engng Res*. 72, 291-298

Innova AirTech Instruments. undated. 1314 Photoacoustic multi-gas analyzer, 1412 Photoacoustic Field Gas-Monitor. Technical Documentation. BE6011-11. 252 p

Lim, TT, AJ Heber, JQ Ni, AL Sutton, P Shao. 2003. Odor and gas release from anaerobic treatment lagoons for swine manure. *J. Environ. Qual.* 32(2): 406-416.

McCulloch, RB, GS Few, GC Murray Jr, VP Aneja. 1998. Analysis of ammonia, ammonium aerosols and acid gases in the atmosphere at a commercial hog farm in eastern North Carolina, USA. *Environ. Pollut.* 102, 263-268.

Myers, J, T Kelly, C Lawrie, K Riggs. 2000. Environmental Technology Verification Report: Boreal Laser Inc. GasFinder 2.0 Tunable Diode Laser Open-Path Monitor. ETV Advanced Monitoring Systems Center, Battelle Laboratories, Columbus, OH

Rabaud NE, SE Ebeler, LL Ashbaugh, RG Flocchini.2003. Characterization and quantification of odorous and non-odorous volatile organic compounds near a commercial dairy in California. *Atmos. Environ.* 37, 933-940

Rumberg, B, M. Neger, G.H. Mount, D. Yonge, J. Filipy, J. Swain, R. Kincaid, K. Johnson. 2004. Liquid and atmospheric ammonia concentrations from a dairy lagoon during an aeration experiment. *Atmos. Environ.* 38, 1523-1533.

San Joaquin Valley APC. 2005. Dairy Emissions Factors for Volatile Organic Compounds: Recommendation to Control Officer Regarding VOC Emissions from Dairies. Final Report – May 6, 2005.

SOP S7. 2006. Producer Collaborations at Area Source Monitoring Sites. Standard Operating Procedure S7. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

Todd, L, M Ramanathan, K Mottus, R Katz, A Dodson, G Mihan. 2001. Measuring chemical emissions using open-path Fourier transform infrared (OP-FTIR) spectroscopy and computer-assisted tomography. *Atmos. Environ.* 35, 1937-1947.

US Environmental Protection Agency, 2006. MOP 6844: Interim Standard Operating Procedure for Open Path Measurement of Air Pollutants with the CEREX Ultraviolet Differential Optical Absorption Spectrometer. Office of Research and Development, National Risk Management Research Laboratory, Air Pollution Prevention and Control Division

US Environmental Protection Agency, 2005. Animal Feeding Operations Consent Agreement and Final Order: Notice, Part IV, Environmental Protection Agency, Federal Register 70(19):4958-4877.

US Environmental Protection Agency. 1992. Method 301- Field Validation of Pollutant Measurement Methods from Various Waste Media. Notice, Part IV, Environmental Protection Agency, Federal Register 57(250) 61998-62002.

Walker, B. 2001. Final Report of Air Testing swine lagoons in south east Colorado. August, 2001. AgSkill Inc

7. Quality Objectives and Criteria for Measurement Data

7.1 Data Quality Objectives (DQOs)

The normal procedure for determining DQOs cannot be followed because there is a paucity of sequential long-term emission measurements that can be used to determine accuracy or completeness criteria. Since CERCLA and EPCRA reporting requirements are based on daily emissions and Clean Air Act (CAA) permit thresholds are based on annual emissions, both must be considered. Of the chemical emissions to be calculated in the study, the NH_3 and H_2S emissions are regulated by CERCLA and EPCRA while the VOC are regulated by the CAA. Since the normal procedure for determining accuracy and completeness is not possible due to lack of information, limitations on the completeness must be based on a best-estimate of the optimum instrumentation operation under outdoor weather conditions. Ignoring instrument failures, there are emission model limitations for both the RPM and bLS methods due to wind speed and wind direction variability.

The first overall DQO is to **provide mean daily lagoon/ basin emission calculations for each farm waste storage area under study that are within 30% of the true values for each measurement period**. This DQO is derived from the emissions model errors associated with the measurements used in the study and not from statistical analysis of previous measurements due to the very limited duration of previous lagoon/ basin emissions measurements. As previously stated, emissions of NH_3 are calculated in this study using two methods: the RPM method and the bLS method. Emissions of H_2S are calculated using the bLS method or the ratio of H_2S measured by PF from air sampled by the S-OPS to the nearest equivalent NH_3 PIC measured by TDLAS multiplied by the NH_3 emissions measured by RPM method. Emission of the VOCs (CH_4, THC, MeOH and EtOH) are calculated using the bLS method or the ratio of VOC measured by PAS from air sampled by the S-OPS to the nearest equivalent NH_3 PIC multiplied by the RPM-calculated emissions of NH_3. Non-methane hydrocarbon (NMHC) emissions will be calculated by adding the MeOH and EtOH emissions to the THC emissions. An evaluation of the emission calculation errors follows.

bLS emissions calculation

The model errors for the bLS emissions calculation method (21%) include: (1) 10% error for the estimate of the Monin-Obukov Length (L) derived from measurements, (2) 5% error in turbulence statistics: 10% error for the normalized variability statistics in the x and y directions (U and V) and 5% in the z direction (W) where the error in w is the most critical, (3) 15% error associated with the roughness length (z_o) estimate, and (4) 10% error due to stochastic methodology (Laubach and Kelliher, 2005).

Emissions of NH_3, H_2S, and VOCs at the corral are based on the bLS emission calculation method. In addition, emissions of H_2S and VOCs at some of the lagoon sites are based on the bLS emission calculation method. VOC concentrations are measured using the INNOVA multi-gas analyzer. The measurement precision error of the INNOVA is 1% except for EtOH and

MeOH (2%) while the calibration errors are 1% for NH_3 (1% due to diluter and 1% associated with the calibration gas), 1% for CH_4 (1% due to diluter and 1% associated with the calibration gas), 10% for THC (1% due to diluter and 10% associated with the propane calibration gas), 2% for MeOH (1% due to diluter and 2% associated with the calibration gas), and 1% for EtOH (1% due to diluter and 1% associated with the calibration gas). The H_2S measurement precision error of the PFA is 1% while the calibration error is approximately 3% (1% due to diluter and 3% associated with the calibration gas). The path-integrated concentration (PIC) measurement errors for H_2S using PFA or UV-DOAS are 5% and 10% respectively, while the calibration errors associated with the concentration of the calibration gas are 3% H_2S and 1% associated with the diluter (for the multipoint calibration).

Additional errors associated with the bLS emissions calculations include wind measurement errors of 3% in each direction. We also assume that non-ideal atmospheric and site conditions (such as limited fetch, variations in surface roughness, inhomogeneous non-stationary turbulence, and local variability in atmospheric mixing due to land-water temperature contrasts) introduce an error of approximately 20%. The overall bLS NH_3 and H_2S emissions calculation error is theoretically approximately 31%. This is consistent with empirically-estimated errors of the bLS emission calculation method, when constrained by the data quality indicator (DQI), of between 5% and 36%.

RPM emissions calculation

The model errors for the RPM emissions calculation method include errors in interpolation and extrapolation of the plume concentration map and errors associated with the interpolation of wind speeds through the concentration map domain. Prior studies indicate the method results in a 20% error when the entire plume is measured and mapped (this includes errors in wind speed measurement and PIC measurements described above). Extrapolation errors made when the plume is not entirely mapped could be as high as 20%. We assume that there is less error associated with non-ideal atmospheric and site conditions since the mean airflow adjusts to changes in surface roughness and heating more quickly than the turbulent structure of the flow and arbitrarily assume an error of 10% for these effects. As with the bLS emissions calculation, the TDLAS measurement error of 10% must also be included. Calibration errors associated with the concentration of the NH_3 calibration gas (1%) and diluter (1%) contribute little to the TDLAS error. The overall theoretical RPM NH_3 emissions calculation error is then approximately 30%.

Ratiometric emissions calculation

Emissions of H_2S and VOCs at some of the lagoon sites are based on the ratiometric emission calculation method. This method relies on the RPM-calculated NH_3 emission, the NH_3 concentration nearest the location of H_2S and VOC measurements, and the H_2S and VOC concentration measurements at all locations except the corral (where it is based on the bLS emissions calculation method in the absence of RPM methodologies). The RPM-calculated NH_3 emission error is approximately 30% while the individual TDLAS NH_3 concentration measurements have a combined error of approximately 10%. The combined errors (described above) of the INNOVA are 1% for NH_3, 1% for EtOH, 2% for MeOH, 1% for CH_4, and 10% for THC. The combined H_2S measurement error (described above) of the PFA is 3%. The errors of estimating the emissions of the various VOCs are therefore approximately 35%. The error of estimating the emissions of H_2S is approximately 30%.

Adherence to the DQI for the critical measurements of the TDLAS, PFA, UV-DOAS, PAS multi-gas analyzer, 3D sonic anemometers, and RPM and bLS emissions calculations will assure the successful fulfillment of the first DQO.

A second DQO of critical interest is the completeness criteria for the study. **A valid sample of NH_3 and H_2S emissions during each quarter will consist of 75% of 10 d of valid measurements or 7.5 d of valid daily measurements**. The rationale for this DQO follows:

- NH_3 emissions calculations rely on NH_3 concentration measurements and the 2 m abl, 4 m agl, and 16 m agl 3D sonic anemometer measurements. It is expected that the NH_3 concentrations at the lagoon/basin and corral will be at least 3 times the MDL for the TDLAS. Therefore the 75% completeness DQO for NH_3 emissions calculations will likely be met provided the DQI for the emissions calculation methods are met. An analysis of the expected completeness of emissions calculations is below.
- H_2S emissions calculations rely on H_2S concentration measurements and either the 2 m abl 3D sonic anemometer measurements or the NH_3 concentration and RPM NH_3 emissions measurement. H_2S concentrations at the lagoons, basin and corral will typically be at least 3 times the MDL for the UV-DOAS or PF under most conditions. Therefore the 75% completeness DQO for H_2S emissions calculations will likely be met provided the DQI for the emissions calculation methods are met. An analysis of the expected completeness of emissions calculations is below.

A valid sample of CH_4, THC, EtOH and MeOH emissions during each quarter will consist of 75% of 10 d of valid measurements or 7.5 d of valid daily measurements. The rationale for this DQO follows:

- VOC emissions calculations rely on VOC concentration measurement of the photoacoustic multi-gas analyzer and either the 2-m abl 3D sonic anemometer measurements or the TDLAS NH_3 concentration measurement and RPM NH_3 emissions measurement. Although the NH_3 PIC measurements of the TDLAS will rarely be below MDL, the concentrations measured by the PAS at the lagoons, basin and corral may frequently be below the MDL of the photoacoustic multi-gas analyzer. These measurements will be set to ½ MDL.
- CH_4 and THC concentrations at the lagoons and basin will rarely be below MDL. Consequently, the EtOH and MeOH concentrations calculated from these measures will also be possible most of the measurement time. However since the NH_3 concentrations will often be below MDL for the photoacoustic multi-gas analyzer, it is expected that the emissions of CH_4, EtOH and MeOH will be 75% complete but the setting of NH_3 concentrations to ½ MDL for those measurements below detection limits will provide completeness but likely underestimate total emissions.

The MeOH and EtOH concentrations at the lagoons, basin and corral will often be below MDL. No emissions completeness criteria can be established for these chemical species- they will be considered only as supporting evidence of the composition of the NMHC.

The periods of valid NH_3 emissions will be limited in part due to TDLAS scanner failures and TDLAS errors associated with severe weather conditions. Periods of valid VOC and H_2S emissions will be limited by the orientation of the winds relative to the orientation of the two S-OPS paths. Further limiting the fraction of each measurement period resulting in valid emission are the criteria for valid RPM or bLS computations. The emissions computation methods used in the study do not generally perform adequately under very light winds (less than 1 ms^{-1}) or very high winds (greater than 8 ms^{-1}), and very stable or unstable atmospheric conditions (valid conditions indicated by the respective method's DQI). It was estimated from an analysis of CASTNet monitoring locations (Converse Station, CA, Centennial CO, Cherokee Nation, OK, Bondville, IL, and Candor, NC) that low winds occur up to 25% of the time in some parts of the country, high winds occur up to 14% of the time in some parts of the country, and very stable atmospheres occur up to 40% of the time in some locations. Since the co-occurrence of these conditions is expected, it is reasonable to assume that there will be invalid emissions calculations 30-40% of the time, with a greater fraction invalidated during the night time. Consequently, for any given fixed period of time the measurement completeness may be less than 75%.

A valid day of measurements will consist of 75% of the 30-min intervals in the day. To accomplish a 75% completeness for 10 d of data in a quarter (representing the weather during that quarter), it is expected that measurements will be made at a given farm location in the measurement rotation for up to 21 d of measurements. The need for 21 d of measurements to accomplish a 75% completeness of 10 d of emissions measurements is due to the complexity of the instrumentation and the necessity of having multiple measurements be valid (atmospheric concentration, winds, barometric pressure, relative humidity, and emissions calculation) for a valid emission measurement.

A 10-d period is needed to represent the within-season emissions variability. Within a season, most extratropical storms systems are spaced in time by approximately 3-4 d with weather associated with the storm lasting one to two days. A representative sample in a given season (quarter of the year) must span several weather systems and consequently represent about 10 d. Variability across the year is assessed by measurement periods occurring at each location during each season of the year. Three of the four quarters each year must attain the 75% 10 d completeness criteria for the year to be adequately represented in the study results.

If the second DQO for any gas emissions is not met within the 21 d period of sampling, there is no remediation possible; the mobile team will still need to move on to the next measurement location. There is no means of extending the measurement period to satisfy the second DQO for a given measurement location without impacting the potential successful completion of subsequent measurement periods and locations.

A result of the project will be the accumulation of sufficient measurements and calculated emissions to define the variability found at manure storage facilities and consequently provide the information needed to establish preliminary DQO for at least NH_3 and H_2S emission from lagoons. The measurement at only one corral and one swine basin will limit the validity of DQO established for these situations.

7.2 Data Quality Indicators

DQIs are goals established to assure the quality of measurements to meet the DQO. Failure to achieve any of the acceptance criteria described below triggers an immediate examination of sampling and/or analytical practices in order to correct the problem.

7.2.1 TDLAS NH_3 Measurements.

The scanning path-integrated concentration (PIC) measurements of NH_3 will be measured using Boreal Laser GasFinder2® instruments. The quality of the 15-s TDLAS spectra is defined by the instrument quality control tests described in the Standard Operating Procedure for Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS) (SOP C2). System accuracies of the Boreal Laser GasFinder2® were assessed in 2000 by the Environmental Technology Verification Program. The Environmental Technology Verification Program was established by the EPA to verify performance characteristics of innovative environmental technology. Results of this study are found in Table 7.1. The DQIs are established at a lower accuracy and precision for this study to allow for non-ideal environmental conditions. The DQIs are set at 10% accuracy and 10% precision for the PIC measurements. Measurement MDL, linearity, accuracy and precision DQI are met by calibration/verification and quality assurance audits. These are critical measurements.

Table 7.1.- Reported system accuracy, precision and DQIs for NH_3 concentration using the Boreal Laser GasFinder2®.

Parameter	**Measure**	**DQI**
MDL	5.32 ppm-m at 220 m pathlength	< 10 ppm-m
Linearity (r^2)	0.99	$\geq 0.9\ r^2$
Accuracy	1-10% at 220 m pathlength	Within 10%
Precision	3.14% at 475 ppm	< 10% at 100 ppm
Interferences	No consistent	

7.2.2 UV-DOAS NH_3 and H_2S Measurements.

The PIC measurements of NH_3 and H_2S will be made using Cerex UVSentry® instruments. The quality of the 15-min UV-DOAS spectra is defined by the instrument quality assurance tests described in the Standard Operating Procedure for Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer (UV-DOAS) (SOP C1). The Cerex UVSentry® instrument has not been assessed by the Environmental Technology Verification Program, so manufacturer-provided measures of the accuracy and precision are found in Table 7.2. The instrument provides 10% accuracy and 10% precision for the PIC measurements. MDL values are a combination of laboratory tests made by the manufacturer and a field test made by the PAML. Since the UV-DOAS has not been validated for the measurement of H_2S, a validation study will be conducted. This study is described in section 10.8. Measurement MDL, accuracy, and precision DQI are met by calibration/ verification and quality assurance audits. These are critical measurements.

Table 7.2.- Manufacturer-reported system accuracy, precision and DQIs for NH_3 and H_2S concentrations using the Cerex Environmental Systems UVSentry®

Parameter	**NH_3 Measure**	**NH_3 DQI**	**H_2S Measure**	**H_2S DQI**
MDL	0.14-0.5 ppm-m	Within 0.5 ppm-m	0.32-1.9 ppm-m	Within 2.0 ppm-m
Accuracy	2-10%	Within 10%	3-10%	Within 10%
Precision	4-10%	Within 10%	3-10%	Within 10%
Interferences	H_2S		NH_3, HAc	

7.2.3 PAS VOC Measurements.

The VOC measurements will be made using an INNOVA 1412 Photoacoustic multi-gas analyzer following the Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer (SOP G7). VOCs to be measured include MeOH, EtOH, CH_4, and THC. The manufacturer-reported instrument performance for each parameter given the specified wavelength of detection are indicated in Table 7.4. Of these, CH_4 and THC are critical measurements while MeOH and EtOH are non-critical measurements. Measurement accuracy and precision DQI are met by calibration/verification and quality assurance audits.

Table 7.3.- Manufacturer-reported system accuracy, precision and DQIs for VOC concentrations using the INNOVA 1412 multi-gas analyzer.

Parameter	**Detection wavelength nm**	**Accuracy (%)**	**MDL, ppm**	**Precision % full scale**	**Interferences**	**DQI (% accuracy)**
NH_3	976	±1	0.2	±1	Ethanol	±1
CH_4	968	±1	0.2	±1	Acetic acid, Methanol, Ethanol	±1
THC	987	±1	0.2	±1	Methane, Methanol, Ethanol	±1
MeOH	971	±2	0.03	±1	Ammonia, Ethanol	±2
EtOH	974	±2	0.06	±1	Ammonia, Methanol	±2

The calculation of NMHC (THC + MeOH + EtOH) will have an accuracy of approximately 1% and a precision of ±1% of full scale.

7.2.4 Sonic Anemometer Measurements.

Turbulent wind components (u′, v′, w′) are derived from the measured instantaneous orthogonal wind components (u, v, w) according to:

$$u' = U - u \quad v' = V - v \quad w' = W - w \qquad \text{(Equation 7.1)}$$

where u, v, and w are the time-averaged mean wind components in the northerly, easterly, and upwards directions. Wind speed along the axis of the emission plume will be calculated as a resultant over the period of measurement. The orthogonal components of wind (u, v, w) and virtual temperature (T_v) will be measured using RM Young 81000 sonic anemometers following the Standard Operating Procedure for the Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer (SOP W2). Mean wind speed and wind direction will be calculated for 2-s measurement intervals at 2, 4, and 16 m agl heights to match the scan of five sequential TDLAS PIC measurements (section 7.2.1) for RPM plume reconstructions (Section 7.2.8). Turbulence (u′, v′, w′) and deviations in virtual temperature (T_v' where T_v'=instantaneous measured T_v – period-averaged T_v) will be derived from 30-min averaging periods at 2-m height abl at the lagoons and basin and 3-m height agl at the corral to match the UV-DOAS PIC measurements (Section 7.2.2) for bLS plume emissions calculations (section 7.2.5).

The desired accuracies and resolution of the sonic anemometer sensors are shown in Table 7.4. Also shown in the table are measurement resolutions and DQIs. Measurement resolutions are attained by the selection of measurement instruments. Measurement accuracy DQIs are met by calibration/verification and quality assurance audits. These are critical measurements.

Table 7.4. System accuracy, resolutions and DQIs for sonic anemometer measurements

Meteorological Parameter	**Intercomparison Bias**	**Measurement Resolution**	**DQI**
Orthogonal wind velocities U, V, and W	± 0.2 m/s	0.01 m/s	Within 0.2 m/s
Sonic temperature (T_v) calculated from V_o	±2 °C[1]	0.02°C	Within 2 °C
Wind speed (horizontal)	± 0.2 m/s	0.01 m/s	Within 0.2 m/s
Wind direction (azimuth)	± 5 degrees	1 degree	N/A (computation from orthogonal components)

1: Sonic temperatures (T_v) will not be utilized in the project but is a measureable quantity to determine sensor performance. T_v’ will be used to compute the Monin Obukov Length (*L*).

7.2.5 bLS Plume detection.

The bLS emissions methodology, calculated by the WINDTRAX® software, are assessed for quality using range limits for input variables. There is at present no explicit measure of the emission measurement accuracy. In general, low wind speeds and highly unstable or stable conditions result in poor performance of the method. These conditions are expressed by L and the friction velocity (u_*) (Table 7.5). The Method 301 Validation Study described in section 10.7 will provide a better external measurement of the method accuracy. Details of the DQIs for the method are found in the Emissions Estimation Using the Thunder Beach Scientific Windtrax® Backward Lagrangian Stochastic (bLS) Model (SOP O1). These are critical measurements.

Table 7.5 Data Quality Indices for the bLS Methodology

Measurement Parameter	**Analysis Method**	**DQI**
U,V,W wind components	Side-by-side comparison of two wind monitors	<0.2 m/s
UV-DOAS [NH_3]	Comparison with primary standard gas	Within 10%
TDLAS [NH_3]	Comparison with primary standard gas	Within 10%
UV-DOAS [H_sS]	Comparison with NIST-certified standard gas	Within 10%
PF [H_2S]	Comparison with NIST-certified standard gas	Within 10%
PAS [MeOH]	Comparison with NIST-certified standard gas	Within 10%
PAS [EtOH]	Comparison with NIST-certified standard gas	Within 10%
PAS [THC]	Comparison with NIST-certified standard gas	Within 10%
PAS [CH_4]	Comparison with NIST-certified standard gas	Within 10%
bLS	u_*	>0.15m/s
bLS	$\vert L \vert$	> 2 m

7.2.6 RPM Plume Reconstruction.

The RPM emissions methodology plume reconstructions are assessed for quality using three statistical parameters: Concordance Correlation Factor (CCF) that indicates the goodness of fit between measured and predicted PIC (similar to Pearson correlation coefficient), the plume positioning parameter (A) that is a correction factor to describe the shift in magnitude and location of the measured and predicted PIC vectors, and a plume capture parameter that described the fraction of the predicted plume cross-section that was based on measured concentrations by the scanning measurement system. Details of these DQIs (listed in Table 7.6) are found in the Standard Operating Procedure for Emissions Estimation Using the Arcadis Radial Plume Mapping (RPM) (SOP O2). These are critical measurements.

Table 7.6 Data Quality Indices for the RPM Methodology

Measurement Parameter	**Analysis Method**	**DQI**
TDLAS [NH_3]	Comparison with lab-checked standard gas	Within 10%
Wind Speed	Side-by-side comparison of two wind monitors	<0.2 m/s
Plume Reconstruction	CCF	≥0.8[a]
Total Mass Positioning	A	≥0.9[b]
Plume capture	Fractional change in vertical gradient of PIC	Topmost PIC ≤0.8 mid-height PIC

a The calculated CCF value associated with the RPM algorithm must be ≥0.8 for the reconstruction to be considered valid.

b The calculated CCF value associated with the RPM algorithm must be ≥0.9 for the reconstruction to be considered valid.

7.2.7 Non-critical Meteorological Measurements.

Meteorological measurements are used to characterize weather conditions during the measurement period(s). Measurements include solar radiation using LiCor silicon photodiode pyranometers following the Standard Operating Procedure for the Measurement of Solar Radiation with the LiCOR Model 200SL or 200SZ Silicon Pyranometer (SOP E3), ambient air temperature and humidity using capacitive hygrometers following the Standard Operating Procedure for Measurement of Atmospheric Temperature and Humidity with the Viasala Model HMP45C Sensor and Solar Shield (SOP W1), barometric pressure using Setra resonant silicon aneroid barometers following the Standard Operating Procedure for the Measurement of Barometric pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer (SOP W5), and surface wetness using resistance-grid surface wetness sensors following the Standard Operating Procedure for the Measurement of Wetness with the Campbell Scientific Model Resistance Grid (SOP W3). Measurements will be made every 5 min and stored on a data logger following the Standard Operating Procedure for Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware (SOP W6). Configuration of the sensors is indicated in SOP W6. These are non-critical measurements.

Desired system accuracies are shown in Table 7.7. Also shown in the table are measurement resolutions, defined as the smallest parameter measurement that can be distinguished. All recommendations are from the On-Site Meteorological Program Guidance for Regulatory Application (USEPA, 2000) or from the Atmospheric Radiation Measurement Program (Atmospheric Radiation Measurement Program, 2004b). Measurement resolutions are attained by the selection of measurement instruments. Measurement accuracy DQIs are met by calibration/verification and quality assurance audits. Since surface wetness is a binary measure of wet or dry condition, accuracy of condition is verified by application of water. The corresponding DQI is the sensor responding to a wet and dry condition with appropriate resistance documented in SOP W3.

Table 7.7. Required system accuracy, resolution and DQIs for meteorological measurements.

Meteorological Parameter	Accuracy	Measurement Resolution	DQI
Ambient Temperature	± 0.5°C	0.1°C	Accuracy within 0.5°C
Humidity	± 3%	0.3%	Accuracy within 5%
Barometric Pressure	± 3 hPa or 0.09 inches of Hg	0.5 hPa or 0.015 inches of Hg	Accuracy within 0.5 hPa
Radiation	± 5% of observed	10 Wm^{-2}	Accuracy within 5%

7.2.8 Non-Critical Lagoon/ basin Characterization Measurements.

Lagoon/ basin measurements will be used to characterize conditions during the measurement period(s). The pH and redox state will be measured using submersible plunger-style pH glass electrodes with a Teflon liquid junction according to the Standard Operating Procedure for the Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor (SOP L1) and the Standard Operating Procedure for the Measurement of Lagoon redox potential with Innovative Sensors Model CSIM11 Sensor (SOP L3). The redox probe has a platinum band wrapped around the glass electrode to cause response to the electron density of the fluid. The temperature will be measured using a thermistor probe according to the Standard Operating Procedure for the Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor Standard Operating Procedure (SOP L2). A measurement platform will be used to place the pH, temperature, and redox state probes at a depth of 0.3 m. Measurements will be made every 5 min and stored on a data logger (SOP W6). Measurement resolutions are attained by the selection of measurement instruments. Measurement accuracy DQIs are met by calibration/verification and quality assurance audits (Table 7.8).

Samples of manure will be collected at the corral and manure basin every measurement period (four times per year) according to the Manure Sampling Standard Operating Procedure (SOP M1). The composition of manure in the basin and corral will be used to characterize the emission source. Manure will be analyzed for pH, total and ammoniacal nitrogen, and total and volatile solids content. These measurements will be made by Midwest Laboratories, Inc. using procedures based on the same EPA Methods on which the Standard Operating Procedure for Conducting pH Measurements on Manure Samples (SOP M2), the Standard Operating Procedure for Determining Solids Content of Manure Samples (SOP M3), the Standard Operating Procedure for Determining Total (Kjeldahl) Nitrogen Content of Manure Samples (SOP M4) and the Standard Operating Procedure for Determining Ammonia Content of Manure Samples Standard Operating Procedure (SOP M5) are based. DQI associated with the analyses conform to the applicable EPA Method (see individual SOP). Measurement DQIs are based on measurement accuracy for pH and total and ammoniacal nitrogen content and on measurement precision for volatile and total solid content (Table 7.8).

Table 7.8. Required system accuracy, resolution and DQIs for lagoon/ basin measurements.

Parameter	Accuracy	Measurement Resolution	DQI
Lagoon/basin wastewater temperature	± 0.9^{o}C	0.1^{o}C	Accuracy within 0.9^{o}C
Lagoon/basin pH	± 0.2 pH	0.01 pH	Accuracy within 0.2 pH
Lagoon/basin redox state	± 10 mV	0.1 mV	Accuracy within 20 mV
Sludge depth	± 0.05 m	0.01 m	Accuracy within 0.05 m
Manure pH	0.05 pH	0.01 pH	Accuracy within 0.05 pH units
Manure total nitrogen	0.02 mg/L	0.05 mg/L	Accuracy within 0.02 mg/L
Manure ammoniacal nitrogen	0.02 mg/L	0.05 mg/L	Accuracy within 0.02 mg/L
Manure total solids content	Non stated	3 mg/L	Precision and recovery 80% to 110%
Manure volatile solids content	Non stated	7 mg/L	Precision and recovery 70% to 110%

The lagoon/ basin loading will be calculated based on the volume and the sludge depth. The lagoon sludge solids depth will be measured using a liquid visibility depth finder probe at the beginning of each measurement period at the rotation farms and every three months at the continuous measurement lagoons.

7.2.9 PFA H_2S Measurements.

The synthetic PIC measurements of H_2S will be conducted using a Thermo Electron Corporation Pulsed-Fluorescence H_2S analyzer. The quality of the measurements is defined by the instrument quality assurance tests described in the Standard Operating Procedure for Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450i Pulsed- Fluorescence Analyzer (SOP G5). The manufacturer-provided measures of the accuracy and precision are provided in Table 7.2. The instrument will collect samples from the synthetic open-path sampling system described in the Standard Operating Procedure for the Synthetic Open-Path Sampling System (SOP C4), and provides 5% accuracy and 5% precision for single samples and an unknown accuracy for PIC measurements. MDL values are based on laboratory tests made by the manufacturer. Since the PF/S-OPS has not been validated, a validation study will be conducted. This study is described in Section 10.8. Measurement MDL, accuracy, and precision DQIs are met by calibration/verification and quality assurance audits. These are critical measurements.

Table 7.9.- Manufacturer-reported system accuracy, precision and DQIs for H_2S concentrations using the Thermo 450i Pulsed Fluorescence Analyzer

Parameter	**H_2S Measure**	**H_2S DQI**
MDL	1.0 ppm	
Accuracy	5%	Within 10%
Precision	5%	Within 10%
Interferences	Methyl mercaptan: 0.8 ppm increase per 1 ppm of CH_3SH Dimethyl disulfide: 0.5 ppm increase per 1 ppm of CH_3SSCH_3 Dimethl sulfide: < 0.1 ppm increase per 1 ppm of CH_3SCH_3 NO: Increase of < 3 ppb at 500 ppb NO *m*-xylene: Increase of < 1 ppb at 200 ppb *m*-xylene Water: < 2% of reading per 2% humidity ratio	

7.2.5 Ratiometric emission calculation.

The ratiometric emissions methodology relies on a good RPM plume reconstruction and valid concentration measurements of the gas of interest (H_2S, MeOH, EtOH, CH_4, or THC). Consequently, the DQI for the calculation method are those for the respective components (Table 7.10). These are critical measurements.

Table 7.10 Data Quality Indices for the Ratiometric Methodology

Measurement Parameter	**Analysis Method**	**DQI**
U,V,W wind components	Side-by-side comparison of two wind monitors	Within 10%
TDLAS [NH_3]	Comparison with primary standard gas	Within 10%
Wind speed	Side-by-side comparison of two wind monitors	<0.2 m/s
Plume reconstruction	CCF	$\geq 0.8^a$
Total mass positioning	A	$\geq 0.9^b$
Plume capture	Fractional change in vertical gradient of PIC	Top PIC ≤ 0.85 mid-height PIC
PFA [H_2S]	Comparison with NIST-certified standard gas	Within 10%
PAS [MeOH]	Comparison with NIST-certified standard gas	Within 10%
PAS [EtOH]	Comparison with NIST-certified standard gas	Within 10%
PAS [THC]	Comparison with NIST-certified standard gas	Within 10%
PAS [CH_4]	Comparison with NIST certified standard gas	Within 10%

7.3 Measurement Quality Objectives (MQOs)

Measurement data will undergo quality control (QC) review, which will assess, among other things, representativeness, completeness, comparability, bias and precision. Data quality is evaluated by inspecting QC flags and variables in processed data as described below.

Data representativeness will be assured by the overall sampling design, which includes high frequency and multi-location sampling. Each facility will be monitored 24 hours a day for approximately 21 d every three months (quarter) for two years. Since most mid-latitude extratropical weather systems have a periodicity of about 3-4 d through much of the country, at least 9- 10 d of measurements are needed to represent a given season's weather patterns. Locations to be measured will be chosen to represent the range in typical farm operations in the industry and a range of climatic conditions.

Data completeness will be achieved by assuring that valid data obtained from the measurement system will be no less than 75% of 10 d within the measurement period any quarter of the year. Also, at least seven of the eight scheduled sampling runs will be conducted.

Data comparability will be maintained by consistent use of the same analytical methods defined in the applicable SOP.

Accuracy and precision of all measurements will be assured through the use of regular quality assurance/ quality control procedures (described in the respective sensor or instrument SOP) so that the data quality objectives will be met. Details of the accuracy and precision of each measurement are found in the tables of Appendix A.

Individual MQOs for the critical measurements, including NH_3 PIC by the Boreal Laser GasFinder2®, H_2S PIC by UV-DOAS or S-OPS/PF, NH_3, CH_4 and THC concentrations by S-OPS/PAS and u', v', w' and T_v' and non-critical measurements including air temperature, relative humidity, atmospheric pressure, lagoon/ basin pH, lagoon/ basin redox potential, lagoon/ basin temperature, CH_4, MeOH, and EtOH concentrations by PAS, lagoon depth to solids, manure pH, manure total and volatile solids content, manure total and ammoniacal nitrogen content are described in Appendix A.

References

APHA. 1995. Standard Methods for the Examination of Water & Wastewater, 19th Edition, Method 4500-H+, AD Eaton, LS Clesceri, AE Greenberg (Eds.), AWWA, WEF.

APHA, 1995. Standard Methods for the Examination of Water & Wastewater, 19th Edition, Method 2580, AD Eaton, LS Clesceri, AE Greenberg (Eds.), AWWA, WEF.

Atmospheric Radiation Measurement Program. 2004a. Carbon Dioxide Flux Measurement Systems (CO2FLX) instrument specifications, http://www.arm.gov/instruments/static/co2flx.stm last update June 24, 2004.

Atmospheric Radiation Measurement Program. 2004b. Surface Meteorological Observation System (SMOS) instrument specifications, http://www.arm.gov/instruments/static/co2flx.stm last update June 23, 2004.

Battelle. 2002. Generic Verification Protocol for Optical Open-Path Monitors. Environmental Technology Verification Program. Advanced Monitoring Systems Center, Columbus Ohio. http://www.epa.gov/etv/pdfs/vp/01_vp_openpath.pdf

Boreal Laser, Inc. 2003. GasFinder2.0 Portable System Operation Manual. Ver 0.39, Boreal Laser, Inc, Spruce Grove, Alberta, Canada, 38 p.

Innova AirTech Instruments. undated. 1412 Photoacoustic Field Gas Monitor. Technical Documentation. BE6011-11. 252 p

Laubach, J, FA Kelliher. 2005. Measuring methane emission rates of a dairy cow herd (II): results from a backward-Lagrangian stochastic model. *Agric. For. Meteorol*. 129(3-4):137-150.

Midwest Laboratories, Inc. 2004. Quality Assurance Manual. Ver 6, Midwest Laboratories, Inc, Omaha, NE, 138 p.

Myers, J, T Kelly, C Lawrie, K Riggs. 2000. Environmental technology verification Report: Boreal Laser Inc. GasFinder 2.0 Tunable Diode Laser Open-Path Monitor. ETV Advanced Monitoring Systems Center, Battelle Laboratories, Columbus, OH

SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP C4. 2006. Standard Operating Procedure for the Synthetic Open Path Sampling System. Standard Operating Procedure C4. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP E3. 2006. Measurement of Solar Radiation with the LiCOR model 200SL or 200SZ Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP G5 2006. Standard Operating Procedure for Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450C Pulsed- Fluorescence Analyzer Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP M1. 2006. Manure Sampling. Standard Operating Procedure M1. Purdue Ag Air Quality Lab.

SOP M2. 2006. Conducting pH Measurements on Manure Samples. Standard Operating Procedure M2. Purdue Ag Air Quality Lab.

SOP M3. 2006. Determining Solids Content of Manure Samples. Standard Operating Procedure M3. Purdue Ag Air Quality Lab.

SOP M4. 2006. Determining Total (Kjeldahl) Nitrogen Content of Manure Samples. Standard Operating Procedure M4. Purdue Ag Air Quality Lab.

SOP M5. 2006. Determining Ammonia Content of Manure Samples. Standard Operating Procedure M5. Purdue Ag Air Quality Lab.

SOP O1. 2006. Emissions Estimation Using Backward Lagrangian Stochastic (bLS) Model. Standard Operating Procedure O1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP O2. 2006. Emissions Estimation Using Radial Plume Mapping (RPM). Standard Operating Procedure O2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W1. 2006. Measurement of Atmospheric Temperature and Humidity with the Viasala Model HMP45C Sensor and Solar Shield. Standard Operating Procedure W1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W3. 2006. Measurement of Wetness with the Campbell Scientific Model Resistance Grid. Standard Operating Procedure W3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W5. 2006. Measurement of Barometric pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer. Standard Operating Procedure W5. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware. Standard Operating Procedure W6. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

US Environmental Protection Agency. 2005. EPA-Boreal CRADA Test #1. Scanning tunable diode laser system for fugitive emission measurement applications. Draft Quality assurance plan, Category IV/ Basic Research.

US Environmental Protection Agency. 1999. Compendium Method TO-16: Long-Path Fourier Transform Infrared Monitoring Of Atmospheric Gases. Office of Research and Development. Washington, D.C. EPA/625/R-96/010b.

US Environmental Protection Agency. 1997. EPA Traceable Protocol for Assay and Certification of Gaseous Calibration Standards, National Exposure Research Laboratory, Research Triangle Park, NC. EPA-600/R-97/121

US Environmental Protection Agency. 1992. Method 301- Field Validation of Pollutant Measurement Methods from Various Waste Media. Notice, Part IV, Environmental Protection Agency, Federal Register 57(250) 61998-62002.

US Environmental Protection Agency. 2000. Meteorological Monitoring Guidance for Regulatory Modeling Applications. Office of Air Quality Planning and Standards. Research Triangle Park, NC. EPA-454/R-99-005.

8. Special Training Requirements/Certification

TDLAS and other ambient air monitoring must be performed by qualified personnel. Supervisors must be experienced in the operation of the open path TDLAS, UV-DOAS, PAS and PFA monitors and knowledgeable in open-path TDLAS, UV-DOAS, PAS and PF theory as well as the theory and operation of the sonic anemometer. The site operators and staff must be thoroughly familiar with all SOPs for this project and the reference manuals supplied by all instrument manufacturers. A record of SOPs read and understood and training completed will be kept by each FOS.

Training for the open-path TDLAS and UV-DOAS (if method is validated for H_2S measurement) will consist of a group training session conducted by factory representatives or their designate prior to the measurements. Training for the PAS multigas and PFA (if H_2S measurement method is not validated) analyzers will consist of a group training session conducted by the PM or his designate. Training on the use of the emissions models will be conducted by the PM in conjunction with the model authors. Training on the meteorological and data communications equipment will be conducted by the PM or his designate. Basic training for medical emergencies will be conducted by certified staff. Additional training will occur as needed on the job by either communication with manufacturer representatives or the PM. To maximize operational efficiencies and minimize lost data due to illness, all personnel in the project excluding the SA will take part in the training.

Records of the date, type of training, and satisfactory completion of training for each individual and each instrument and method will be ensured by the QAM with documentation of completion maintained by the PM. All personnel will follow Standard Operating Procedures (SOPs) when carrying out their duties. Appendix A contains all SOPs used in this study.

Training of the laboratory analysts at the commercial laboratory (Midwest Laboratories, Inc., 13611 B St., Omaha, NE; Lab ID E87918) is conducted by the Midwest Laboratories Laboratory Supervisor according to their Quality Assurance Manual. Certification of the laboratory to conduct the analyses to the EPA methods indicated in this study is conducted by the Environmental Laboratory Certification Program of the Florida Department of Health. Certification Certificates are provided by the laboratory to the SA on request. The Certification will be requested regularly from the Laboratory by the SA or his designate based on the expiration date of the previous certificate.

References

Boreal Laser, Inc. 2003. GasFinder2.0 portable system Operation Manual. Ver 0.39, Boreal Laser, Inc, Spruce Grove, Alberta, Canada, 38p.

Campbell Scientific Inc. 2004. CR1000 Measurement and Control System Operators Manual, preliminary, Logan, UT.

Innova AirTech Instruments. undated. 1314 Photoacoustic multi-gas analyzer, 1412 Photoacoustic Field Gas-Monitor. Technical Documentation. BE6011-11. 252 p

Midwest Laboratories, Inc. 2004. Quality Assurance Manual. Ver 6, Midwest Laboratories, Inc, Omaha, NE, 138 p.

RM Young. 2005. Manual for Model 81000 ultrasonic anemometer, Rev C031405. R.M. Young Co., Traverse City, MI. 9p.

9. Documents and Records

Field and laboratory documentation is necessary for the successful completion of the project. The various types and levels of documentation required for this study are described below.

9.1 Field operations documentation

Manure samples will be collected at the corral and at the basin location by the FOS at the beginning of each measurement period. Three composited samples will be stored on ice and transported to the commercial laboratory for analysis at the time of each manure sampling event. Details of the sampling protocol are found in SOP M1. A chain of custody form (example in Appendix D) will be transmitted with the samples to the laboratory.

Each site visit by the FOS/PI (typically at the beginning and end of each measurement period for the rotating farm locations and at least every 21 d for the continuous monitoring locations) will involve physical inspections, QC checks and calibration verifications. At the end of each measurement period, the FOS/PI will collect from the producer any production and activity records for the measurement period. The PM will receive by email all updated logs on a daily basis while personnel are on site. Listed below is a summary of the field documentation required:

- Activity log book (as Adobe Acrobat pdf files) maintained at each monitoring site.
- Production and activity records provided by the producer- including the documentation of animal inventories and weights, feed compositions, water quality tests, lagoon water/basin manure removal events, land manure application events, agitation periods, power failures, etc.
- Daily monitoring notes (as Adobe Acrobat pdf files) including equipment physical inspections, calibrations, audits, QC checks, repairs or other corrective actions, weather conditions, power failures.
- Results of in-field QC checks on instruments during the beginning and end of measurement periods and any non-routine equipment investigations (as Adobe Acrobat pdf files and Microsoft EXCEL® files; examples in Appendix D)
- Chain of custody forms for manure (for basin location) and manure, feed, milk, and bedding samples (for corral locations) (example in Appendix D).
- Chain of custody forms for data CD and DVD transfers (example in Appendix D).
- Analytical instrument and analysis log books (as Adobe Acrobat pdf files and Microsoft EXCEL® files) for QC checks and reanalysis (examples in Appendix D).
- Inventory control spreadsheets (in Microsoft EXCEL®) for the timely replacement of expendable supplies.
- Meteorological equipment logbook and checklist for operations, repairs, QC checks, and audits (example in Appendix D).
- Site drawings (found in SMPs in Appendix C).
- Site installation QC checksheets (example in Appendix D).
- Amendments and/or deviations from this QAPP and the appended SOPs and SMPs.

Unless indicated otherwise, all forms are appended to the individual applicable SOPs

In general, documents will be electronic in form, although two printed copies of the completed documents will be made at the completion of each sampling period, with one stored on site and a second hand-carried to Purdue by field operations staff. Paper forms will be filled out in indelible ink and scanned and stored in a project file on the LAN server computer (Management of Open-Source, Weather, and Lagoon Characterization Data Standard Operating Procedure, SOP D1). Corrections to paper documents will be made in indelible ink with deletions struck by single line. All corrections will be initialed by the author of the correction and form rescanned and stored in a project file on the LAN server computer with a suffix in the filename of '–cor'. A printer will be located at each measurement location to create paper forms on demand and a scanner will be located at each location to scan images of hand-written notes and drawings for electronic storage.

All forms and logs for a given measurement location will be stored by site/measurement period. The DM will maintain the validated, quality-coded meteorological and analytical data by site and measurement period (SOP D1) on a dedicated computer for their particular portion of the study. Additionally, the DM will place this data on a computer network so that the data will be available in a timely manner to the personnel for ready distribution to inquiries for information. Copies of these validated, raw data will be maintained on the PDM and DM computers throughout the study period, as long as deemed necessary by the SA.

Data management is described in SOP D1. Raw data files represent files of data as received at the instrumentation trailer from the meteorological and lagoon/ basin measurement data logger, the GSS data logger, the two TDLAS systems, two UV-DOAS systems (if H_2S measurement method is validated), the PF analyzer (if H_2S measurement method is not validated) and the PAS analyzer. These data are already provided in standard units from their respective control and processing software. The files are then evaluated according to the quality assurance protocols defined in their respective instrument SOP and QA flags are added to each data value. All instruments will have calibration data files associated with calibrations conducted on-site and at Purdue. The emissions calculations resulting from the use of the RPM and bLS models with corresponding QA evaluations (indicated by a flag for each value) will be done at PAML. A summary of the types of files and storage devices used to store the files developed by each major measurement component of the project are listed in Table 9.1.

Any files in which data is corrected will be stored in the same directory as the original data file with the suffix '-cor' to the filename and the nature of the correction(s) documented in an EXCEL spreadsheet.

Table 9.1 Electronic data records.

File characterization	Turbulence	Meteorology	Lagoon/ basin/corral[1]	PAS	PFA or UV-DOAS	TDLAS	S-OPS, GSS
Raw data	DVD	Memory card CD	Memory card CD	CD	CD	CD	CD
Post process w/flags	HD	HD	HD	HD	HD HD	HD HD	HD HD
Calibration files		CD,HD	CD,HD	CD,HD	CD,HD	CD,HD	CD,HD
Emission w/flags					CD, HD	CD, HD	CD, HD

[1] Measurements characterizing the lagoon/basin or corral

9.2 Laboratory operations documentation

The commercial laboratory will document the person receiving the samples, number of samples, temperature of the samples, integrity of the sample containers, and time of receipt on arrival of the samples to the laboratory on the chain of custody form. The laboratory report on each sample set (specific location and sample date) will include:

- Name of submitter of the sample
- Sample origin location, date, time, type, and replicate number
- Date and time of receipt at laboratory
- Name of individual receiving sample
- Condition of sample on receipt
- Analyses requested
- Number of sample containers
- Time of analysis for each analyte.
- Measured values for each analyte in samples (pH, total nitrogen, ammoniacal nitrogen, total solids, total volatile solids)
- Initials of the analyst for the measurement
- Measured blanks, spikes, and replicates of samples.
- Results of instrument calibrations
- Corrective actions if instrument fails any performance check
- Deviations in procedures from those indicated in SOPs M2 through M5

Copies of all above field and laboratory documents will be maintained by the PM.
Copies of this QAPP, all SOPs, software, and instrument manuals will be kept with each team on-site. Copies of all log sheets, forms, and checklists will be maintained in the project files throughout the study period and for six years after the completion of the study.

Changes to the QAPP or SOPs will be made as necessary, with approval by the QA Manager, PM, and SA in consultation with the USEPA Quality Assurance Manager. Changes will be reported by email to all participants listed in section 3. Copies of any changed QAPP sections and SOPs will be routed to the same list defined in section 3.

The interim and final reports for the study will include summaries of validated data, documentation of invalidated data fractions, summary measurement statistics, charts of validated data if appropriate, and a discussion of quality assurance audits.

All validated data for the reporting period will be provided in electronic form to EPA at the time of each report. Records resulting from this project will be retained for a period of not less than six years by the SA and PM.

References

Atmospheric Radiation Measurement Program. 2004. Atmospheric Radiation Monitoring Network: Standard Operating Procedures

SOP D1. 2006. Management of Open-Source, Weather, and Lagoon Characterization Data. Standard Operating Procedure D1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP M1. 2006. Manure Sampling. Standard Operating Procedure M1. Purdue Ag Air Quality Lab.

B. Data Generation and Acquisition

10. Sampling Process Design (Experimental Design)

The experimental design outlines the configuration of equipment to be used in the study, the sampling and averaging intervals to be used in the study, and the manner in which the study integrates the sampling-related information. The general protocol used in the study has been reviewed by a scientific panel of some 30 scientists between 2003 and 2006. Specifics associated with most SOPs have been evaluated by leading scientists in the respective fields associated with each measurement. No further review of methodologies is planned.

Siting criteria: The primary objective of instrument siting is to place the instrument in a location where it can make precise measurements that are representative of the general state of the atmosphere upwind or downwind of the storage facility that is consistent with the objectives of the data collection program. AFO lagoons and basins are not located with consideration for potential gaseous and air flow measurements. Trees are often used to reduce visibility of the lagoons and the distance between barns and lagoons are often too close to separate the barn emissions from the exhaust fans from the lagoon or basin. In addition, lagoons are often built up from the surrounding ground by the soil removed to form the lagoon, especially in areas with high water tables, creating a substantial berm height. Consequently, great care has been taken in locating the best possible ten farms for the study measurements and deviations from the preferred lagoon surroundings have been minimized. Specific locations chosen for the study are documented in the SMPs in Appendix C. Additional site photographs (beyond those in the respective SMP) will be taken at each site location. Latitude and longitude coordinates along with site elevation will also be measured by GPS and documented. Details of the siting criteria are found in the Installation of Open Source Measurement Equipment Standard Operating Procedure (SOP U5). Guidelines for the siting of equipment, and hence the choice of farms to be measured follow.

10.1. Meteorological measurements

Meteorological stations will be established at each site location to collect data to support the study. The parameters to be measured at all of the sites are the turbulent components of the wind, horizontal wind speed, wind direction, temperature, relative humidity, and barometric pressure. Meteorological parameters at the lagoon/ basin sites will be measured at 2 m above berm height (abl), 4 m above ground level (abl), and 16 m abl. The meteorological equipment will be located adjacent to the waste storage areas under study according to SOP U5 and SOP W6. The siting criteria for the wind speed, direction, temperature, relative humidity, solar radiation, and barometric pressure sensors are generally in accordance with the Quality Assurance Handbook for Air Pollution Measurement Systems: Volume 4. The desire is to locate sensors in areas of open terrain to comply with the assumptions used in the emission models. Open terrain is defined as an area where the horizontal distance between the instrument and any obstruction (building, hill, trees and other vegetation) is at least ten times the height of that obstruction.

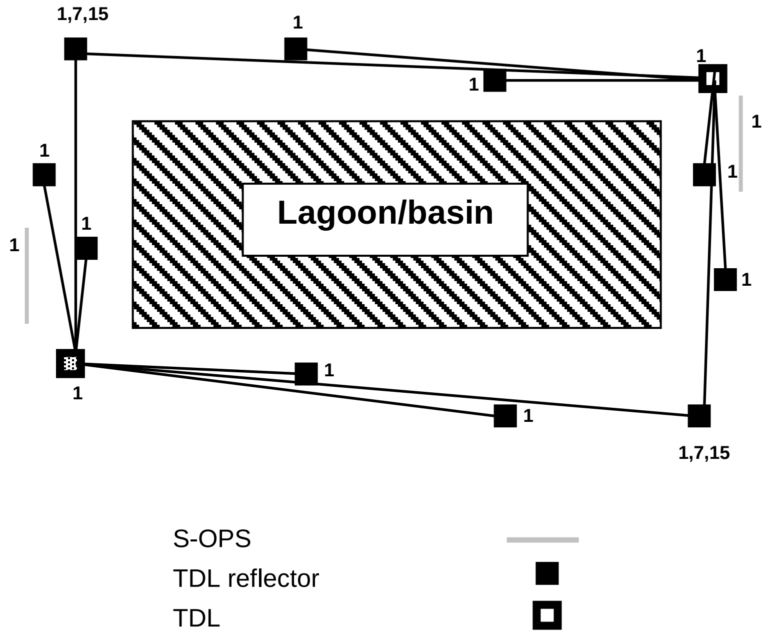

Figure 10.1- Example of lagoon/basin open path sampling plan. Labels represent height of instrument or retro-reflector in meters above lagoon/ basin berm.

Meteorology Towers: Meteorology towers will be located near the lagoon or basin or in an open level area such that instruments will be downwind of the lagoon or basin (based on prevailing wind direction) and unaffected by local obstructions or objects such as buildings, building exhaust fans and have minimal effects from hills and valleys. The towers will be located at a distance away from the obstruction of at least ten times the nearest upwind obstruction's height and three times the nearest downwind obstruction height. These protocols may be difficult to accomplish at all locations. Deviations from these protocols will be documented. Orientation and positioning of the towers at a lagoon or basin measurement location is detailed in SOP U5 (Figure 10.1). Orientation and positioning of the towers at a corral measurement location is detailed in the Installation of Open Source Measurement Equipment (Corrals) Standard Operating Procedure (SOP U7).

Wind Speed and Wind Direction Sensor (sonic anemometer): The locations of the wind sensors differ by type of measurement location; lagoon/ basin or corral. According to the World Meteorological Organization (WMO), the standard height for wind instruments over level, open terrain is 10 m above the ground. All lagoon/ basin measurement locations will have sensors at 2 m above berm level (abl) and 4 m and 16 m abl to provide wind profile information for the RPM emission measurements (described later) (SOP U5). Wind sensors will be 0 to 10 m from the edge of the berm at the lagoon and basin sites, more than 10 times the fan diameter away from building exhaust fans for mean wind measurements associated with the RPM emissions model (for 4 ft diameter fans, 40 ft) and 30 times the fan diameter away from the building exhaust fans for turbulence measurements associated with the bLS emissions model (for 4 ft diameter fans, 120 ft). Preferably, wind measurements will be made downwind of the lagoon or basin (based on prevailing wind direction). In general, the lagoon berms of the study locations are less than 1 m high. Consequently the distance from the anemometers to an obstruction will be at least 10 times the difference in height of the sensor and the nearest obstruction. The close proximity of the sensors to the measurement plane of the TDLAS beam paths is desired to reduce RPM emissions calculation error (RPM method described later). A 3D sonic anemometer will be securely mounted on the top of a 2-m mast and a 15-m corner tower. One additional 3D sonic anemometer will be mounted on a corner tower on a boom projecting at least two tower diameters away from the tower at 4-m height. This boom will be in a direction that provides the least wind distortion due to the tower structure for the most important wind direction or the prevailing wind direction. In this study, the wind speed and direction sensors will be combined using the 3D sonic anemometers. This is a critical project measurement.

Wind sensors will be at least 100 m from the edge of the feedlot at the corral sites to minimize roughness changes associated with the corral, providing a fetch of at least 10 times the height of the nearest obstruction. The anemometers will be securely mounted at the top of 2-m masts within 10 m of TDLAS paths along the sides of the corral.

Temperature and Humidity Sensors: The On-Site Meteorological Program Guidance for Regulatory Applications indicates temperature sensors must be housed in a ventilated radiation shield to protect the sensor from thermal radiation and should be mounted over a plot of open level ground at least 9 m in diameter. The ground surface should be covered with non-irrigated or un-watered short grass or, in areas where grass does not grow, natural earth. The surface must not be concrete or asphalt. The standard height for recording surface temperature and humidity is 2 m agl. Guidelines indicate that the sensors should not be closer to obstructions such as trees and/or buildings than a distance equal to four times their height. While guidelines indicate the sensors should be at least 30 m from large paved areas and not close to steep slopes, ridges, or hollows, in this study, the sensors will be between 0 m and 10 m from the lagoon/ basin berm and 1 m abl (SOP U5). The proximity of the sensor to the water body is consistent with it’s use as a means to correct the measured gas concentration for ambient temperature and water vapor. At the lagoon/ basin sites in this study, the temperature and relative humidity instrument will be mounted in an unventilated radiation shield at 1 m abl. At the corral sites, the temperature and relative humidity instrument will be mounted in an unventilated radiation shield at 2 m agl at a distance of 100 m from the corral. The error induced in the gas law correction for temperature by not ventilating the sensor is small since a 2^{o}C error (typical difference between a non-ventilated to ventilated temperatures) induces an error of approximately 1% in the gas law correction to a gas concentration measurement. This is a non-critical project measurement.

Solar Radiation Sensors : On-Site Meteorological Program Guidance for Regulatory Applications indicates that solar radiation measurements should be taken throughout the year in a location free from any obstruction that could cast a shadow over the sensor. The sensor should not be located near light colored walls or artificial sources of radiation. In this study, the solar radiation sensor will be mounted on a beam off the south side of the meteorology mast/tower (SOP U5). This is a non-critical project measurement.

Wetness sensors: Guidelines derived from numerous studies indicate that the wetness sensor should be oriented off horizontal. Because the purpose of this sensor is to estimate whether there has been rain or dew to wet the ground or add to the lagoon, sensor height is not critical provided it is above vegetation and not under obstructions. For this study the sensors will be mounted at approximately 30° slope on the meteorology mast/tower near the height of the lowest sonic anemometer (SOP U5). This is a non-critical project measurement.

Barometric Pressure Sensors: Sensor height is not critical, however, 2 m agl is generally considered acceptable. The sensor should be protected from wind by placement within an enclosure. In this study the sensor will be mounted within a NEMA 4 box at 1 m abl on the meteorology mast/tower (SOP U5, SOP W6). This is a non-critical project measurement.

Sampling plan: All measurements except wind measurements will be made every 5 s with statistics calculated at 5-min intervals on a data logger (SOP W6). Wind measurements will be made at 100 Hz, filtered to 16 Hz (SOP W2) with statistics calculated on 100-s intervals and recorded on the LAN server computer in the instrumentation trailer (SOP D1).

10.2. Open path TDLAS

Siting criteria: The general site configuration is found in SOP U5. Two scanning open path TDLAS instruments will be mounted on opposite corners of the monitored lagoon or basin (Figure 10.1). Each open path system will be oriented approximately parallel to the (assumed rectangular) lagoon or storage area side and between 0 m and 10 m from the lagoon/ basin edge to minimize edge-of-source problems. Each of two monostatic TDLAS systems, located on opposite corners of the lagoon or basin, will scan five retro-reflectors on each of two adjacent sides of the lagoon or storage area: three at 1 m abl equally subsecting the length of the lagoon/ basin and two at 7 m agl and 15 m agl on a tower located at the corner down the adjacent sides of the lagoon or storage area (Figure 10.2). This will result in scan lines down each of the four sides of the lagoon/ basin. The locations of the corner towers and scanners will be determined after considering the prevailing wind direction(s) and wind obstructions such as trees, buildings, and building exhaust fans.

TDLAS Source/Receiver: The source/receiver will be located up to 10 m from the corner of the lagoon or storage facility in an open level area such that instruments will be unaffected by local obstructions or objects such as buildings and paved parking lots and minimizing the effects of hills and valleys. The instrument will be mounted at least 1 m above the top of any berm on a scanner that will move the TDLAS laser beam to aim at each of the ten retro-reflectors in sequence.

<u>TDLAS retro-reflectors</u>: For each side of the lagoon or basin, three retro-reflectors will be located at 1 m height above the berm at 0.3W, 0.7W and approximately 1.1W distance across the width of the lagoon or basin (W) and up to 10 m away from the lagoon berm (Figure 10.2). Two additional retro-reflectors will be mounted at 7 m agl and 15 m agl on a tower located approximately 1.1W from the TDLAS. (Figure 10.2). Assuming a lagoon with no elevation of the berm, the resulting mean scan path height associated with the highest retro-reflector (15 m agl) across the width of the lagoon is 7.5 m agl. This height is approximately the σ_z of a Gaussian plume under the slightly-unstable Pasquill stability class C. All retro-reflectors will be located such that an unobstructed view of the source/receiver is possible. In addition, every effort will be made to locate beamlines such that:

- Retro-reflector towers are in the direction of the prevailing winds and more than their height away from power lines.
- Beamlines are more than 10 times the diameter of the fan away from barn fans.
- Retro-reflectors and scanners are more than 1 m away from on-farm vehicular traffic, 3 m away from off-farm vehicular traffic, and 5 m away from irrigation equipment.

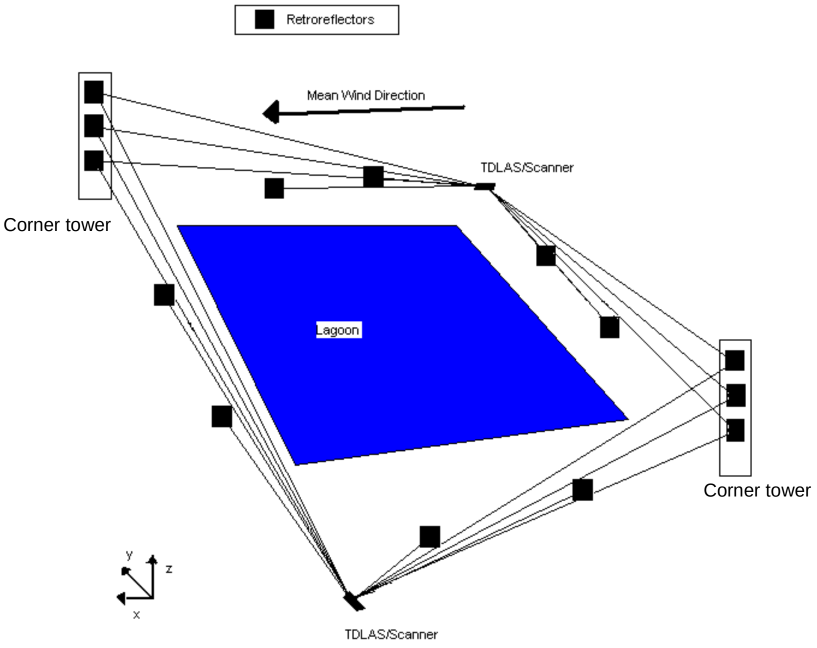

Figure 10.2 Example of a TDLAS Setup. Filled squares represent retro-reflectors. Lines represent optical paths

Specific configurations for the farms to be studied are found in the SMPs in Appendix C. These are critical project measurements.

Sampling plan: A complete set of measurements per TDLAS instrument consists of ten beamline PICs. Samples of each beamline will be sequential and continuous. The ten beamlines represent two sets of five beamlines that each define a vertical measurement plane along adjacent sides of the lagoon/ basin. Each vertical measurement plane is measured along five beamlines sequentially sampled over approximately100 s (15 s dwell time with approximately 5 s time for moving to new OP position for each of 5 OP). On completion of the series of five beamlines along one vertical measurement plane, the instrument will align with the second measurement plane and measure the PIC along five beamlines over the next approximately 100 s (Figure 10.3). An emission rate using the RPM method will be calculated after each complete cycle (approximately 100 s).

```
                         Time ----------------→                          Averaging
Measure                                                                    interval
PAS        |----------side A---------------------|-------side B--------------------------|   900-s
TDLAS-1    |----|    |----|    |----|    |----|    |----|    |----|    |----|    |----|    |----|    |  ~100-s

TDLAS-2    |    |----|    |----|    |----|    |----|    |----|    |----|    |----|    |----|    |----|  ~100-s

RPM        |--1-|-2-|--1-|-2-|-1--|-2-|-1--|-2-|-1--|-2-|-1--|-2-|-1--|-2-|-1--|-2-|-1--|-2-|  ~100-s

UV-DOAS    |----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|   100-s

PFA        |----------side A---------------------|-------side B--------------------------|   900-s

bLS        |---------------------------------------|---------------------------------------|   900-s
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Figure 10.3 Coordination of sampling times at lagoon/basin locations. Each dash represents 20-s. Vertical lines indicate last 20-s for averaging (or integrating) time.

Siting criteria - corrals:

The general site configuration is presented in SOP U7. Two scanning open-path TDLAS instruments will be mounted on opposite corners of the monitored corral (Figure 10.4) with beamlines at 1 m abl along all sides of the corral (Figure 10.4). The locations of the retro-reflectors and scanners will be determined after considering the prevailing wind direction(s) and wind obstructions such as trees, wind structures, and buildings.

TDLAS Source/Receiver: The source/receiver will be located up to 100 m from the corner of the corral facility in an open level area, such that instruments will be unaffected by local obstructions or objects such as buildings and paved parking lots, and minimizing the effects of hills and valleys. The instrument will be mounted at least 1 m agl on a scanner that will move the TDLAS laser beam to aim at each of the retro-reflectors in sequence.

TDLAS retro-reflectors: For each side of the corral system, one retro-reflector will be located at 1 m height near or beyond the length of the corral and up to 100 m away from the corral (Figure 10.4). All retro-reflectors will be located such that an unobstructed view of the source/receiver is possible. In addition, every effort will be made to locate beamlines such that retro-reflectors and scanners are more than 1 m away from on-farm vehicular traffic, 3 m away from off-farm vehicular traffic, and 5 m away from irrigation equipment. Specific configurations for the farms to be studied are found in the SMPs in Appendix C. These are critical project measurements.

Sampling plan: A complete set of TDLAS measurements consists of two to three beamline PIC measurements per TDLAS instrument. Samples of each beamline will be sequential and continuous. Each beamline will be sampled over 15-s dwell time (Figure 10.3). After twenty complete cycles (approximately 600 s or 10 min), the average PIC of each beamline and corresponding emission rate will be calculated.

10.3 Synthetic Open path System with PAS and PFA or open path UV-DOAS

Siting criteria - lagoon/basin sites: Two synthetic open-path systems (S-OPS) will be mounted on opposite sides of the monitored lagoon (Figure 10.1). Each S-OPS will be mounted approximately 2-4 m from the edge of the lagoon and within 2 m of a TDLAS path, 1 m height above the lagoon berm. The S-OPS will be approximately 50 m long. A multipoint air sampling system in the shelter will draw air sequentially from the nominally upwind and downwind S-OPS and deliver selected streams to a manifold, from which on-line PFA and PAS gas monitors draw their sub samples. Previous experience (Heber et al, JAWMA, 2006) has shown that the residence time for gas in a 300-ft long, ¼″ diameter sampling line of the type used here, flowing at 4 L/min, is approximately 45 s. Tubing connecting the S-OPS to the gas sampling system (GSS) will be approximately 500 to 1000 m long, resulting in a residence time in the tubing of 192 to 382 s when the flow is at least 5 L/min flow rate (Table 10.1). Each S-OPS is sampled for 15 min, using the first 3 min to allow the source air to reach the analyzer and the next 8 min to allow the gas analyzers to reach and maintain equilibrium. The distance from the analyzer manifold of the GSS to the analyzers themselves will never exceed 3 m (10 ft), which is well within the sample-drawing capabilities of each analyzer. Sample flow will always exceed the total draw of the gas analyzers by at least 25%.

Sampling plan: The GSS sampling manifold pressure and analyzer manifold flow rate and flow direction will be sampled continuously every 30 s. The PF analyzer will measure H_2S

concentrations of air coming from the GSS every minute. The PAS analyzer will measure NH_3 and VOCs in the air coming from the GSS every minute. The samples (omitting the first four minutes and last minute of each 15-min interval) will be averaged every 15 min. Each S-OPS will be sampled sequentially every 15 min, resulting in an upwind and downwind average pair every 30 min. Emission rates for the H_2S and VOC will be calculated for each 30-min period.

Table 10.1. Residence time in sampling lines, as a function of sampling line length and flow rate.

	Flow rate (L/min)	
Tube length, m	**5**	**10**
0 (GSS only)	2 s	1 s
50	21 s	10 s
100	40 s	20 s
200	78 s	39 s
500	192 s	97 s
1000	382 s	191 s

Notes:
Tubing ID = 0.25 in (0.0064 m)   Tubing internal volume = 0.97 L/100 ft
Sampling manifold is 20 in long, with a 3/8″ ID, for a volume of 0.036 L; Sampling pump has a volume of 0.06 L.

If the UV-DOAS measurement of H_2S is validated, the UV-DOAS systems will be located as follows:

- _UV-DOAS Receiver_: The UV-DOAS receiver will be located within 10 m of the TDLAS source/receiver and at least 10 m from the lagoon edge.
- _UV-DOAS Source_: The UV-DOAS source will be located at least 10 m from the lagoon edge and 1 m above the lagoon berm at a distance of between 50 and 150 m from the UV-DOAS receiver.

Every effort will be made to locate beamlines such that they are within 1 m of berm height, more than 30 times the diameter of the fan away from barn fans, more than three times the height of the nearest downwind obstruction away from the downwind obstruction, and more than ten times the height of the nearest upwind obstruction away from the upwind obstruction. In addition, the siting of receiver and source will be more than 1 m away from on-farm vehicular traffic, 3 m away from off-farm vehicular traffic, and 5 m away from irrigation equipment.

Specific configurations for the farms to be studied are found in the SMPs in Appendix C. These are critical project measurements.

Sampling plan - lagoon/basin sites: If the UV-DOAS method for H_2S measurement is validated, the UV-DOAS will sample the ambient air concentration of NH_3 and H_2S at approximately 100-ms integration times with values averaged every 100-s and 5 min (Figure 10.3). Two 5-min integrations will be averaged to 10-min intervals in matching periods of 10-min intervals of valid wind measurements for NH_3 and H_2S emissions calculations.

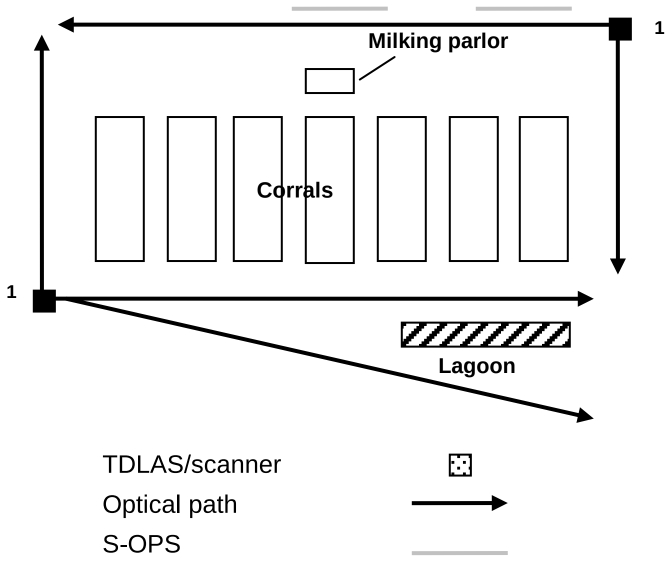


Figure 10.4- Example of corral open path sampling plan. Labels indicate height of instrument in meters.

If the UV-DOAS method for H_2S measurement is not validated, the S-OPS will sample the ambient air for analysis using PFA with values averaged for each 15-min interval (Figure 10.3). Regardless of the validation of the UV-DOAS, the S-OPS will sample the ambient air for VOC analysis using PAS with values averaged for each 15-min period (Figure 10.3). Each 15-min interval will be paired with the 15-min average of periods of valid wind measurements for VOC (and H_2S emissions if the UV-DOAS is not validated) calculations.

<u>Siting criteria - corral site</u>: Two open-path S-OPS paths will be mounted at least 100 m away from the predominant upwind side of the dairy corral operation to provide at least a 50:1 fetch (Figure 10.4). If the UV-DOAS method is validated for H_2S, UV-DOAS paths will be mounted at least 100 m away from the predominant upwind and downwind sides of the corral operation to provide at least a 50:1 fetch (Figure 10.4). Each S-OPS or UV-DOAS system will be mounted at 1 m agl. The S-OPS will be located within 5 m of a TDLAS path. The locations of the S-OPS and/or UV-DOAS will be determined after consideration of the prevailing wind(s) and terrain. Every effort will be made to locate paths that are more than 1 m away from on-farm vehicular traffic, more than 3 m away from off-farm vehicular traffic, and more than 5 m away from irrigation equipment. Specific configuration for the farm to be studied is found in the respective SMP in Appendix C.

<u>Sampling plan - corral site:</u> If validated for H_2S measurement, the UV-DOAS will measure H_2S in ambient air, and the S-OPS will sample the ambient air for measurement of VOC. If the UV-DOAS is not validated for H_2S measurements, the S-OPS will sample the ambient air for

measurement of H_2S. H_2S and VOC measurements will be averaged in 15-min periods for reported concentration measurements.

10.4 Photoacoustic multi-gas analyzer

(section deleted)

10.5 Lagoon/basin characterization

Lagoon or basin parameters to be recorded on site will include dimensions, volume and years in service. At lagoons, the pH (SOP L1), redox potential (SOP L3), depth of solids (Markland Sludge Gun Standard Operating Procedure; SOP L5) and temperature (SOP L2) will be continuously recorded during each measurement period. At the basin, the manure will be sampled and laboratory measurements of pH (SOP M2), total nitrogen (SOP M4), ammonia nitrogen (SOP M5) and total and volatile solids content (SOP M3) will be made. These are non-critical project measurements.

Sampling plan: Lagoon pH, redox potential, and temperature will be sampled every 5 min at 0.3 m depth on a data logger (SOP D1). Depth of solids will be manually determined by optical transmission at the beginning or end of each measurement period (SOP L5). Manure samples at the basin will be collected from three random locations near the basin rim or berm (SOP M1) at the beginning or end of each measurement period) with specifics addressed in SMP IA3A. A record of the sample number codes and any deviations in sampling protocol resulting from inaccessibility will be documented in the Field Notes for the sampling day. Samples will be shipped to Midwest Laboratories, Inc. within one day of collection by overnight shipping. Total transit time will not exceed two days. If a sample is lost or sample integrity compromised, the samples will be retaken at the conclusion of the measurement period. All manure samples will be analyzed at Midwest Laboratories, Inc. within 2 weeks of receipt.

10.6 Corral characterization

Manure will be sampled at the corral. Samples will be sent to Midwest Laboratories, Inc. where measurements of pH (SOP M2), total nitrogen (SOP M4), ammonia nitrogen (SOP M5) and total and volatile solids content (SOP M3) will be made. These are non-critical project measurements..

Sampling plan: Manure samples at the corral will be collected at some point during each measurement period from mixed slurries of manure collected from the corrals, the scraping lanes, the deposited manure piles, and the milking parlor (SOP M1), with specifics addressed in SMP TX5A. All manure samples will be analyzed at the designated laboratory. A record of the sample number codes and any deviations in sampling protocol resulting from inaccessibility will be documented in the Field Notes for the sampling day. Samples will be shipped to Midwest Laboratories, Inc. within one day of collection by overnight shipping. Total transit time will not exceed two days. If a sample is lost or sample integrity compromised, the samples will be retaken and resent within one week. All manure samples will be analyzed at Midwest Laboratories, Inc. within 2 weeks of receipt.

10.7 bLS method validation

The bLS method has not been validated to measure the emissions from open sources and consequently cannot be used without qualification. To validate the method, it must be compared to a validated method. There is no method that has been validated for such a measurement. Although there is no method that is validated to measure emissions from open sources, the RPM method is in the process of validation. Consequently the bLS method validation must be against the RPM method. H_2S and VOC emissions calculations can be conducted using either the ratiometric method or the bLS method. Under a situation in which not all PIC values on a RPM measurement plane are valid, emissions will be calculated using time-averaged PICs and the bLS method. Therefore the bLS method must be validated. Ideally, the validation of the bLS method should use the same measurements that the RPM method uses to reduce method errors associated with the concentration measurements. Consequently, since the TDLAS system is unable to measure H_2S or the VOCs of interest but is used in the RPM method of NH_3 emission measurement, and the S-OPS does not have sufficient paths for the RPM method; the validation of the bLS method must be through the measurement of NH_3 emissions using the TDLAS.

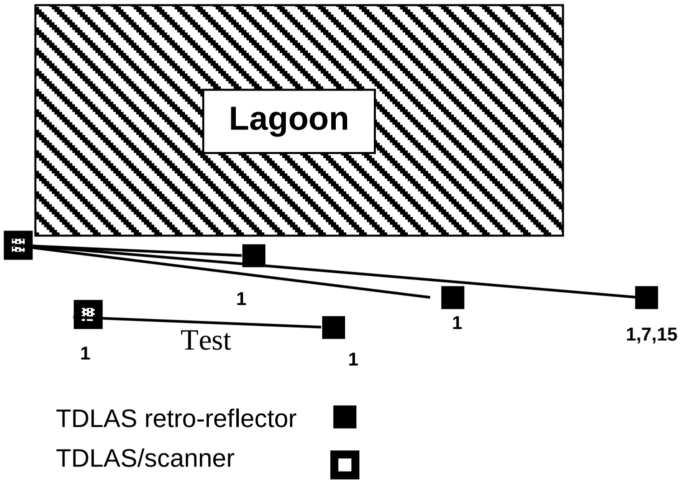


Figure 10.5 bLS Method Validation study instrument configuration. Labels represent heights of instrument or retro-reflector above lagoon berm.

Two validation studies will be conducted: (1) to validate the use of the bLS method by the RPM method for <u>continuous PIC measurements</u> along the single path used for the bLS method, and 2) to validate the use of the bLS method by the RPM method for <u>intermittent PIC measurements</u> along one of the five possible paths usually used for the RPM method:

- *Continuous PIC measurement bLS method validation*: A validation study of the bLS method will be conducted in accordance with EPA Method 301 ("Comparison with a validated method", Sections 5.2 and 6.2). One downwind side of a continuous monitoring lagoon will be instrumented with an additional TDLAS beamline (designated 'Test') according to Figure 10.5 with an established TDLAS system measuring PIC along five beamlines downwind of the lagoon. Measurements of NH_3 emissions will be made for several days using the bLS method and the single added TDLAS path and using the RPM method and the existing five TDLAS paths in conjunction with the sonic anemometers and meteorological characterization measurements described previously. From the measurement period, at least nine sets of paired 30-min measurement periods will be chosen such that the wind direction is less than 20^o off the perpendicular of the measurement plane. The final paired dataset will be used for method validation statistics based on bracketed classifications of meteorological conditions (as a function of mean wind speed and atmospheric stability). Validation and QA/QC criteria for the measurements will be identical to that for the overall study.

- *Intermittant PIC measurement bLS method validation*: The bLS method will also be used to determine the emission rate from the five individual established scan lines during the sets of 30 min measurement periods when the wind direction is less than 20^o off the perpendicular of the measurement plane. This will result in one measurement of the emissions by RPM paired with five measurements of emissions by the bLS method for each period of valid TDLAS and wind measurements. The final paired dataset will be used for method validation statistics based on bracketed classifications of meteorological conditions (as a function of mean wind speed and atmospheric stability). Validation and QA/QC criteria for the measurements will be identical to that for the overall study.

The precision of the bLS method for each individual bLS measurement will be assessed, assuming the RPM method is accurate. Since the RPM method is assumed to be accurate, the DQI associated with the RPM method will be used to restrict the measurement periods used in the validation. Since multiple independent measures of the bLS emissions calculation are possible for comparison with a single RPM measurement, a further result of the precision determination will be a collective precision estimation and possibly criteria defining optimal beamline location for bLS emissions calculations. The F-test will be used to determine if the precision of the bLS method is significantly different from that of the RPM method under a range of meteorological conditions. The experimental *F*-value is calculated according to.

$$F = \frac{S_{bLS}^2}{S_{RPM}^2} \qquad \text{(Equation 10.1)}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from a single PIC, and S^2_{RPM} is the variance of the RPM measurement method determined from the five PICs on a given side for the paired 30-min measurement periods. The experimental *F*-value will be compared to the critical range of *F* at a 95 percent confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* is above the critical range, the precision of the bLS method is significantly greater than the RPM method and the bLS method precision is unacceptable. If the experimental *F* is below the critical range, the precision of the bLS method will be accepted as equivalent to the RPM method.

The bias of the bLS method will be determined from the measurement periods and beamlines used in the precision determination. Bias will be determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval will be used (t=1.397). If the difference is significant, then the correction factor is calculated. The correction factor must fall within the range of 0.90 to 1.10 for the bLS method to be valid for measuring the emissions under the given meteorological conditions. If the correction factor is more than 1.10 or less than 0.90 then the bLS method will be used differently for lagoon/ basin and corral measurements. At the lagoon/ basin locations, the bLS model will not be considered valid for H_2S emissions estimates, and emissions of H_2S will be estimated from the ratio of PFA or UV-DOAS concentration measurements to nearby NH_3 concentration and RPM-calculated NH_3 emissions using

$$Q(H_2S) = Q_{RPM}(NH_3)\frac{\left\lfloor C_{x,j}(H_2S) - C_{x,bg}(H_2S)\right\rfloor}{\left[C_{x,j}(NH_3) - C_{x,bg}(NH_3)\right]} \qquad \text{(Equation 10.2)}$$

where the subscripts TDLAS, RPM, and x (UV-DOAS or S-OPS) refer to the instrument or method of determination, *bg* and *j* refer to the upwind and downwind path of the S-OPS, UV-DOAS, and H_2S (or VOC) and NH_3 refer to the measured gas. At the corral location, all bLS emission estimates will be considered valid but qualified at a reduced accuracy in accordance with that calculated from the validation experiment.

10.8 UV-DOAS H_2S measurement characterization and validation

The UV-DOAS instrument has not been validated for the measurement of H_2S in lagoon/manure storage environments and consequently cannot be used in the study until characterized and validated.

Characterization of the UV-DOAS H_2S measurement precision, accuracy, stability, sensitivity, and interferences in the lagoon environment will be conducted according to procedures outlined in the ETV “Generic Verification Protocol for Optical Open-Path Monitors” document. Initial characterization documented in Tables 6.1, 7.2, and A13 will be confirmed or modified in accordance with the characterization study results. The characterization will utilize a 1-m long function cell (provided by E. Thoma of USEPA) and N_2 dilutions of H_2S EPA protocol gas. The dilution system will be a calibrated Environics Inc. Model 4040 diluter operated according to SOP G11. The diluted gas streams will be introduced into the function cell while the cell is in the beam line along the lagoon edge so that characterization is in the presence of the other, potentially interfering gases emitted by the lagoon, such as acetic acid.

Validation of the UV-DOAS H_2S measurement (including precision, accuracy or bias, and stability) in the lagoon environment will be conducted according to procedures described in EPA Method 301. In this validation study, the UV-DOAS will be compared to a synthetic open-path system (S-OPS) using the Standard Operating Procedure for the Synthetic Open-Path Sampling System (SOP C4) in conjunction with Pulsed-Fluorescence H_2S Analyzers (USEPA Method EQSA-0486-060 and EMTIC TM-006C) using Standard Operating Procedure for the Measurement of Hydrogen Sulfide with the Thermo Electron Corporation Model 450I Pulsed-Fluorescence Analyzer (SOP G5) as suggested by EPA OAQPS personnel. The S-OPS consists of the measurement of gas concentration from a gas sample drawn uniformly from multiple points along a sampling line simulating the beamline of an open-path measurement. The H_2S measurements made with two UV-DOAS systems will be compared to those obtained with the two S-OPS over a period of 21 d (the maximum duration of continuous unattended operation at the Rotation farm lagoons/ basin) at the dairy lagoons of the Purdue University Animal Sciences Research and Education Center in Montmorenci, Indiana. The study will be conducted prior to the initiation of the routine measurements (Table 4.2) The precision, bias, and stability of the UV-DOAS gas measurement system in the measurement of H_2S will be evaluated in this study.

The validation study will consist of two UV-DOAS systems and two synthetic open-path systems (S-OPS) measuring the H_2S concentrations downwind of a lagoon and synthetic H_2S source (Figure 10.6). Each S-OPS consists of ten Teflon inlet nozzles spaced 5 m apart along Teflon tubing connected to calibrated pulsed fluorescence (PF) H_2S analyzers according to SOP G5. To avoid potentially biased plume sampling due to unequal inlet flows along the entire sampling system, each nozzle will have a flow of 1 L/min that is balanced using calibrated flow meters. To minimize biased sampling due to lags in flow associated with varying distances to each air intake, the S-OPS will operate under a 10 L/min flow rate, resulting in a lag time of only 20 s for the air drawn in at the furthest inlet nozzle. To minimize the differences in sampled air volume during the study, the two UV-DOAS optical paths will be located as close together as possible, and the two S-OPS systems will be located as close as possible to the UV-DOAS beamlines without obstructing the beams. The two S-OPS will be staggered by 2.5 m so that the lateral sampling distance of the combined two S-OPS will be only 2.5 m (Figure 10.6).

To assure measurable concentrations of H_2S in the measurement volume, the lagoon will be agitated to maximize the area emission of H_2S and a synthetic line source will be used at intervals during the study. The line source will be composed of tubing with five nozzles spaced 5 m apart at 1 m agl distributing H_2S from a 10% H_2S tank, and will be located upwind of the gas measurement systems (Figure 10.6) such that the PIC along the measurement path is at least 60 ppb-100m (3 x MDL of UV-DOAS system). The synthetic line source will only be activated during 3 h per day (representing one complete tank of gas under winds less than 4 m/s and flow of 20 L/min) for at least several days when the wind is blowing in the direction of the sensors and the stability is such to assure adequate concentrations at the measurement paths (Pasquill Stability Classes A through D). Measurements and QA data from each instrument will be recorded using 30-min averages, identical to the averaging period for the study (Section 10.3). Wind conditions and stability will be monitored using the 3D sonic anemometer (SOP W2) and validation will be based on only measurements made under meteorological conditions in which the emissions methods are valid. Validation and QA/QC criteria for the measurements will be identical to those for the overall NAEMS (SOP C1, SOP G5).

The stability of the UV-DOAS gas measurement system under field conditions will be evaluated by assessing the variation in integration time and maximum peak emission over the entire study period. Analysis of the variation will include evaluation of the variations associated with sun location, temperature, winds and other weather fluctuations.

The sampling effectiveness of the S-OPS inlet spacing will be evaluated by comparing the time-varying statistics of H_2S concentration for the individual S-OPS (with 10 inlets spaced at 5 m) and the combined S-OPS (20 inlets spaced at 2.5 m).

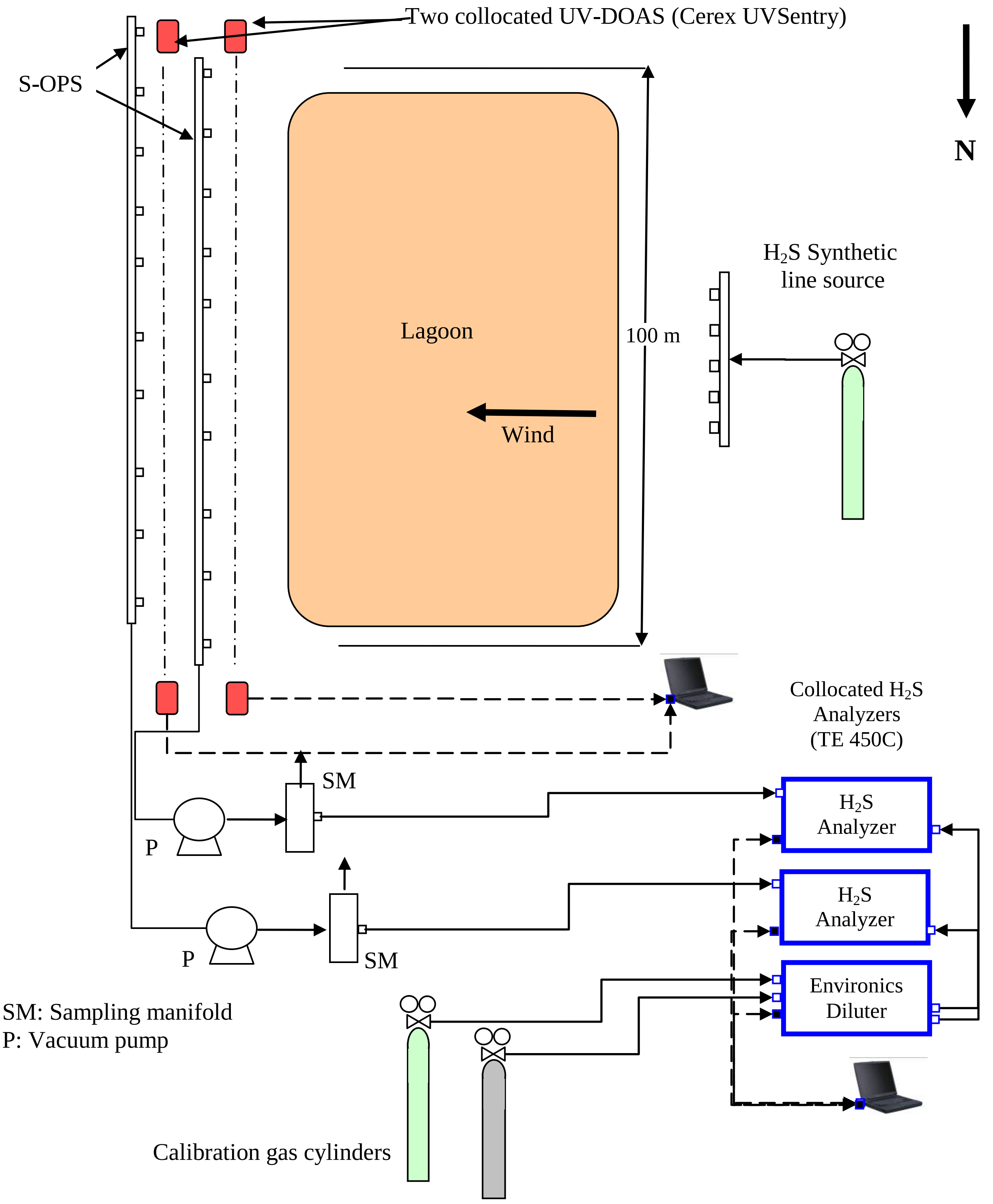


Figure 10.6. Configuration of sampling equipment and emission sources for the UV-DOAS verification study.

The average concentration of valid measurements from the two S-OPS measurement systems and the two UV-DOAS measurement systems will be used for the assessment of precision and bias of the UV-DOAS method.

The F test will be used to determine if the precision of the UV-DOAS H_2S measurement method is significantly different from that of the S-OPS H_2S measurement method. The experimental F-value is calculated according to:

$$F = \frac{S_p^2}{S_v^2} \qquad \text{(Equation 10.3)}$$

where $S^2{}_p$ = the variance of the UV-DOAS measurement method from p 100-s measurement periods and $S^2{}_v$ = the variance of the S-OPS measurement method from v 100-s measurement periods.

The experimental F value will be compared to the critical range of F at a 95 percent confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental F is above the critical range, the precision of the UV-DOAS H_2S measurement method is significantly greater than the S-OPS measurement method and the UV-DOAS H_2S measurement is unacceptable. As a result, the S-OPS measurement system will be substituted for the UV-DOAS measurement system for the measurement of H_2S at all locations in the NAEMS.

The bias of the UV-DOAS H_2S measurement system from the S-OPS measurement system will be determined for selected measurement periods (100-s) used in the previously-described measurement system precision comparison. Bias will be determined by t-test of the mean differences between the mean of the two UV-DOAS measurement systems and the mean of the two S-OPS measurements. An 80% confidence interval will be used (t=1.397). If the difference is significant, then the correction factor is calculated. The correction factor must fall within the range of 0.90 to 1.10. If the correction factor is more than 1.10 or less than 0.90 then the UV-DOAS measurement method cannot be used in the study and the S-OPS measurement system will be substituted for the UV-DOAS system for the measurement of H_2S at all locations in the NAEMS.

10.9 S-OPS sampling validation

The S-OPS consists of the measurement of gas concentration from a gas sample drawn uniformly from multiple points along a sampling line, simulating the beamline of an open-path measurement. The S-OPS method of sampling the line concentration of a gas has not been validated, and consequently cannot be used in the study until characterized and validated.

Validation of the S-OPS sampling system (including precision, accuracy or bias, and stability) will be assessed in an open-field environment in accordance with procedures described in EPA

Method 301. In this validation study, the open path UV-DOAS measurement of SO_2 using Standard Operating Procedures for the Open-Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer (SOP C1) (substituting SO_2 for NH_3) will be compared with a synthetic open path system (S-OPS) using the Standard Operating Procedure for the Synthetic Open-Path Sampling System (SOP C4) in conjunction with Pulsed-Fluorescence H_2S Analyzers (USEPA Method EQSA-0486-060 and EMTIC TM-006C) using Standard Operating Procedure for the Measurement of Hydrogen Sulfide with the Thermo Electron Corporation Model 450C Pulsed-Fluorescence Analyzer (SOP G5), as suggested by EPA OAQPS personnel. The S-OPS consists of a manifold of 10 orifices spaced 5 m apart with air drawn through the manifold at 10 L/min. The SO_2 measurements of the air sampled from the S-OPS and the SO_2 PIC measured with the UV-DOAS will be averaged for 1 min. The S-OPS and UV-DOAS will be positioned approximately 20 m downwind of a 5-orifice 25-m line source of 10% SO_2 (Figure 10.7) such that the PIC along the measurement path is at least 30 ppb-100m (3 x MDL of UV-DOAS and PFA instruments).

Measurements from both the PFA and UV-DOAS instruments will be made for at least five (5) half-hour periods of emission with 10 min of ambient air measurements made between emissions. Instruments will be calibrated prior to and after the study. Validation and QA/QC criteria for the measurements will be identical to those for the overall NAEMS (SOP C1, SOP C4, SOP G5). SO_2 concentrations measured by the two instruments will be compared in accordance with EPA Method 301.

The average concentration of valid measurements from the S-OPS/PFA measurement system and the UV-DOAS measurement systems will be used for the assessment of precision and bias of the S-OPS sampling method.

The F-test will be used to determine if the precision of the UV-DOAS SO_2 measurement method is significantly different from that of the S-OPS/PFA SO_2 measurement method. The experimental *F*-value is calculated according to

$$F = \frac{S_p^2}{S_v^2} \qquad \text{(Equation 10.4)}$$

where S^2_p equals the variance of the UV-DOAS measurement method from *p* 100-s measurement periods, and S^2_v is the variance of the S-OPS/PFA measurement method from *v* 100-s measurement periods.

The experimental *F*-value will be compared to the critical range of *F* at a 95 percent confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* is above the critical range, the precision of the UV-DOAS SO_2 measurement is significantly greater than the S-OPS/PFA SO_2 measurement method and the S-OPS sampling method as a surrogate for a

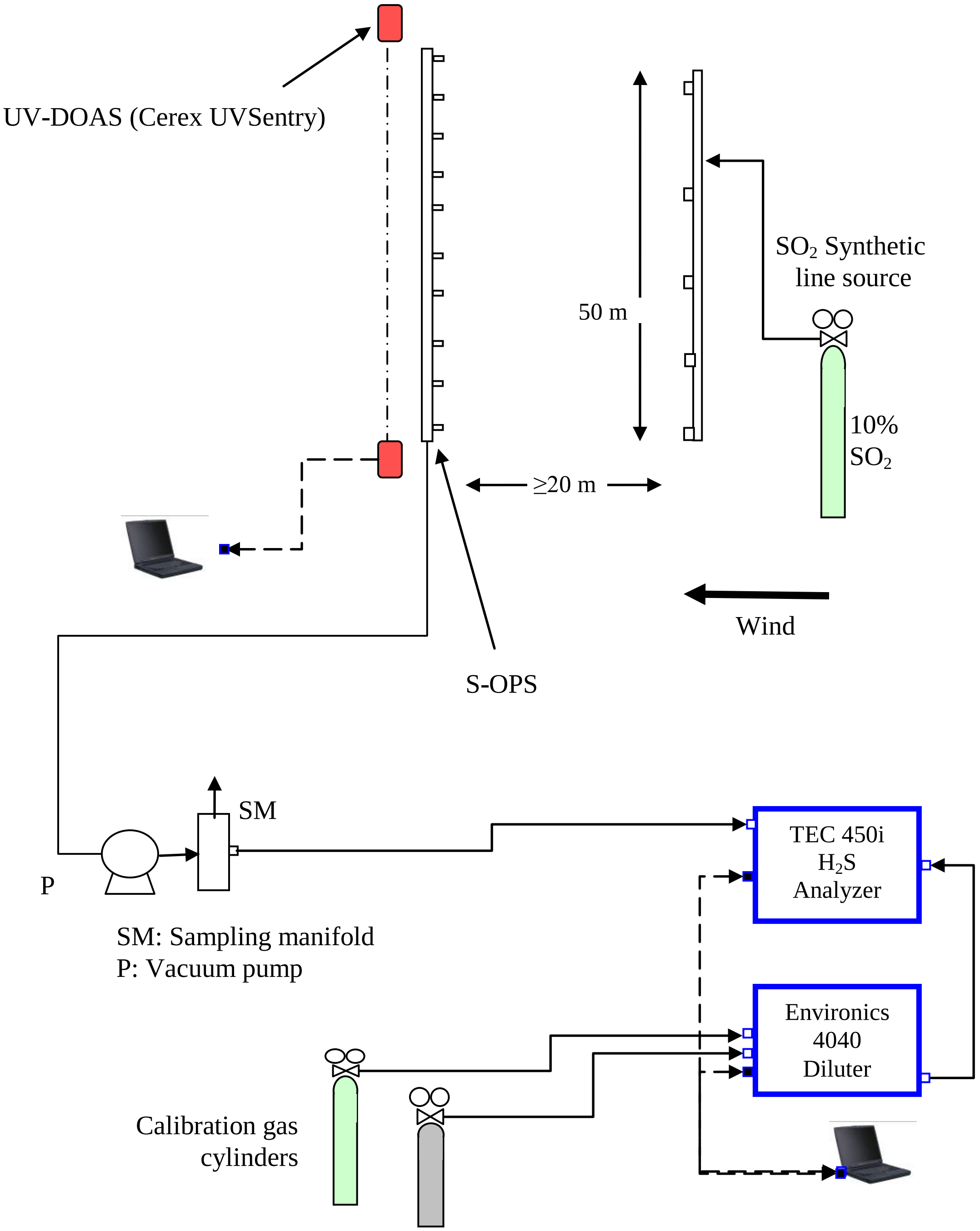


Figure 10.7. Configuration of sampling equipment and emission sources for the S-OPS validation study.

open-path measurement is unacceptable and measurements made of air collected through the S-OPS will consequently be considered as a line sample.

The bias of the UV-DOAS SO_2 measurement system from the S-OPS/PFA measurement system will be determined for selected measurement periods (30-min) used in the previously-described measurement system precision comparison. Bias will be determined by t-test of the mean measurement period differences of the UV-DOAS and S-OPS/PFA SO_2 measurements. An 80% confidence interval will be used (t=1.397). If the difference is significant, then the correction factor is calculated. The correction factor must fall within the range of 0.90 to 1.10. If the correction factor is more than 1.10 or less than 0.90 then the S-OPS measurement method cannot be used in the study as a surrogate for open-path measurement and will consequently be considered as a line sample in the NAEMS.

References

American Society for Testing and Materials (ASTM) Standard Guide E1865-97 (Reapproved 2002), Standard Guide for Open-Path Fourier Transform Infrared (OP/FT-IR) Monitoring of Gases and Vapors in Air; July 1997.

American Society for Testing and Materials (ASTM) Standard Practice E1982-98, Standard Practice for Open-Path Fourier Transform Infrared (OP/FT-IR) Monitoring of Gases and Vapors in Air; March 1999.

Battelle. 2002. Generic Verification Protocol for Optical Open-Path Monitors. Environmental Technology Verification Program. Advanced Monitoring Systems Center, Columbus Ohio. http://www.epa.gov/etv/pdfs/vp/01_vp_openpath.pdf

Heber, A.J., J.-Q. Ni, T.-T. Lim, A.M. Schmidt, J. A. Koziel, P.C. Tao, D.B. Beasley, S.J. Hoff, R.E. Nicolai, L.D. Jacobson, and Y. Zhang. 2006. Quality assured measurements of animal building emissions: Gas concentrations. *AWMA Journal* 56:1472-1483.

IMPROVE, Particulate Monitoring Network: Standard Operating Procedures, University of California, Davis.

SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP C4. 2006. Standard Operating Procedure for the Synthetic Open Path Sampling System. Standard Operating Procedure C4. Purdue Ag Air Quality Lab.

SOP G5. 2006. Standard Operating Procedure for the Measurement of Hydrogen Sulfide (H2S) with the Thermo Electron Corporation Model 450I Pulsed Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Standard Operating Procedure G7. Purdue Ag Air Quality Lab.

SOP G11. 2006. Standard Operating Procedure for the Operation of the Environics Model 4040 Diluter. Standard Operating Procedure G11. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L

Thermistor. Standard Operating Procedure L2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11 ORP Sensor. Standard Operating Procedure L3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L5. 2006. Markland Sludge Gun. Standard Operating Procedure L5. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP M1. 2006. Manure Sampling. Standard Operating Procedure M1. Purdue Ag Air Quality Lab.

SOP M2. 2006. Conducting pH Measurements on Manure Samples. Standard Operating Procedure M2. Purdue Ag Air Quality Lab.

SOP M3. 2006. Determining Solids Content of Manure Samples. Standard Operating Procedure M3. Purdue Ag Air Quality Lab.

SOP M4. 2006. Determining Total (Kjeldahl) Nitrogen Content of Manure Samples. Standard Operating Procedure M4. Purdue Ag Air Quality Lab.

SOP M5. 2006. Determining Ammonia Content of Manure Samples. Standard Operating Procedure M5. Purdue Ag Air Quality Lab.

SOP S5. 2006. Nutrient Balance. Standard Operating Procedure S5. Purdue Ag Air Quality Lab.

SOP S6. 2006. Determining Total Kjeldahl Nitrogen (TKN) Contents of Feed, Bedding, Milk and Eggs. Standard Operating Procedure S6. Purdue Ag Air Quality Lab.

SOP U5. 2006. Installation of Open Source Measurement Equipment. Standard Operating Procedure U5. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP U7. 2006. Installation of Open Source Measurement Equipment (Corrals). Standard Operating Procedure U7. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W6. 2006. Weather Data Acquisition and Control Hardware. Standard Operating Procedure W6. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

US Environmental Protection Agency. 1999. Compendium Method TO-16: Long-Path Fourier Transform Infrared Monitoring Of Atmospheric Gases. Office of Research and Development. Washington, D.C. EPA/625/R-96/010b.

US Department of Commerce- Weather Bureau. 1963. Manual of Barometry. Federal Meteorological Handbook No. 7, U.S. Government Printing Office. Washington, D.C.

US Environmental Protection Agency. 2000. Meteorological Monitoring Guidance for Regulatory Modeling Applications. Office of Air Quality Planning and Standards. Research Triangle Park, NC. EPA-454/R-99-005.

US Environmental Protection Agency. 1992. Method 301- Field Validation of Pollutant Measurement Methods from Various Waste Media. Notice, Part IV, Environmental Protection Agency, Federal Register 57(250) 61998-62002.

11. Sampling Methods Requirements

The only sampling in this study involves the sampling of manure at the corral and basin measurement locations (Standard Operating Procedure for Manure Sampling; SOP M1) and the sampling of feed, bedding, and milk at the corral location. At the corral location, surface manure sampling will be conducted during every measurement period. Surface samples will be collected at random locations in the corrals themselves, as well as the scraping lanes, the deposited manure piles, and the milking parlor. At the basin, manure will be sampled from three locations near the basin rim at the beginning or end of each measurement period.

Extensive measurements, however, are made in this study, including: (1) wind measurements at three heights described in SOP W2, (2) ambient air temperature, humidity, and barometric pressure described in SOPs W1 and W5, (3) incident solar radiation described in SOP E3, (4) surface wetness described in SOP W3, (5) lagoon/basin pH, redox state and temperature at 0.3 m depth described in SOPs L1, L2, and L3, (6) path-integrated concentrations of NH_3 along many beamlines described in SOP C2 (and SOP C1 if UV-DOAS is validated for H_2S measurement), (7) synthetic path-integrated concentrations of H_2S along two paths described in SOP G5 and C4 or path-integrated concentrations of H_2S along two paths described in SOP C1 if UV-DOAS is validated for H_2S measurement, (8) synthetic path-integrated concentrations of NH_3, CH_4, THC (referenced to propane), MeOH, and EtOH described in SOP G7 and C4, (9) NH_3 emissions described in SOP O1 and O2, (10) H_2S emissions described in SOP O1, and (11) lagoon sludge depths described in SOP L5. The respective SOP documents define method summaries, interferences, safety issues, necessary supplies, acceptance, installation, operation, calibration, and troubleshooting procedures as well as QA/QC procedures for each instrument.

Facilities in support of the measurements are described in SOP D1 and SOP U4. Site installation, operation, and take-down for lagoons and basins are described in SOP U5. Site installation, operation, and take-down for corrals are described in SOP U7.

Requests for changes in protocols and any occurrences of deviations from approved protocols must be documented on a ‘Document Deviation Report’ Form (Appendix D). The PQAM in consultation with the QAM, PM and SA will determine the resolution of the deviation. Possible resolutions of a deviation include: accept deviation and revise a section of the QAPP or SOP, accept revision (minor) no changes necessary, reject deviation and data, reject deviation but retain data (for instance incomplete replication). All changes in operating protocol must be approved by the EPA prior to activation.

References

SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

SOP C4. 2006. Standard Operating Procedure for the Synthetic Open Path Sampling System. Standard Operating Procedure C4. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP E3. 2006. Measurement of Solar Radiation with the LiCOR model 200SL or 200SZ Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

SOP G5. 2006. Standard Operating Procedure for the Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450I Pulsed Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Purdue Ag Air Quality Lab.

SOP M1. 2006. Manure Sampling. Standard Operating Procedure M1. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L5. 2006. Markland Sludge Gun. Standard Operating Procedure L5. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

SOP O1. 2006. Emissions Estimation Using Backward Lagrangian Stochastic (bLS) Model. Standard Operating Procedure O1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP O2. 2006. Emissions Estimation Using Radial Plume Mapping (RPM). Standard Operating Procedure O2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP U4. 2006. Open Source Instrument Trailer. Standard Operating Procedure U4. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP U5. 2006. Installation of Open Source Measurement Equipment. Standard Operating Procedure U5. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP U7. 2006. Installation of Open Source Measurement Equipment (Corrals). Standard Operating Procedure U7. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W1. 2006. Measurement of Atmospheric Temperature and Humidity with the Viasala Model HMP45C Sensor and Solar Shield. Standard Operating Procedure W1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W3. 2006. Measurement of Wetness with the Campbell Scientific Model Resistance Grid. Standard Operating Procedure W3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W5. 2006. Measurement of Barometric pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer. Standard Operating Procedure W5. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware. Standard Operating Procedure W6. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

12. Sample Custody

Physical manure samples are collected in this study. Manure, feed, bedding, and milk samples will be collected from the basin and corral locations according to the respective SMP and SOPs M1 and S6 and shipped to the analytical laboratory (Address: Midwest Laboratories, Inc., 13611 B St., Omaha, NE) on ice (maintaining <4^{o}C temperature) with a chain of custody form. A copy of the chain of custody form will be made and retained on-site and scanned into the computer records in the directory for the site. Samples will be labeled using indelible markers with the sample number code, sealed in two plastic bags, and shipped with the chain of custody form in foam freezer boxes sealed using duct tape or shipping tape. The integrity of the sample bag and the temperature of the shipping container will be determined on receipt at the laboratory and documented on the chain of custody form (Appendix D).

The chain of custody form (example in Appendix D) includes:

- Name of submitter of the sample
- Sample origin location, date, time, type, and number code.
- Date and time of receipt at laboratory
- Name of individual receiving sample
- Condition of sample on receipt
- Analyses requested
- Number of sample containers

The sample number code will be coded according to: Location code (Table C1)/ Day-Month-Year / Sample type (Manure) / replicate #.

Electronic measurement data are collected in this study. Raw data are stored in multiple places prior to transfer to PAML. PF, GSS and PAS raw data are stored on the LAN computer HD. UV-DOAS (if validated for H_2S measurements) raw data will be stored on flash memory drives of each instrument, as well as being stored on the LAN computer HD. TDLAS raw data (Figure 12.2) are stored on the TDLAS data acquisition computer HD, LAN computer and associated external HD. Meteorological/Lagoon Datalogger raw data (excluding wind measurements) are stored on a Compact Flash memory card attached to the data logger, the memory of the on-site data logger, the LAN server HD and the associated external HD. Wind data are stored on the LAN server HD and associated External HD.

All field data will be transferred to PAML by multiple means: ftp downloads and courier data pouches (carried at two different times). A daily ftp download will occur that will include daily raw and processed files from the two UV-DOAS systems (PIC values of NH_3 and H_2S), the two TDLAS systems (PIC values of NH_3), the meteorological (ambient air temperature, relative humidity, barometric pressure, solar radiation, surface wetness, wind components) and lagoon/basin (pH, temperature and redox state) characterization measurements. After each measurement location has been established, the returning Scientist in the FOS will bring with them a data pouch containing flash memory drives, CDs, and DVDs. The pouch will include:

- For latest measurement period:
  - Two 4Gb UV-DOAS flash memory drives (if UV-DOAS method validated).
  - Two CDs with copies of UV-DOAS flash memory drives (if UV-DOAS method validated).
  - One DVD with 16-Hz sonic anemometer wind data
  - One CD with TDLAS, PF, PAS, GSS, wind (except 16-Hz data), and weather and lagoon/basin data (if using PFA and S-OPS measurements).
  - One 64Mb flash memory chip of weather and lagoon/basin data.
  - One 256Mb memory stick with field notes, calibration data and control charts.
- For the previous measurement period (material previously stored in on-site data vault in environmentally-controlled instrumentation trailer):
  - Two CDs with copies of UV-DOAS flash memory drives (if UV-DOAS method validated).
  - One CD with TDLAS, PF, PAS, GSS, wind (except 16-Hz data), and weather and lagoon/basin data (if using PFA and S-OPS measurements).
- Electronic data transfer forms for both recently-completed and previous measurement periods (Appendix D) with the upper section filled out.

The data pouch will be carried back to PAML and delivered to the PDM. Receipt of raw and post-processed data at PAML will be logged on the electronic data transfer forms and data transferred to the project database by the PDM. The Electronic data transfer forms will be filed by the DM. Additional detail in the process of sample handling are described in SOP D1.

Example forms used in the instrument calibration and quality assurance checks, data collection, and sample custody, and data transfer are included in Appendix D.

References

SOP D1. 2006. Management of Open-Source, Weather, and Lagoon Characterization Data. Standard Operating Procedure D1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W6. 2006. Weather Data Acquisition and Control Hardware. Standard Operating Procedure W6. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

13. Analytical and Calculation Methods

Approved analytical methods will be used in all experiments. Analytical data will be generated in accordance with the Standard Operating Procedures and instrument manufacturer's manuals.

13.1. Meteorological measurements

Meteorological measurements will be used to monitor the atmosphere during the PIC and S-OPS concentration measurements by TDLAS, UV-DOAS (if validated), PF (if UV-DOAS not validated), and PAS described below. Air temperature, relative humidity, pressure, and solar radiation will be measured every 5-s and averaged over 5-min intervals. Wind profiles will be derived from the 2-s averaging of 16-Hz sampling of the instantaneous orthogonal wind components. Atmospheric stability and other characteristics of the atmosphere will be derived from the wind information and 5-s sampling of air temperature, relative humidity, and barometric pressure. Turbulence characteristics will be derived from 16 Hz sampling of the instantaneous orthogonal wind components and the virtual temperature will be derived from the speed of sound. Mean wind speed and direction will be determined from 100-s records. Wetness plates will be sampled at 5 min intervals and used to assess rain or dew at the site. Analysis of the meteorological data is covered in the SOPs in Appendix B.

AFO lagoons and basins are not located with consideration for potential gaseous and air flow measurements. Trees are often used to reduce visibility of the lagoons and the distance between barns and lagoons are often too close to separate the barn emissions from the exhaust fans from the lagoon or basin. In addition, lagoons are often built up from the surrounding ground by the soil removed to form the lagoon, creating a substantial berm height. Computational methods used below for the determination of stability, aerodynamic roughness, and turbulence characteristics assume that measurements are made over homogeneous surfaces and that the turbulence is stationary. Clearly this is not always true at AFOs or for all periods of time at a given AFO. Consequently, great care has been taken in locating the best possible ten farms for the study measurements so that deviations from the preferred terrain conditions have been minimized and tests of homogeneity and stationarity of turbulence are made in the validation of all turbulence measurements. Exclusion zones and invalidated methods are identified in the respective SMP where upwind or downwind conditions will clearly violate siting criteria designed to minimize location homogeneity problems.

Corrective action by the on-site teams will be necessitated by any deviation from published procedure or instruction manual direction.

13.2. Open path TDLAS

Narrowband open path TDLAS spectroscopy in the near infrared (1512 nm) will be used to monitor NH_3 in the atmosphere. Each of two TDLAS systems per waste storage location will scan along 10 OPs (five on each of two adjacent sides of the waste storage area). Concentration measurements along the individual OPs are sampled for approximately 15 s (integration or dwell time) with up to 5 s provided to move to the next OP. A full scan set (one complete cycle of two sides of the open source) will require approximately 200 s. Concentration measurements along one side of the open source will require approximately 100 s. Three cycles over a period of approximately 600 s will constitute one complete set of measurements to be used in the RPM emissions model (Figure 10.3). Details of the measurement are found in SOP C2. Corrective action by the on-site teams will be necessitated by any deviation from published procedure (SOP C2) or the instrument instruction manual direction.

It is anticipated that during the winter months, lagoons at a number of locations will be frozen over during the measurement period, resulting in sub-MDL gaseous concentrations at the lagoon berm. Rather than set the measurements below MDL to ½ MDL concentrations, the poor accuracy of the measurement will be indicated by the corresponding r^2 value.

13.3. Open path UV-DOAS

Broadband UV-DOAS spectroscopy, if validated for H_2S measurement, will be used to monitor NH_3 and H_2S concentrations in the atmosphere over the 190 to 230 nm waveband (Figure 13.1). Two UV-DOAS instruments will be located on opposite sides of a waste storage area. Each measurement will consist of a spectrum with a 100-s integration time (Figure 10.3). Once spectra are generated, the spectra are filtered, aligned with a reference NH_3 spectrum, and analyzed using a classic least squares technique to quantify the NH_3. The absorption spectrum associated with the quantified NH_3 concentration is subtracted from the measured/filtered spectrum and the remaining absorption spectrum is analyzed for H_2S using partial least squares techniques. The FT-IR Open-Path Monitoring Guidance Document is used to provide guidance in the techniques used to acquire valid spectra. Details of the procedures are found in SOP C1. Corrective action by the on-site teams will be necessitated by any deviation from published procedure (SOP C1) or the instrument instruction manual direction.

It is anticipated that during the winter months, lagoons at a number of locations will be frozen over during the measurement period, resulting in sub-MDL gaseous concentrations at the lagoon berm. Measurements below MDL will be assigned ½ MDL concentrations.

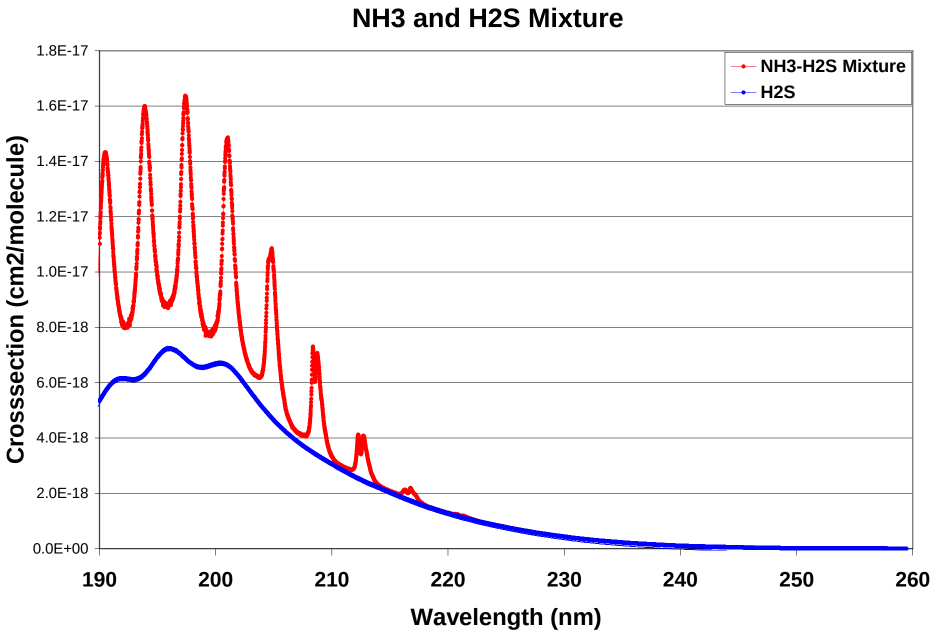


Figure 13.1 Typical broadband spectrum of the UV-DOAS instrument showing NH_3 and H_2S features.

13.4 Photoacoustic Spectroscopy

Photoacoustic IR spectroscopic techniques will be used to measure NH_3 and various VOCs including CH_4, MeOH, and EtOH (SOP G7). Measurements will be made from air sampled along two synthetic open-paths: up- and downwind of the lagoon or basin. Measurements will only be made one side of the corral. Air will be sampled on 1-min intervals for 15 min, with the mean of the equilibrated measurements used as the 15-min concentration per S-OPS. Measurements will be continuous with sequential sampling from the two S-OPS. The time required for equilibration will be experimentally determined from the measurement time history.

It is anticipated that during the winter months, lagoons at a number of locations will be frozen over during the measurement period resulting in sub-MDL gaseous concentrations at the lagoon berm. Measurements below MDL will be assigned ½ MDL concentrations.

13.5 Pulsed-fluorescence measurements

Pulsed-fluorescence techniques will be used to measure H_2S (SOP G5). Measurements will be made from air sampled along two synthetic open-paths: up- and downwind of the lagoon, basin, or corral. Air will be sampled at 1-min intervals for 15 min, with the mean of the equilibrated measurements used as the 15-min concentration. Measurements will be continuous with sequential sampling from the two S-OPS. The time required for equilibration will be experimentally determined from the measurement time history.

It is anticipated that during the winter months, lagoons at a number of locations will be frozen over during the measurement period resulting in sub-MDL gaseous concentrations at the lagoon berm. Measurements below MDL will be assigned ½ MDL concentrations.

13.6 Gas concentration data transformation

The open path TDLAS and UV-DOAS operating programs process the raw spectra data files into files containing PIC measurements in parts per billion (ppb) (UV-DOAS instrument) or parts per million (ppm) (TDLAS instrument). The PF and PAS produce files containing concentration measurements in ppm. Validated concentration measurements are reported in units of parts per billion (ppb), consequently the TDLAS and UV-DOAS PIC values are divided by the corresponding path lengths. The ideal gas law ($PV = nRT$) is used to convert volumetric gas concentrations to actual and standardized mass concentrations (moist) with eqns 13.1 and 13.2 respectively.

The emissions models calculate emissions based on the ‘wet’ (air including water vapor) concentrations computed from the measurements as:

$$C = \frac{PcM}{R(273.15 + T)} \qquad \text{(Equation 13.1)}$$

Where:

c	Volumetric concentration, ppb
C	Actual mass concentration, mg/m^3 or µg/m^3
M	Molecular weight, M=17.03 g/mol and 34.08 g/mol for NH_3 and H_2S respectively
P	Pressure at sampling location, atm
T	Temperature at sampling location, °C
R	Universal Gas Constant: 0.08206 L-atm/mol-°K

The reported gas concentrations are reported as if in ‘dry’ air at standard pressure (1 atm) and temperature (20^{o}C). The volumetric gas concentration of any pollutant is converted to the standard mass concentration C′ according to:

$$C' = \frac{P'cM}{R(273.15 + T')} \qquad \text{(Equation 13.2)}$$

where:

c	volumetric concentration, ppb
C'	Standard mass concentration moist basis, µg/m^3
P'	Standard pressure, 1 atm
T'	Standard temperature, 20°C

and to the dry standard concentration according to:

$$C'' = \frac{C'}{(1-W)} \qquad \text{(Equation 13.3)}$$

where:

C''	Dry standard mass concentration dry basis, µg/m^3, and
W	Humidity ratio (kg/kg), is calculated as:

$$W = 0.62198\frac{e^{f(T)}\varphi}{P_a - e^{f(T)}\varphi} \qquad \text{(Equation 13.4)}$$

where:

P_a = barometric pressure at the sampling location (Pa)

φ= relative humidity at the sampling location, decimal, and

$$f(T) = \frac{C_1}{T} + C_2 + C_3 T + C_4 T^2 + C_5 T^3 + C_6 T^4 + C_7 \ln T \quad \text{for T < 273K.} \qquad \text{(Equation 13.5)}$$

$$f(T) = \frac{C_8}{T} + C_9 + C_{10} T + C_{11} T^2 + C_{12} T^3 + C_{13} \ln T \quad \text{for T > 273.16K}$$

C_1= -5.675x10^3, C_2= 6.392, C_3= -9.678x10^{-3}, C_4= 6.222x10^{-7},
C_5= 2.075x10^{-9}, C_6= -9.484x10^{-13}, C_7= 4.163, C_8= -5.800x10^3,
C_9= 1.391, C_{10}= -4.864x10^{-2}, C_{11}= 4.176x10^{-5}, C_{12}= -1.445x10^{-8}, and
C_{13}= 6.545.

13.6 Meteorological data transformations

Turbulence measures will be derived from 5-min averaging of 16-Hz sampling of instantaneous wind components u′, v′, w′ and the virtual temperature T_v', derived from the speed of sound (V_o). Detailed procedures are found in SOP W2. In general, raw component wind speed measurements (u, v, w in m/s; T_v in K) are evaluated for extreme value spikes (with spike data omitted and measurements used in computations if fewer than 160 in 5 min of data), and period statistics are computed (mean and variance of u, v, w, and T_v and covariances between all signal pairs). Support frame wake corrections are made on the measurements internally in the instrument.

From the 2-m wind instruments (or 4-m if no 2-m measurements are available), the friction velocity will be calculated according to

$$u_* = \sqrt[4]{\overline{u'w'}^2 + \overline{v'w'}^2} \qquad \text{(Equation 13.6)}$$

the characteristic temperature will be calculated according to

$$T_* = \overline{w'T_v'} / u_* \qquad \text{(Equation 13.7)}$$

and the Obukov length (*L*) will be calculated according to

$$1/L = \frac{-kg\overline{w'T_v'}}{\overline{T_v}u_*^{\;3}} \qquad \text{(Equation 13.8)}$$

where *k* is von Karman's constant and *g* is the gravitational acceleration. Mean values of L and u_* will be calculated for the two heights, and will be flagged if they fall outside of acceptable limits for the bLS emissions model.

T_v is calculated from the relative humidity, air temperature, and atmospheric pressure measurements according to:

$$T_v = (1+0.614W)(T+273.14) \qquad \text{(Equation 13.9)}$$

for air at temperature *T*. Values are flagged if the period-averaged T_v derived from the speed of sound and the T_v (calculated from the relative humidity, air temperature, and atmospheric pressure measurements) differ by more than 2^oC (DQI).

Since the terrain is not ideal for homogeneous turbulence measurements, the stationarity and homogeneity of the time series are evaluated using the 2-m (or 4-m if 2-m values are not available) wind measurements. The stationarity is evaluated by comparing the 5-min covariances of u′ and w′ and w′ and T_v' to the 30-min averaged covariances (where *i* and *j* are different variables) using:

$$\left[\frac{\sum_1^6\left(\overline{u'_i\,u'_j}\right)_{5\min}}{6} - \left(\overline{u'_i\,u'_j}\right)_{30\min}\right] \Bigg/ \left(\overline{u'_i\,u'_j}\right)_{30\min} \qquad \text{(Equation 13.10)}$$

where u has been rotated into the mean wind direction. Turbulence is not stationary for any 30-min interval when the difference between the average 5-min and 30-min values are greater than 30%, and data will be correspondingly flagged. The homogeneity of turbulence is evaluated by comparing the theoretically derived and measured integral turbulence scales of w′, u′ (where u has been rotated into the mean wind direction) and T_v' (u_* and T_{v*}) to the standard deviation of w′ and T_v' as:

$$\frac{\sigma_w}{u_*} = 2.00(-z/L)^{1/6}, 2.00(-z/L)^{1/8}, 1.41, 1.25 \text{ for } z/L \text{ of } <-1,\ -1..-0.0625,\ -0.0625..<0$$

and ≥0 respectively

$\frac{\sigma_u}{u_*} = 2.83(-z/L)^{1/6}, 2.83(-z/L)^{1/8}, 1.99, 2.4$ for z/L of <-1, -1..-0.0625, and -0.0625..<0 and ≥0 respectively

$\frac{\sigma_T}{T_*} = 1.00(-z/L)^{1/3}, 1.00(-z/L)^{1/4}, 0.50(-z/L)^{1/2}$ for z/L of <-1, -1..-0.0625, and -0.0625..<0 respectively

(Equation 13.11)

Turbulence data is inhomogeneous when the measured and derived values differ by more than 30% (data will be correspondingly flagged).

The bLS emissions method can compute the roughness length (z_o) from single-height wind information it is provided or can be provided previously-calculated site-specific input information derived from multiple heights. The average value of z_o will be computed from the three heights of wind measurements (2 m abl, 4 m agl, 16 m agl), each calculated as:

$$z_o = \frac{(z-d)}{e^{kS/u_* + \psi_m}} \qquad \text{(Equation 13.12)}$$

where:
ψ_M= -4.7 (z-d)/L for z/L>0.0001
ψ_M= 0 for 0.0001>z/L>0.0001
ψ_M= 2 $ln[(1+x^2)/2 \cdot (1+x)^2/4]$- $2\tan^{-1} x$ and $x=(1-15(z\text{-d})/L)^{1/5}$ for z/L>0.0001

The dissipation rate (ε) is calculated using the 2-m and 4-m wind measurements according to:

$$\varepsilon = \frac{u_*^3}{kz}\varphi_\varepsilon \qquad \text{(Equation 13.13)}$$

where:
$\varphi_\varepsilon = 1 + 5z/L$ for L>0
$\varphi_\varepsilon = \frac{b_w^4(1-3z/L)^{1.33}+1}{(b_w^4+1)(1-3z/L)^{0.33}(1-6z/L)^{0.25}}$ for L<0.

QA Flags associated with each condition are described in SOP W2.

13.7 Emissions calculation transformations

The 15-min averages of turbulence, meteorological data, and OP spectra (if the UV-DOAS is validated) will be used in conjunction with the backward Lagrangian Stochastic (bLS) method to determine NH_3 and H_2S emissions for that 15-min period. Emissions will be reported at 30-min intervals.

Since the S-OPS-sampled air from the two sides of the area source are each measured for 15 min, a complete set of measurements around the area source takes 30 min. Consequently, the VOC and H_2S (if UV-DOAS is not validated) measurements of the S-OPS sampled air represent 30-min intervals that will be matched with 30-min averages of turbulence and meteorological data to determine emissions with either the backward Lagrangian Stochastic (bLS) method or the ratiometric method. The 2-s averages of wind speed will be aligned with each set of five PIC for use in the RPM method to determine the NH_3 emission for each approximately 100-s period. The approximately 100-s emissions measurements will be averaged to the 30-min reporting periods. Emissions will be calculated based on the difference between downwind and background PICs. The background PIC (PIC_{bg}) will be the lowest concentration PIC among upwind beamlines. Both models will be uniquely configured for each measurement location prior to sampling.

Since the RPM emissions calculation for each side of the area source requires five valid PIC values for each side of the area source, there is a significant likelihood that at least one of the paths may be invalid sometimes due to various causes. Under these conditions, a bLS emissions calculation will be made using the 30-min average PIC for the (less than five) valid paths. The mean value of the calculated emissions for each valid PIC will represent the calculated emissions for that period of time.

13.7.1 bLS emissions calculation transformations

The bLS method is based on an inverse dispersion analysis. The WINDTRAX® model will be used to estimate the emissions of NH_3, H_2S, and various VOCs from 15- or 30-min average concentration measurements. The model uses turbulence data from the sonic anemometers and barometric pressure and air temperature measurements from the barometric pressure sensor and hygrometer respectively. WINDTRAX® simulates short-range atmospheric dispersion (for horizontal distances within about 1 km of the source) using a Lagrangian stochastic particle model. The simulation elements are represented by icons on a graphical interface showing a plan-view map with the location of sources and sensors at each location. Data files and the underlying numerical models are also represented by icons on the map. The model assumes that:

- The ground surface is horizontally homogeneous. Lagoons are water bodies of 100 m to 300 m on a side (criteria in this study) generally surrounded on two to three sides by cropland and one side by barns. Therefore the terrain does not have a homogeneous surface type. The location of the 2 m anemometer and meteorological tower are chosen when possible to be downwind of the lagoon (capturing the conditions of the modified air from the lagoon). As previously discussed, the upwind fetch is maximized but at least 1:10 (rise:run) for the 2 m above berm anemometer measurement height. The downwind fetch must be at least 1:3. A lagoon inner berm is usually at least approximately 1 m high while outer berms vary from flat with surrounding land to up to 3 m. These conditions will result in non-horizontal flow that will likely decrease the accuracy of the model and will be assessed in a verification study at the beginning of the project. Shifting wind direction will change the turbulence characteristics as the incidence angle changes between the berm and the wind. This however should be measurable at least at the 2 m sonic anemometer location and will be partially expressed in the turbulence statistics used by the model. In addition, the measures of homogeneity and stationarity will provide useful information concerning these effects on the model emissions estimates. Changes in roughness will also influence the model estimates. As winds shift in direction, the upwind roughness will vary over the lagoon and basin relative to the upwind fetch conditions. These changes with direction will be consistent by location and over time may be resolvable from the wind profile information. This will be explored during the study but will be viewed as a source of error for the model estimates. While the distribution of cows will be variable in the corral, the dominant roughness components are not the animals but the shade structures and fences. Therefore it is anticipated that the roughness at the corral will be relatively constant.

- The source strength is homogeneous across the source area. Crusting and scum layers on the lagoon surface, manure intakes from the barns, and agitation associated with removal of waste for land application all will result in inhomogeneity of emission strength within the lagoon. Crusting and scum layers cannot be avoided and consequently introduce errors in the model emissions estimate. Inhomogeneities associated with the intakes are reduced by avoiding measuring the PIC near the intakes. Inhomogeneities associated with agitation are reduced by making measurements when manure removal events are not being made or excluding periods of time when the removals are made.
- Turbulence is homogeneous and stationary. These two conditions are tested using Equations 13.10 and 13.11.
- PIC measurements are contemporaneous. This condition is not strictly met, but can be assumed approximately true when considering individual 20-s PIC sampling intervals being averaged over the 30-min reporting periods.

Inputs to the model include each measured PIC, barometric pressure, air temperature and calculated statistics of the wind (σ_u/u_*, σ_v/u_*, σ_w/u_*) and mean u, v, w for each 15 or 30 min sampling period. Detailed description of the model is found in SOP O1.

In general, the program calculates the emission rate (Q_{obs}) corresponding to the measured background ($C_{obs,bg}$) and downwind (C_{obs}) beamline-averaged concentrations based on the assumption that ($C_{obs} - C_{obs,bg}$) / Q_{obs} is only a function of atmospheric conditions. For the measured atmospheric conditions, this ratio is determined by using the bLS model to simulate the flight path of air parcels backwards from the beamline until each parcel intersects the ground (a ‘touchdown’). The modelled ratio is given as C_{sim} / Q_{sim} , where C_{sim} is the simulated averaged beamline concentration and Q_{sim} is the simulated source strength corresponding to this simulated concentration. The actual emission rate (Q_{obs}) is calculated using:

$$Q_{obs} = \frac{(C_{obs} - C_{obs,bg})}{\left[C_{sim} / Q_{sim}\right]} \qquad \text{(Equation 13.14)}$$

To determine the relationship between C_{sim} and Q_{sim}, the model simulates the flight path of air parcels backwards from the beamline until each parcel intersects the ground (a 'touchdown'). The velocity of each air parcel is varied during each modeling time step Δt according to:

$$\Delta u_k = \alpha_k \Delta t + \beta_k P_k \qquad \text{(Equation 13.15)}$$

where k is a directional indicator, $\beta_k = (4.41\varepsilon)^{0.5}$ implying a Schmidt number of 0.64 at neutral stability, P_k is a Gaussian random number from a population with mean zero and variance Δt, and α_k is a function of turbulence statistics. The location of each parcel ($x_k(u_1, u_2, u_3)$ = x, y, z directions) is then calculated as:

$$\Delta x_k = u_k \Delta t \qquad \text{(Equation 13.16)}$$

iteratively for a large number of cycles. At some time, all parcels will impact the surface. The location of intersection of the parcel with the surface is determined and the vertical velocity at impact with the surface (w_0) is recorded. Parcels rebound from the surface. If the parcel impacts the surface within the source domain area, then it contributes to the flux. If it does not impact the surface within the source domain, then the parcel does not contribute to the flux.

The model calculates "touchdown catalogs" of x, y, and w_0 for each concentration measurement point j along the beamline. The number of impacts within the source domain, weighted by w_0 and divided by the number of parcels (n) released from P equidistant points along each beamline, each with concentration C_{sim}, provides the ratio C_{sim} / Q_{sim} for the concentration measurement height:

$$a_{sim} = \frac{\mathrm{C_{sim}}}{\mathrm{Q_{sim}}} = \frac{1}{P}\sum_{j=1}^{P}\left(\frac{1}{\mathrm{n}} \sum_{\text{within source area}} \frac{2}{|w_0|}\right) \qquad \text{(Equation 13.17)}$$

The PIC values (units of ppm-m) are converted to beamline-averaged volume concentrations (c_{obs} and $c_{obs,bg}$, with units of ppm) by dividing by the corresponding instrument pathlength. Mass concentrations (C_{obs} and $C_{obs,bg}$ with units of mg/m^3) are obtained by taking into consideration the molecular weight of the target gas, atmospheric pressure and the ambient temperature(Equations. 13.1- 13.3). The final emission rate, (Q_{obs}) , in units of kg/m^{2}s, is calculated as:

$$Q_{obs} = \frac{C_{obs} - C_{obs,bg}}{a_{sim}}\left(\frac{1\,kg}{1{,}000{,}000\,mg}\right) \qquad \text{(Equation 13.18)}$$

13.7.2 RPM emissions calculation transformations

The Radial Plume Mapping (RPM) method of measuring NH_3 emission from an open source maps the vertical and horizontal shape of the downwind plume through the measurement plane. The NH_3 PIC used in the plume cross-section reconstruction are made using the TDLAS open path system. The model assumes that:

- The ground surface is horizontally homogeneous. Lagoons are water bodies of 100 m to 300 m on a side (criteria in this study) generally surrounded on two to three sides by cropland and one side by barns. Therefore the terrain does not have a homogeneous surface type. The locations of the 2 m anemometer and meteorological tower are chosen when possible to be downwind of the lagoon (capturing the conditions of the modified air from the lagoon). As previously discussed, the upwind fetch is maximized but at least 1:10 (rise:run) and a downwind fetch of at least 1:3 for the minimum 2 m above berm PIC and 2 m above berm height anemometer measurement height. A lagoon inner berm is usually at least approximately 1 m high while outer berms vary from flat with surrounding land to up to 3 m. This results in non-horizontal flow that will likely decrease the accuracy of the model and will be assessed in a verification study at the beginning of the project. Since the flow is not expected to be horizontal but is assumed horizontal, the deviation from horizontal flow is an uncontrollable source of error in the RPM model.
- PIC measurements are contemporaneous. The PIC measurements are sequential, requiring approximately 100 s for a complete vertical plane scan along one side of the lagoon.

Inputs to the model include the coordinates for each beamline path, the 2-s mean horizontal wind components at three heights (from sonic anemometers: SOP W2), and mean PICs for each measurement plane over the approximate 100-s sampling period (Figure 10.3). The horizontal wind component measurements will be matched to the time required for each scan cycle.

The RPM configuration reconstruction technique utilizes a two-dimensional smooth basis function minimization (SBFM) to reconstruct the smoothed mass equivalent concentration map (bivariate Gaussian). Because our interest is in the plane-integrated concentration, and subsequently the flux through the plane and not the exact map of concentrations in the plane, only one smoothed basis function (one bivariate Gaussian) is fitted to reconstruct the smoothed map. For the beam geometry, it is convenient to express the smooth basis function *G* in polar coordinates (pathlength *r* and inclination angle *θ*) as:

$$G(r,\theta)=\frac{A}{2\pi\sigma_y\sigma_z\sqrt{1-\rho_{12}^2}}\exp\left\{-\frac{1}{2\left(1-\rho_{12}^2\right)}\left[\frac{(r\cdot\cos\theta-m_y)^2}{\sigma_y^2}-\frac{2\rho_{12}\left(r\cdot\cos\theta-m_y\right)\left(r\cdot\sin\theta-m_z\right)}{\sigma_y\sigma_z}+\frac{\left(r\cdot\sin\theta-m_z\right)^2}{\sigma_z^2}\right]\right\} \quad \text{(Equation 13.20)}$$

with six unknown independent parameters:

A= normalizing coefficient which adjusts for the peak value of the bivariate surface;

ρ_{12}=correlation coefficient which defines the direction of the distribution-independent variations in relation to the Cartesian directions y and z (ρ_{12}=0 means that the distribution variations overlap the Cartesian coordinates);

m_y and m_z= peak locations in Cartesian coordinates; and

σ_y and σ_z = standard deviations in Cartesian coordinates. To fit the unknown parameters of the smooth basis function to the PIC data, one has to define an error function for minimization.

The bivariate Gaussian function can be resolved with four independent beam paths when we assume: (1) that the reconstructed bivariate Gaussian is limited only to changes in the vertical and crosswind directions (forcing the correlation parameter ρ_{12} equal to zero), and (2) that the height of the peak concentration is at the ground level making m_z zero.

A two-phase SBFM approach to solving the reduced bivariate Gaussian is used. First a one-dimensional SBFM reconstruction procedure is applied to reconstruct the smoothed ground level and crosswind concentration profile. Then, the reconstructed parameters are substituted into the bivariate Gaussian function before applying the two-dimensional SBFM procedure. The one dimensional SBFM reconstruction is applied to the ground level segmented beam paths (Figure 10.1) of the same beam geometry to find the cross wind concentration profile (Hashmonay and Yost 1999b). A Gaussian function is fitted to measured PIC ground level values as a univariate function. The error function for the Simplex minimization procedure is the Sum of Squared Errors (SSE) function defined as:

$$SSE(B, m_y, \sigma_y) = \sum_i \left(PIC_i - \frac{B}{\sqrt{2\pi}\sigma_y} \int_0^{r_i} \exp\left[-\frac{1}{2} \left(\frac{m_y - r}{\sigma_y} \right)^2 \right] dr \right)^2 \qquad \text{(Equation 13.21)}$$

where B is equal to the area under the one dimensional Gaussian distribution (integrated concentration), r_i is the pathlength of the i^{th} beam, m_y is the mean peak location and σ_y is the standard deviation of the Gaussian function. PIC_i is the measured path integrated concentration value of the i^{th} path.

Substituting the solved values of the standard deviation σ_y and peak location m_y of the above one-dimensional SBFM procedure into the bivariate SBFM simplified by the assumptions yields:

$$G(A, \sigma_z) = \frac{A}{2\pi\sigma_y\sigma_z} \exp\left\{ -\frac{1}{2} \left[\frac{(r \cdot \cos\theta - m_y)^2}{\sigma_y^2} + \frac{(r \cdot \sin\theta)^2}{\sigma_z^2} \right] \right\} \qquad \text{(Equation 13.22)}$$

which is solved by minimizing the SSE using the simplex procedure with PIC values for the one long beam along the ground level and the two elevated beams that sample the vertical concentration gradient according to:

$$SSE(A, \sigma_z) = \sum_i \left(PIC_i - \int_0^{r_i} G(A, \sigma_z) dr \right)^2 \qquad \text{(Equation 13.23)}$$

Once the parameters of the function are found for a specific run, the RPM procedure calculates the concentration values for every square elementary unit in a vertical domain. Then, the RPM procedure integrates the values, incorporating wind speed data at each height level to compute the flux according to Equation 13.24. The emission rate Q in units of g/(s m^2) is computed using linear interpolations and extrapolations of the wind profile from the surface to 20 m derived from the three wind sensors (SOP W2 and SOP U5) as:

$$Q = \frac{\sum_{y=0}^{pathlength} \sum_{z=0}^{20m} (C_{y,z}) \widehat{u}_z}{S} \qquad \text{(Equation 13.24)}$$

where S is the source surface area (m^2).

The flux across each measurement plane is calculated separately with fluxes away from the source (downwind plane) as positive values and fluxes towards the source (upwind plane) as negative values. The net flux from or to the source area is determined by adding the fluxes computed for the four measurement sides of the area source. More than one side may represent an upwind or downwind plane.

When the upwind plane is at ambient background concentration (C_{bg}), the concentrations derived from the measured PICs are likely to be nearly identical. Under these conditions, the flux across the upwind plane will not be computed by the RPM method (since the lack of a gradient in concentration will fail the DQI for the method), and the emission rate will be computed according to:

$$Q = \frac{\sum_{y=0}^{pathlength} \sum_{z=0}^{20m} (C_{y,z} - C_{bg}) \widehat{u}_z}{S} \qquad \text{(Equation 13.25)}$$

where the computed RPM plane is downwind of the source.

13.7.3 Ratiometric VOC emissions computation

The VOC emissions of THC, MeOH, EtOH, and CH_4 will be estimated based on the respective PAS VOC concentration measurements in conjunction with the NH_3 emission measurement derived from the RPM method (Figure 10.3). The NH_3 PIC values (units of ppm-m) are converted to beamline-averaged volumetric concentrations by dividing by the corresponding instrument pathlength. These concentrations are then converted to units of mg/m^3 by taking into consideration the molecular weight of the target gas, atmospheric pressure and the ambient temperature. The emission of a given VOC is determined from these values according to:

$$Q(VOC) = Q_{RPM}(NH_3)\frac{C_{S-OPS/INNOVA}(VOC)}{C_{TDLAS}(NH_3)} \qquad \text{(Equation 13.26)}$$

where C_{TDLAS} refers to concentration associated with the shortest TDLAS beamline nearest the S-OPS. Emissions of total non-methane VOC will be determined by addition of *Q(EtOH)* and *Q(EtOH)* to *Q(THC).*

13.7.4 Ratiometric H_2S emissions computation

If the bLS emissions method is invalidated (not meeting DQI) and the RPM emissions calculation is not invalidated, the NH_3 emissions calculation from the RPM method will be used to estimate H_2S emissions. The H_2S emissions will be estimated based on the respective S-OPS/PFA H_2S concentration measurement and nearest TDLAS NH_3 PIC measurement in conjunction with the emission measurement derived from the RPM method (Figure 10.3). The PIC values (units of ppm-m) are converted to beamline-averaged volumetric concentrations by dividing by the corresponding instrument pathlength. These concentrations are then converted to units of mg/m^2 by taking into consideration the molecular weight of the target gas, atmospheric pressure and the ambient temperature. The emission is determined according to:

$$Q(H_2S) = Q_{RPM}(NH_3)\frac{C_{S-OPS/PFA}(H_2S)}{C_{TDLAS}(NH_3)} \qquad \text{(Equation 13.27)}$$

Restrictions on the use of the ratiometric model utilizing S-OPS-sampled air and open path integrated air sampling are:

1) The S-OPS path and corresponding TDLAS path are equivalent such that the path along which the NH_3 PIC values are measured and the S-OPS air is sampled are equal. This requires that the two paths are separated by a distance much less than the averaging period divided by the mean wind speed perpendicular to the paths.
2) The S-OPS path-integrated concentration (PIC) measurements for upwind and downwind components are synoptic. Sampling of the upwind and downwind S-OPS paths will be sequential with each path sampled over a 30-min interval, with each 30-min period synchronized with the corresponding TDLAS path measurements.

13.8 Lagoon/basin characterization

In situ measurements of the lagoon/basin will be used to monitor the conditions during the broadband (UV-DOAS) and narrowband (TDLAS) spectroscopy described above. Measurements will be averaged over 30-min intervals. Waste storage temperature (SOP L2), redox state (SOP L3), and pH (SOP L1) will be measured. No corrections or transformations to the measurements are needed. Basin manure pH (SOP M2), total nitrogen (SOP M4), ammonia nitrogen (SOP M5) and total and volatile solids content (SOP M3) will be determined by a commercial laboratory (Midwest Laboratories, Inc.) from samples collected at the beginning or end of each measurement period. Specifics for the manure sampling procedures are found in SOP M1 and the appropriate SMP. Samples will be stored and shipped at <4°C with sample to analysis time of at most one week. During each site visit, photographs of the lagoon/basin will be taken to document the extent and locations of scum and crust.

The number and types of QC samples used by the laboratory are documented by the Laboratory QA/QC Manual. Laboratory SOPs align with Methods 9040C (pH measurement), 1684 (total and volatile solids), 1687 and 350.2 (total and ammonia nitrogen).

13.9 Corral characterization

Manure from the corral will be collected and tested for pH, total solids content, and ammonia nitrogen every measurement period. Manure pH (SOP M2), ammonia nitrogen (SOP M5) and total and volatile solids content (SOP M3) will be determined by a commercial laboratory (Midwest Laboratories, Inc.). Specifics for the manure sampling procedures are found in SOP M1 and the appropriate SMP. Samples will be stored and shipped at <4°C with sample to analysis time of at most one week.

The number and types of QC samples used by the laboratory are documented by the Laboratory QA/QC Manual. Laboratory SOPs align with Methods 9040C (pH measurement), 1684 (total and volatile solids), 1687 and 350.2 (Total and ammonia nitrogen).

References

American Society for Testing and Materials (ASTM) Standard Guide E1865-97 (Reapproved 2002), Standard Guide for Open-Path Fourier Transform Infrared (OP/FT-IR) Monitoring of Gases and Vapors in Air; July 1997.

Boreal Laser, Inc. 2003. GasFinder2.0 portable system Operation Manual. Ver 0.39, Boreal Laser, Inc, Spruce Grove, Alberta, Canada, 38p.

Cerex Environmental Services Inc. 2006. UV Sentry Open-path Air Monitor End-User Manual, Version 2006329, Cerex Environmental Services, Inc, Atlanta, GA

Flesch, TK, JD Wilson, LA Harper, BP Crenna, RP Sharpe. 2004. Deducing ground-to-air emissions from observed trace gas concentrations: a field trial. J. Applied Meteorol. 43, 487-502.

Flesch TK, JH Prueger, HL Hatfield. 2002. Turbulent Schmidt number from a tracer experiment. Agric. and Forest Meteorol. 111, 299-307

Flesch, TK, JD Wilson, LA Harper, et al. 2005. Estimating gas emissions from a farm with an inversion-dispersion technique. Atmos. Environ. 39: 4863-4874.

Foken, T, B Wichura. 1996. Tools for quality assessment of surface-based flux measurements. Agric. and Forest Meteorol. 78, 83-105.

Hanna, SR, GA Briggs, and RP Hosker Jr. 1982. Handbook of atmospheric dispersion. DOE/TIC-11223. 102 p.

Hashmonay, RA, DF Natschke, K Wagoner, DB Harris, EL Thompson 2001. Field evaluation of a method for estimating gaseous fluxes from area sources using open-path Fourier transform infrared. Environ. Sci. Technol. 35, 2309-2313.

Hashmonay, RA, MG Yost. 1999. Innovative Approach for Estimating Gaseous Fugitive Fluxes Using Computed Tomography and Remote Optical Sensing Techniques. J. Air & Waste Manage. Assoc. 49, 966.

Hashmonay, RA, MG Yost. 1999. Localizing Gaseous Fugitive Emission Sources by Combining Real-Time Remote Optical Sensing and Wind Data. J. Air & Waste Manage. Assoc. 49, 1374-1379.

Hashmonay, RA, MG Yost, Y Mamane, Y Benayahu. 1999. Emission Rate Apportionment from Fugitive Sources Using Open-Path FTIR and Mathematical Inversion. Atmos. Environ. 33, 735-743.

Hashmonay, RA, MG Yost, CF Wu. 1999. Computed Tomography of Air Pollutants Using Radial Scanning Path-Integrated Optical Remote Sensing. Atmos. Environ. 33(2), 267.

Hashmonay, RA, DF Natschke, K Wagoner, DB Harris, EL Thompson, MG Yost. 2001. Field Evaluation of a Method for Estimating Gaseous Fluxes from Area Sources Using Open-Path Fourier Transform Infrared. Environ. Sci. Technol. 35, 2309-2313.

Innova AirTech Instruments. undated. 1314 Photoacoustic multi-gas analyzer, 1412 Photoacoustic Field Gas-Monitor. Technical Documentation. BE6011-11. 252 p

Kaimal, JC and JJ Finnigan, 1994. Atmospheric Boundary Layer Flows: Their Structure and Measurement. Oxford University Press, Inc., New York, NY.

Laubach J, FA Kelliher. 2005. Measuring methane emission rates of a dairy cow herd (II): results from a backward-Lagrangian stochastic model. Agricultural & Forest Meteorol. 129(3-4):137-150.

Piccot, SD, SS Masemore, W Lewis-Bevan, ES Ringler, DB Harris. 1996. Field Assessment of a New Method for Estimating Emission Rates from Volume Sources Using Open-Path FTIR. J. Air & Waste Management Assoc. 46, 159.

Price, PN 1999. Pollutant Tomography Using Integrated Concentration Data from Non-Intersecting Optical Paths. *Atmos. Environ.* 33(2), 275-280.

Scotto, RL, TR Minnich, MR Leo. 1991. A Method for Estimating VOC Emission Rates from Area Sources Using Remote Optical Sensing. In Proceedings of the EPA/A&WMA International Symposium on the Measurement of Toxic and Related Air Pollution, Raleigh, NC, 698.

Simpson, OA, RH Kagann, 1990. Measurements of Emissions at a Chemical Waste Water Site with an Open Path Remote Fourier Transform Interferometer. In Proceedings of the EPA/ A&WMA International Symposium on the Measurement of Toxic and Related Air Pollution, Raleigh, NC, 937.

SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP G5. 2006. Standard Operating Procedure for the Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450I Pulsed Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L5. 2006. Markland Sludge Gun. Standard Operating Procedure L5. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP M1. 2006. Manure Sampling. Standard Operating Procedure M1. Purdue Ag Air Quality Lab.

SOP M2. 2006. Conducting pH Measurements on Manure Samples. Standard Operating Procedure M2. Purdue Ag Air Quality Lab.

SOP M3. 2006. Determining Solids Content of Manure Samples. Standard Operating Procedure M3. Purdue Ag Air Quality Lab.

SOP M4. 2006. Determining Total (Kjeldahl) Nitrogen Content of Manure Samples. Standard Operating Procedure M4. Purdue Ag Air Quality Lab.

SOP M5. 2006. Determining Ammonia Content of Manure Samples. Standard Operating Procedure M5. Purdue Ag Air Quality Lab.

SOP O1. 2006. Emissions Estimation Using Backward Lagrangian Stochastic (bLS) Model. Standard Operating Procedure O1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP O2. 2006. Emissions Estimation Using Radial Plume Mapping (RPM). Standard Operating Procedure O2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

Spellicy, RL. 2000. Challenges to CLS analysis to the real world. Presented at Air & Waste Management Assoc. Conference, Salt Lake City, Utah, June 2000.

Stull, RE. 1988. An introduction to Boundary Layer Meteorology, Kluwer Acad. Pub.

Thoma, ED, RC Shores, EL Thompson, DB Harris, SA Thornloe, RM Varma, RA Hashmonay, MT Modrak, DF Natschke, HA Gamble. 2004. Open Path Tunable Diode Laser Absorption Spectroscopy for Acquisition of Fugitive Emission Flux Data. J. Air & Waste Manage. Assoc. 55, 658-668.

Todd, L, M Ramanathan, K Mottus, R Katz, A Dodson, G Mihan. 2001. Measuring chemical emissions using open-path Fourier transform infrared (OP-FTIR) spectroscopy and computer-assisted tomography. Atmos. Environ. 35, 1937-1947.

Turner, B. 1969. Workbook of atmospheric dispersion estimates. Public Health Service Publication 999-AP-26., 84 p

US Environmental Protection Agency. 1974. Method 350.2 – Nitrogen, Ammonia (Colorimetric, Titrimetric, Potentiometric Distillation Procedure). Online at www.umass.edu/tei/mwwp/acrobat/epa350_2NH3titration.pdf, Accessed 1/19/2006.

US Environmental Protection Agency. 2000. Meteorological Monitoring Guidance for Regulatory Modeling Applications. Office of Air Quality Planning and Standards. Research Triangle Park, NC. EPA-454/R-99-005.

US Environmental Protection Agency. 2001a. Method 1684 – Total Fixed and Volatile Solids in Water, Solids, and Biosolids. Office of Water, Office of Science and Technology, Washington, DC. EPA-821/R-01-015 (CD).

US Environmental Protection Agency. 2001b. Method 1687 – Total Kjeldahl Nitrogen in Water and Biosolids. Office of Water, Office of Science and Technology, Washington, DC. EPA-821/R-01-004 (CD).

US Environmental Protection Agency. 2004. Method 9040C (Rev. 3) pH Electrometric Measurement. Online at www.epa.gov/sw-846/pdfs/9040c.pdf. Accessed 3/7/2006.Werle, PW, P Mazzinghi, FD Amato, M De Rosa, K Maurer, F Slemr. 2003. Signal processing and calibration procedures for an in situ diode laser absorption spectroscopy. Spectrochemica Acta part A, 60, 1685-1705.

Wu, CF, MG Yost, RA Hashmonay, DY Park. 1999. Experimental Evaluation of a Radial Beam Geometry for Mapping Air Pollutants Using Optical Remote Sensing and Computed Tomography. Atmos. Environ. 33(28), 4709-4716.

Yost, MG, R Hashmonay. 2003. Mapping Air Contaminants Using Path-Integrated Optical Remote Sensing with a Non-Overlapping Variable Path Length Beam Geometry. U.S. Patent 6,542,242 B1.

14. Quality Control Requirements

In order to insure the validity of the data generated from the study and meet the data quality objectives set forth by the study it is imperative to establish quality assurance and quality control measures in each aspect of the study. Quality control involves the evaluation of instrument performance by comparison to measurement standards or through the use of QC checks. Quality assurance includes the use of properly maintained and reliable instrumentation, approved analytical methodologies and standard operating procedures and well-trained analysts. Copies of QC records, including control charts (Standard Operating Procedure for Use of Control Charts for Performance Monitoring of Gas Analyzers and Analytical Instruments; SOP Q1) for gas analyzers, will be added as appendices to the final report as well as the interim quarterly reports as appropriate.

14.1 QC checks of meteorological measurements

QC checks vary by measurement and are specified in detail in the corresponding SOP. The frequency of each check described in the applicable SOP is summarized in Table 14.1. The results of these checks are documented on forms illustrated in the respective SOP (and Appendix D). The criteria for QC check acceptance and corrective actions are also documented in the respective SOP and the appropriate Tables A1 through A6 in Appendix A. All 100 s and 5-min checks are conducted within the sensor with results included in the data stream. 30-min and daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS and documented on forms similar to those at the end of each respective SOP (and in Appendix D). Checks made every 180 d are made at PAML by FOS and documented on forms similar to those at the end of each respective SOP (and in Appendix D). Where applicable, control charts will be maintained for the calibration verification and calibration of each sensor.

Spikes in the wind speed measurements are defined as instantaneous values that exceed three standard deviations from the 100-s running mean value. Checks on the turbulent components of the wind and the temperature fluctuations cannot be made directly. The quality of the wind turbulence will be checked daily through evaluating the spectral structure of the turbulence near solar noon and intercomparisons of the measurements made at the three heights. The quality of T_v' will likewise be checked using the spectral structure.

Table 14.1 Quality control (QC) checks for meteorological sensors.

Meteorological variable	100 s	5 min	30 min	Daily	Beginning and end of each measurement period	180 d	Annual	SOP
Wind speed (horizontal)	Spikes, Path obstruction check	Spikes, Path obstruction check	Comparison with NWS measurement	NA	In-field intercomparison Zero check	Unused triad inter-comparison		W2
Turbulent wind components u’, v’, w	Spikes, Path obstruction check	Spikes, Path obstruction check	Stationarity check Homogeneity check	Spectral structure check	In-field intercomparison Zero check	Unused triad inter-comparison		W2
‘Sonic’ air temperature	Spikes, Path obstruction check	Spikes, Path obstruction check	Comparison with computed T_v	NA	In-field intercomparison	Unused triad inter-comparison		W2
Temperature fluctuations in ‘sonic’ temperature	Spikes, Path obstruction check	Spikes, Path obstruction check	Stationarity check Homogeneity check	Spectral structure check	In-field intercomparison	Unused triad inter-comparison		W2
Ambient temperature	NA	NA	Comparison of computed T_v with ‘sonic’ air temperature and NWS measurement	NA	NA		Lab calibration with NIST-traceable standard	W1
Ambient humidity	NA	NA	Comparison with NWS measurement	NA	NA		Lab calibration with NIST-traceable standard	W1
Barometric pressure	NA	NA	Comparison with NWS measurement	NA	NA	Lab calibration with NIST-traceable standard		W5
Solar radiation	NA	NA	NA	NA	NA		Lab calibration with NIST-traceable unused sensor	E3

14.2 QC checks of lagoon/basin characterization

QC checks vary by measurement and are specified in detail in the corresponding SOP. The frequency of each check described in the applicable SOP is summarized in Table 14.2. Control charts will be maintained for the calibration verification and calibration of each sensor. Acceptance criteria and corrective actions are documented in the respective SOP and Tables A7 through A10 in Appendix A.

Table 14.2 Quality control (QC) checks for lagoon/basin characterization sensors.

Sensor	Beginning and end of each measurement period	180 d	Annual	SOP
Redox state	Calibration verification		Lab calibration with NIST-traceable standard	L3
Temperature	NA	Lab calibration with NIST-traceable standard		L2
pH	Calibration verification		Lab calibration with NIST-traceable standard	L1
Depth finder		Lab calibration		L5

The NIST-traceable pH and redox probe standards will be purchased at the same concentration as is used in the respective calibration procedures (SOP L1, L3). No dilutions or solution preparation is necessary.

Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d are made at PAML by FOS. Results of beginning/end of measurement period and 180-d checks are documented on forms illustrated in SOP L1, L2, L3, and L5 and illustrated in Appendix D.

14.3 QC checks of Open Path UV-DOAS

Currently there are no EPA guidance documents available that specifically address QC checks for broadband UV spectroscopy. But because these systems operate in a similar manner as infrared air monitoring systems, we can borrow from the vast array of documentation for these air monitors. The open path UV-DOAS to be used is a bistatic broadband spectral absorption instrument designed to measure the concentration of various constituents (for this study, primarily NH_3 and H_2S) in the open air along a path of at least 50 m.

QC procedures, acceptance criteria and corrective actions for the UV-DOAS are documented in SOP C1 and Table A12 and A13 of Appendix A. They include the following:

- *Dark Current Correction Check*: Charged diode array spectrometers build up a charge over time that is independent of the actual light being detected. This charge buildup is defined as “dark current” and must be subtracted from each single beam spectra before data is analyzed. This performance audit is automatically conducted by the Cerex UVS software.
- *Baseline stability check*
- *Single beam ratio test*: The single beam ratio test for an open-path UV system is a fast and easy check on whether the UV Source is adequate for gas measurement. A weak UV source will produce data with low signal to noise ratios.
- *Precision and accuracy checks using single point calibration checks in the field and multiple point calibration checks in the lab.* TO-16 does not give a definitive test method

for determining the precision and accuracy of open-path instruments. However, the document does suggest that if an instrument is designed in a manner that all of the light beam can pass through an external cell that is placed in the instrument's beam path, a flow-through cell can be used to measure precision and accuracy. The UV-DOAS system precision and accuracy are determined using an external calibration cell in its beam path. Calibration verifications will be made using 50 ppm NH_3 in N_2 (±1% traceable to NMi standard) and 50 ppm H_2S in N_2 (±1% traceable to NIST). Zero and span are also checked.

- *Spectral Feature Match Check*: Comparison of reference table and measured peak location of Benzene calibration 'lollipop'.

The frequency of each QC procedure is listed in Table 14.3. All results of end of measurement period and 180 d QC checks are reported on a form illustrated in SOP C1. Control charts will be maintained for the calibration verification and calibration of each sensor.

All checks made throughout the sampling duration will be conducted within the sensor and reported in the output data stream for inspection at PAML on the day following the measurements. Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d are made at PAML by FOS. Results of beginning/end of measurement period and 180 d checks are documented on forms illustrated in SOP C1.

Table 14.3 QC checks for open-path concentration measurement sensors.

Sensor	Every Sample	Daily	Beginning and end of each measurement period	180 days	SOP
UV-DOAS-NH_3 and H_2S	Baseline stability Obstruction check Dark current	Single beam ratio Baseline stability	Spectral feature check with NIST traceable (H_2S) or vendor-certified FTIR-checked standards. Single point calibration verification with NMi-traceable gases.	Multipoint calibration with NIST traceable (H_2S) or vendor-certified FTIR-checked standards.	C1
TDLAS- NH_3	Obstruction check Linearity (every 100 samples)		Single point calibration verification with lab-checked gases.	Multipoint calibration with lab-checked gases	C2

14.4 QC checks of Open Path TDLAS

Currently there are no EPA guidance documents available that specifically address QC checks for TDLAS systems. However, as with the UV-DOAS systems, the TDLAS system operates in a similar manner as infrared air monitoring systems, so we can borrow from the documentation established for these air monitors. The open path TDLAS to be used is a monostatic narrowband spectral absorption instrument designed to measure the concentration of NH_3 in the open air along a path of at least 50 m. The instrument is mounted on a scanner and tripod with data processing and control through a computer.

Quality control procedures, acceptance criteria and corrective actions for the TDLAS are documented in SOP C2 and Table A11 in Appendix A. They include the following:

- *Single point calibration check:* Precision and accuracy can be checked using an external calibration cell. Calibration verifications will be made using 100 ppm NH_3 in N_2 (±1%, verified with FTIR). A zero and span check of the instrument is possible using the permanent stable calibration cell by tuning the instrument off and on the NH_3 absorption line following procedures described in the SOP.
- *Multipoint calibration check:* Because the anticipated gas concentrations are expected to span a few orders of magnitude, the assumptions of Beers Law do not hold and a calibration curve needs to be generated to compensate for the large differences between the reference spectra and the data spectra (as suggested by TO-16). Thus a three-point calibration spanning the anticipated concentration range is needed.
- Internal performance audits performed by the software include:
    - *Internal linearity check*: The internal linearity check involves a comparison of the sample waveform and the reference waveform. The sample waveform is of the returning laser signal after it has passed through the sample gas, the receiver converts it to the shape of a specific waveform or curve. These waveforms are digitized and compared (Figure 14.1) using Least Squares Regression analysis.

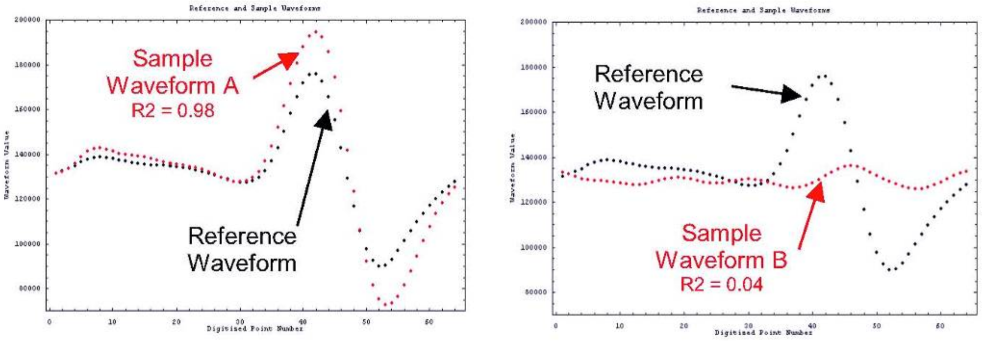


Figure 14.1 Waveform alignment of TDLAS. A good (left) and poor (right) fit of the reference gas and sample gas are illustrated.

The regression, indicated in Figure 14.2, illustrates the fit of the sample gas to reference gas. With low levels of sample gas, the R^2 between concentration and sensor response decreases, and equal zero when there is no gas present. As the signal from the gas becomes stronger, the effect of noise, both electronic and optical, is reduced and the R^2 will increase (i.e., the signal to noise ratio will increase). Based on company-derived data generated in the laboratory under controlled conditions, measurement accuracy has been found to correspond to the R^2 values- an R^2 of about 0.83 corresponds to a +/-10% accuracy (Table 14.3.1).

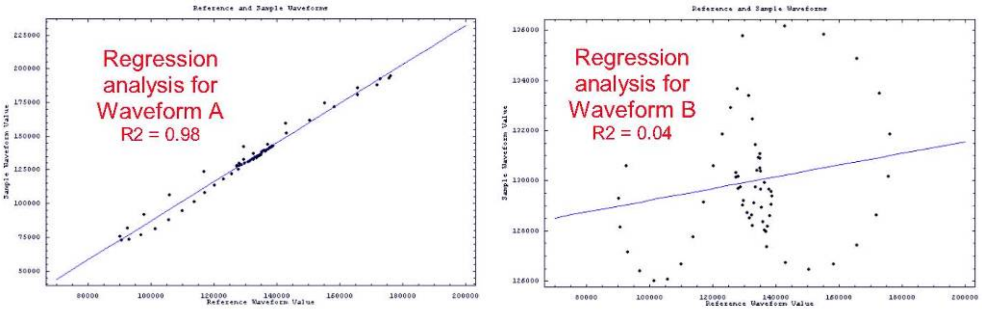


Figure 14.2 Regression analysis of TDLAS waveform measurements in Figure 14.1. The blue line represents the Linear Least Squares fit of the data.

Table 14.3.1 Correspondence of R^2 to measurement accuracy for NH3.

R^2	Accuracy		
>90	+/-	2	%
80	+/-	13	%
70	+/-	24	%
60	+/-	35	%
50	+/-	46	%
40	+/-	57	%
30	+/-	67	%
20	+/-	78	%
10	+/-	89	%
0	+/-	100	%

The frequency of each QC procedure is listed in Table 14.3. Sampling Duration checks are made internally and reported in the data stream for evaluation at PAML on the day following the measurement day. Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d are made at PAML by FOS. Results of beginning/end of measurement period and 180-d QC checks are reported on a form illustrated in SOP C2. Control charts will be maintained for the calibration verification and calibration of each sensor.

14.5 QC checks of photoacoustic spectrometer method

All QC checks and acceptance criteria for the INNOVA 1412 photoacoustic multi-gas analyzer are documented in SOP G7 and itemized in Table 14.4. Acceptance criteria and corrective actions are also documented in Tables A14 through A18 in Appendix A. Value reasonableness is assessed initially by the range of values documented in the literature. As measurements progress and histories of each parameter at each location are developed, the reasonableness of the value will be based on the value falling within the 95th percentile of the record at that location. If values fall outside the reasonable range, careful inspection of other measurements at that time will be conducted.

Calibration verifications will be made using NIST-certified EPA Protocol grade (EtOH, MeOH, methane, propane) or vendor-certified Primary Standard grade (NH_3) gases. The compositions of NH_3 cylinders used for gas analyzer calibrations will be checked using Fourier Transform Infrared (FTIR) spectroscopy, in accordance with SOP G12. If the NH_3 concentrations obtained by the FTIR check are not within ±5% of those certified by the gas provider, the gas provider will be contacted for further verification or re-certification, if necessary. Calibration verification gases include: 500 ppm NH_3 in N_2 (±1) diluted to 50 ppm, 1 ppm MeOH and 1 ppm MeOH in N_2 (± 10% accuracy), 50 ppm propane and 10 ppm methane in N_2 (±1% accuracy traceable to NIST standard) diluted to 5 ppm propane and 1 ppm methane.

Table 14.4 QC checks for photoacoustic spectrometer measurements.

Parameter	**Every Sample**	**Beginning and end of each measurement period**	**180 days**
NH_3 concentration		Single point calibration verification with primary standard gas	Multi-point calibration with primary standard
MeOH concentration		Single point calibration verification with lab-certified standard gas	Multi-point calibration with NIST-certified gases
EtOH concentration		Single point calibration verification with NIST-certified standard gases.	Multi-point calibration with NIST-certified gases
Methane concentration		Single point calibration verification with NIST-certified standard gases	Multi-point calibration with NIST-certified gases
THC concentration		Single point calibration verification with NIST-certified standard gases	Multi-point calibration with NIST-certified gases
Water vapor		Single point calibration verification	NIST-certified humidity calibrator
Response time			Measure using NIST-certified gases
Inlet flow rate	Measure		Measure with NIST-traceable flow meter
Perform leak check			Sample line, flow components and fittings

With every sample, checks are made internally and reported in the data stream for evaluation at PAML on the day following the measurement day. Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d are made at PAML by FOS. The frequency of each QC check is indicated in Table 14.4. Control charts will be maintained for the calibration verification and calibration of each sensor.

14.6 Lineage of Traceable Standards

All gases used in verification and calibration procedures are traceable to either a NIST standard reference material, or to EPA primary standard grade gases verified by FTIR, through a Certified Reference Material. All blending of the analytical gas with N_2 is traceable to a NIST standard by weight. NIST traceable calibration/verification gases include:

- 300 ppm and 4 ppm H_2S in N_2 or air at 3% accuracy
- 10 ppm methane and 50 ppm propane in N_2 at 1% accuracy
- 1 ppm MeOH and 1 ppm EtOH in N_2 at 10% (0.1 ppm) accuracy
- 40 ppm SO_2 in air at 2% accuracy

Primary standard calibration/verification gases include 500 ppm NH_3 in N_2 at 1% accuracy and 1000 ppm NH_3 in N_2 at 2% accuracy.

Standard solutions for pH and redox potential measurements will be traceable to certified NIST standards: pH solutions include pH 4 (potassium biphthalate using Standard Reference Material 185h), pH 7 (potassium phosphate using Standard Reference Material 186-I-g) and pH 11 (sodium borate using Standard Reference Material 187d) standards traceable to NIST, and 230 mV ZoBell's solution standard.

One of the two calibration check methods for the relative humidity sensor (SOP W1) require lithium chloride and potassium sulfate salt packets certified by the Vaisala Oy's Measurement Standards Laboratory which is accredited by Finnish Accreditation Service (FINAS), a member of the European Cooperation for Accreditation of Laboratories.

Table 14.5 QC checks for pulsed-fluorescence H_2S analyzer measurements.

Parameter	**Every sample**	**Beginning and end of each measurement period**	**180 days**
H_sS concentration		Single point calibration verification with NIST-traceable standard gas Multi-point calibration with NIST-certified gases if verification test shows zero deviation of > ±5% full scale from baseline zero or precision shows deviation of > ±10% from baseline	Multi-point calibration with NIST-certified gases
Inlet flow rate	Sample flow rate	Filter check	Leak check
Lamp function	Sample intensity and voltage		

14.7 QC checks of pulsed fluorescence method

All QC checks and acceptance criteria for the TEC 450i pulsed fluorescence H_2S analyzer are documented in SOP G7 and itemized in Table 14.5. Acceptance criteria and corrective actions are also documented in Table A25_in Appendix A. Value reasonableness is assessed initially by the range of values documented in the literature. As measurements progress and histories of each parameter at each location are developed, the reasonableness of the value will be based on the value falling within the 95th percentile of the record at that location. If values fall outside the reasonable range, careful inspection of other measurements at that time will be conducted. Calibration verification gas is 4 ppm H_2S in N_2 or air (±3% traceable to NIST standard) in trailers and at PAML.

With every sample, checks are made internally and reported in the data stream for evaluation at PAML on the day following the measurement day. Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d are made at PAML by FOS. The frequency of each QC check is provided in Table 14.5. Control charts will be maintained for the calibration verification and calibration of the analyzer.

14.8 QC checks of S-OPS and GSS sampling method

All QC checks and acceptance criteria for the S-OPS and GSS system are documented in SOP C4 and itemized in Table 14.6. Acceptance criteria and corrective actions are given in SOP C4.

With every sample, checks are made internally and reported in the data stream for evaluation at PAML on the day following the measurement day. Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d are made at PAML by FOS. The frequency of each QC check is indicated in Table 14.6.

Table 14.6 QC checks for S-OPS and GSS sampling.

Parameter	**Every Sample**	**Beginning and end of each measurement period**	**180 days**
Chamber pressure	Measure		
Chamber flow direction	Measure		Flow direction test
Sampling flow rate	Measure	S-OPS flow check	
Sample integrity		S-OPS and GSS leak checks	

References

APHA. 1995. Standard Methods for the Examination of Water & Wastewater, 19th Edition, Method 4500-H^+, AD Eaton, LS Clesceri, AE Greenberg (Eds.), AWWA, WEF.

APHA, 1995. Standard Methods for the Examination of Water & Wastewater, 19th Edition, Method 2580, AD Eaton, LS Clesceri, AE Greenberg (Eds.), AWWA, WEF.

American Society for Testing and Materials (ASTM) E104 Standard practice for maintaining constant relative humidity by means of aqueous solutions, American Soc. for Testing and Materials.

American Society for Testing and Materials (ASTM) Standard Practice E1982-98, Standard Practice for Open-Path Fourier Transform Infrared (OP/FT-IR) Monitoring of Gases and Vapors in Air; March 1999.

American Society for Testing and Materials (ASTM) Standard Guide E1865-97 (Reapproved 2002), Standard Guide for Open-Path Fourier Transform Infrared (OP/FT-IR) Monitoring of Gases and Vapors in Air; July 1997.

Atmospheric Radiation Measurement Program. 2004. Atmospheric Radiation Monitoring Network: Standard Operating Procedures

Boreal Laser, Inc. 2003. GasFinder2.0 portable system Operation Manual. Ver 0.39, Boreal Laser, Inc, Spruce Grove, Alberta, Canada, 38p.

Cerex Environmental Services Inc. 2006. UV Sentry Open-path Air Monitor End-User Manual, Version 2006329, Cerex Environmental Services, Inc, Atlanta, GA

Foken, T, B Wichura. 1996. Tools for quality assessment of surface-based flux measurements. Agricultural and Forest Meteorol. 78, 83-105.

Hughes, EE and J Mandel. 1981. A Procedure for Establishing Traceability of Gas Mixtures to Certain National Institute of Standards and Technology SRM's, NIST, NBSIR 81-2227.

IMPROVE, Particulate Monitoring Network: Standard Operating Procedures, University of California, Davis.

Innova AirTech Instruments. undated. 1314 Photoacoustic multi-gas analyzer, 1412 Photoacoustic Field Gas-Monitor. Technical Documentation. BE6011-11. 252 p.

Lin, L I-K. 1989. A Concordance Correlation Coefficient to Evaluate Reproducibility. Biometrics. 45, 255-68.

RvA. 2004. Traceability of Gases. Raad voor Accreditatie (Dutch Accreditation Council), RvA-TK-6.2, http://www.rva.nl/uri/?uri=AMGATE_10218_1_TICH_R7227504450162&xsl=AMGATE_10218_1_TICH_L927157665.pdf

SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP C4. 2006. Standard Operating Procedure for the Synthetic Open Path Sampling System. Standard Operating Procedure C4. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP E3. 2006. Measurement of Solar Radiation with the LiCOR model 200SL or 200SZ Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP G5. 2006. Standard Operating Procedure for the Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450I Pulsed Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Standard Operating Procedure G7. Purdue Ag Air Quality Lab.

SOP G12. 2006. FTIR Verification of Gas Cylinder Composition. Standard Operating Procedure G12. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP O1. 2006. Emissions Estimation Using Backward Lagrangian Stochastic (bLS) Model. Standard Operating Procedure O1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP O2. 2006. Emissions Estimation Using Radial Plume Mapping (RPM). Standard Operating Procedure O2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP Q1. 2006. Use of Control Charts for Performance Monitoring of Gas Analyzers. Standard Operating Procedure Q1. Purdue Ag Air Quality Lab.

SOP W1. 2006. Measurement of Atmospheric Temperature and Humidity with the Viasala Model HMP45C Sensor and Solar Shield. Standard Operating Procedure W1. Purdue Applied Meteorology Lab.

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.

SOP W3. 2006. Measurement of Wetness with the Campbell Scientific Model Resistance Grid. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.

SOP W5. 2006. Measurement of Barometric pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.

SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

US Environmental Protection Agency. 1999. Compendium Method TO-16: Long-Path Fourier Transform Infrared Monitoring of Atmospheric Gases. Office of Research and Development. Washington, D.C. EPA/625/R-96/010b.

15. Instrument/Equipment Testing, Inspection, and Maintenance

All equipment will be purchased new. Each site visit will start with a physical inspection of the instrument conditions. Particular attention will be made to looking for damage to wires, dirt and dust on sensors, lightning and other surge damage to sensors, moisture penetration into instruments, and ice and wind damage to instruments and platforms. The results of the physical inspection will be documented in a logbook and scanned for ftp transmission. Acceptance criteria and corrective actions for equipment inspections are indicated in the respective SOP. An example maintenance list for an entire measurement site is in Appendix D and documented in SOP W6, SOP U5, and SOP U7.

15.1 *Meteorological and lagoon/basin characterization equipment*

At each site visit (at least at the beginning and end of each measurement period), the field operator will conduct visual inspections of the meteorological equipment according to SOP W6. Preventive maintenance will occur at the beginning or end of each measurement period (approximately every 21 d) with appropriate documentation and reporting. Particular attention will be made to the lagoon/basin measurement sensors as they will routinely become fouled by wastewater. See SOP L1, L2, and L3 for procedures related to cleaning measurement sensors.

15.2 *Open path UV-DOAS and TDLAS*

At each site visit (at least at the beginning and end of each measurement period) the field operator will conduct visual inspections of the alignment of each beamline and each mirror will be checked for water condensate and dried as needed. All equipment will be properly maintained and tested at the beginning and end of each approximately 20-d sampling period to ensure they are functioning properly in accordance with the manufacturer’s recommended intervals and acceptance parameters. Maintenance procedures related to keeping windows and optics clean, replacing lamps, cleaning filters and other aspects of maintaining instrument upkeep are itemized in the respective manuals and SOPs C1 and C2.

15.3 *Photoacoustic multi-gas analyzer*

At each site visit (at least at the beginning and end of each measurement period) the field operator will conduct a visual inspection of the gas sampling head, pump, and analyzer. Obstruction to air flow will be cleared, All equipment will be properly maintained and tested at the beginning and end of each approximately 20-d sampling period to ensure they are functioning properly in accordance with the manufacturer’s recommended intervals and acceptance parameters. Maintenance procedures related to cleaning air inlet filter and other aspects of maintaining instrument upkeep are itemized in the respective manuals and SOP G7.

15.4 *Pulsed fluorescence analyzer*

At each site visit (at least at the beginning and end of each measurement period), the FOS will conduct a visual inspection of the gas sampling tube filter, pump, and analyzer. Obstructions to air flow will be cleared, and all equipment will be properly maintained and tested at the beginning and end of each approximately 20-d sampling period to ensure they are functioning properly in accordance with the manufacturer's recommended intervals and acceptance parameters. Maintenance procedures related to replacing air inlet filters and other aspects of maintaining instruments are itemized in the respective manuals and SOP G5.

15.5 *GSS and S-OPS*

At each site visit (at least at the beginning and end of each measurement period), the FOS will conduct a visual inspection of the gas sampling tubes, inlet filters, and pumps. Obstructions to air flow will be cleared and filters replaced as indicated. All equipment will be properly maintained and tested at the beginning and end of each approximately 20-d sampling period to ensure they are functioning properly in accordance with SOP C4. Maintenance procedures for replacing air inlet filters and other aspects of maintaining instruments are itemized in SOP C4.

References

Boreal Laser, Inc. 2003. GasFinder2.0 portable system Operation Manual. Ver 0.39, Boreal Laser, Inc, Spruce Grove, Alberta, Canada, 38p.

Cerex Environmental Services Inc. 2006. UV Sentry Open-path Air Monitor End-User Manual, Version 2006329, Cerex Environmental Services, Inc, Atlanta, GA

Innova AirTech Instruments. undated. 1314 Photoacoustic multi-gas analyzer, 1412 Photoacoustic Field Gas-Monitor. Technical Documentation. BE6011-11. 252 p

SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Applied Meteorology Lab.

SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Applied Meteorology Lab.

SOP C4. 2006. Standard Operating Procedure for the Synthetic Open Path Sampling System. Standard Operating Procedure C4. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP G5. 2006. Standard Operating Procedure for the Measurement of Hydrogen Sulfide (H2S) with the Thermo Electron Corporation Model 450C Pulsed Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Purdue Ag Air Quality Lab.

SOP U5. 2006. Installation of Open Source Measurement Equipment. Standard Operating Procedure U5. Purdue Applied Meteorology Lab.

SOP U7. 2006. Installation of Open Source Measurement Equipment (Corrals). Standard Operating Procedure U7. Purdue Applied Meteorology Lab.

SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

16. Instrument / Equipment Calibration and Frequency

Quality assurance of the measurements includes performance and technical systems audits. Calibration and performance audits are needed to maintain the quality of measurements and will be carefully tracked for each instrument. Calibration and performance audit records will document: date, instrument, serial number of instrument being calibrated and standard instrument being calibrated against, name of person performing calibration, calibration procedure used, problems encountered and the statistics of the before and after measurements made during the calibration. No adjustments to the instrument will be made in response to the calibrations. All calibration records will be maintained by the PQAM. Logbooks indicating the calibration activity are maintained in each trailer and images of the pages will be stored by the PDM in location-specific data directories.

16.1 *Meteorological equipment*

On receipt from the manufacturer, the wind, solar radiation, relative humidity, liquid temperature, air temperature and atmospheric pressure sensors will have their calibration verified in the laboratory using the performance audit procedures described in the respective SOP and summarized Table 16.1.

Table 16.1 Performance audit procedures for the meteorological equipment.

Meteorological sensor	**Audit performed**	**Method**
Wind speed (horizontal)	Signal	Comparison with three NIST-traceable (mean wind speed only) collocated *in-situ* sensors
Wind direction	Response	Comparison with three NIST-traceable (mean wind speed only) collocated *in-situ* sensors
Wind direction	Mounting configuration	Comparison with compass direction
Ambient temperature	Response	Comparison with NIST-traceable mercury thermometer in confined air
Humidity	Response	Salt solutions or dew point generator
Barometric pressure	Response	Comparison with Fortin barometer
Solar Radiation	Response	Comparison with NIST-traceable unused sensor under ambient environmental conditions

Relative humidity sensors (SOP W1) will be audited either using saturation salts according to procedures defined in ASTM E104 or using a dew point generator at PAML. Temperature sensors (SOP W1) will be audited at PAML. Atmospheric pressure sensors (SOP W5) will be audited against a Fortin barometer at PAML according to procedures stated in the *Manual of*

Barometry. Solar radiation sensors (SOP E3) will be intercompared with an unused sensor at PAML.

In general, the quality of sonic anemometer turbulence measurements can only be assessed by side by side comparisons. Wind tunnel calibration (which is NIST traceable and provided by the manufacturer) provides only an evaluation of the mean wind and not the turbulent components and the turbulence in a wind tunnel is not sufficient to evaluate the response of the sonic anemometer to turbulence. Therefore all performance audits of sonic anemometers will rely on intercomparisons (Table 16.1). The three-dimensional sonic anemometers will be inter-compared with three NIST-traceable unused sensors (termed a triad) at the Purdue Weather Station open field facility every six months. Details concerning the intercomparison are documented in SOP W2.

Field performance audits will be performed prior to installation of the equipment at each location and only units that "pass" the performance audits will be installed. The "fail" unit will then be returned to the manufacturer for repair. The equipment at the sites utilizing established meteorological monitoring equipment and procedures according to SOP will be audited by the PM and the QAM (technical systems audit). These meteorological equipment audit reports will be generated and archived by QAM.

16.2 *Lagoon/basin characterization equipment*

On receipt from the manufacturer, the pH, redox, and temperature sensors will be calibrated in the laboratory using performance audit procedures outlined in Table 16.2 below.

Table 16.2. Performance audit procedures for the lagoon/basin characterization equipment.

Sensor	**Audit performed**	**Method**
pH		Comparison with NIST-traceable standard buffer solutions
Temperature	Response	Comparison with NIST-traceable mercury thermometer in water bath
Redox state	Response	Comparison with calibration solutions
Depth finder	Response	Comparison with resin bed depth

16.3 *Open path UV-DOAS*

Although the UV-DOAS does not require a multi-point calibration as long as the range of measurement does not exceed the range of spectra stored in the PLS reference library, a multi-point calibration check will be conducted. On receipt from the manufacturer, the UV-DOAS calibration will be checked in the laboratory at multiple concentrations using certified calibration gases of H_2S (500 ppm) and NH_3 (500 ppm) according to procedures outlined in SOP C1. Calibration concentrations of each gas will bracket the range of in-field measurements. Calibration records will be maintained in accordance with SOP D1.

For all 21-d rotation locations, field performance audits consisting of a single-point calibration check will be performed prior to installation of the equipment at each location and measurement period. Certified calibration gases for the single-point check include H_2S (4 ppm, 3% accuracy, NIST certified) and NH_3 (50 ppm, 1% accuracy, lab certified). Only units that "pass" the performance audits will be installed. For all continuous measurement locations, field performance audits consisting of a single-point calibration check will be performed every 21 d and only units that "pass" the performance audits will be reinstalled. All "fail" units will be returned to the manufacturer for repair or recalibration. Records of the calibration checks will be maintained in accordance with SOP D1.

Multi-point calibrations of the UV-DOAS will be conducted every six months in the laboratory with calibration records maintained in accordance with SOP D1 and SOP C1. Procedures to troubleshoot the instrument and possibly resolve the cause for failure are defined in SOP C1. Units that fail the multi-point calibration and cannot be remediated to the point of passing the calibration will be returned to the manufacturer for repair or recalibration. Units that pass will return to the field.

16.4 *Open-path TDLAS*

The TDLAS is shipped already calibrated at the factory, however it will be calibrated using a vendor-certified primary standard 100 ppm NH_3 calibration gas (1% accuracy) according to procedures outlined in SOP C2. The TDLAS does not require any calibration in the field but will be calibration checked with single point calibrations.

During operation, the TDLAS internal reference cell is compared with this stored waveform at frequent intervals. Any significant deviation generates a status code to alert the user to a potential calibration problem (linearity check). The TDLAS software can be used to check the reference cell, as well as to download sample, reference and calibration waveforms to verify that the internal calibration system is functioning correctly. Manual checks of the waveforms can be made on-site using the TDLAS controller program.

Calibration records will be maintained in accordance with SOP D1. Field performance audits of single-point calibration verifications will be performed prior to installation of the equipment at each location and only units that "pass" the performance audits will be installed. The "fail" unit will then be evaluated and adjusted if possible. If it is not possible to remediate, the unit will be returned to the manufacturer for repair or recalibration. Multi-point calibrations of the TDLAS will be conducted every six months in the laboratory with calibration records maintained in accordance with SOP D1 and SOP C2. Calibration concentrations of each gas will bracket the range of in-field measurements. Procedures to troubleshoot the instrument and possibly resolve the cause for failure are defined in SOP C2. Units that fail the multi-point calibration and cannot be remediated to the point of passing the calibration will be returned to the manufacturer for repair or recalibration. Units that pass will return to the field.

16.5 *Photoacoustic multi-gas analyzer*

The Photoacoustic multi-gas analyzer is shipped already calibrated from the factory. However, on receipt from the manufacturer, the photoacoustic multi-gas analyzer will be single-point calibrated (SOP G7) using calibration gases of 10 ppm Methane (10% accuracy traceable to NIST),1 ppm MeOH (10% accuracy traceable to NIST), 50 ppm Propane (1% accuracy traceable to NIST), and 50 ppm NH_3 (lab-checked 1% accuracy). Calibration records will be maintained in accordance with SOP D1. Field performance audits of single-point calibration verifications will be performed prior to installation of the equipment at each location (approximately every 21 d) and only units that "pass" the performance audits will be installed. The "fail" unit will be further evaluated and adjusted if possible. If it is not possible to remediate, the unit will be returned to the manufacturer for repair or recalibration if necessary. Multi-point calibrations of the PAS will be conducted every six months in the laboratory with calibration records maintained in accordance with SOP D1 and SOP G7. Calibration concentrations of each gas will bracket the range of in-field measurements. Specifications for accuracy and precision are documented in SOP G7 and Tables A14 through A18. Specifications for linearity are documented in SOP G7. Procedures to troubleshoot the instrument and possibly resolve the cause for failure are defined in SOP G7. Units that fail the multi-point calibration and cannot be remediated to the point of passing the calibration will be returned to the manufacturer for repair or recalibration. Units that pass will return to the field.

16.6 *Equipment used in the analysis of manure*

The commercial laboratory to conduct these analyses (Midwest Laboratories, Inc.) has defined the audit and calibration frequency and associated documentation of audits and calibrations necessary for the analyses of total solids content, volatile solids content, pH, total nitrogen, and ammonia nitrogen. These are documented in individual SOPs of the laboratory referred to the laboratory’s Quality Assurance Manual.

16.7 *Pulsed Fluorescence H_2S Analyzer*

The Pulsed Fluorescence H_2S analyzer is shipped already calibrated from the factory. However, on receipt from the manufacturer, the analyzer will be multi-point calibrated (SOP G5) using calibration gases of 300 ppm and 4 ppm hydrogen sulfide (3% accuracy traceable to NIST). Calibration records will be maintained in accordance with SOP D1. Field performance audits of single-point calibration verifications will be performed prior to installation of the equipment at each location (approximately every 21 d) and only units that "pass" the performance audits will be installed. Any failing unit will be further evaluated and adjusted if possible. If it is not possible to remediate, the unit will be returned to the manufacturer for repair or recalibration if necessary. Multi-point calibrations of the PF analyzer will be conducted every six months in the laboratory, with calibration records maintained in accordance with SOP D1 and SOP G5. Calibration concentrations of each gas will bracket the range of in-field measurements. Specifications for accuracy and precision are documented in SOP G5 and Table A25.

Specifications for linearity are documented in SOP G5. Procedures to troubleshoot the instrument and possibly resolve the cause for failure are defined in SOP G5. Units that fail the multi-point calibration and cannot be remediated to the point of passing the calibration will be returned to the manufacturer for repair or recalibration. Units that pass will return to the field.

References

APHA. 1995. Standard Methods for the Examination of Water & Wastewater, 19th Edition, Method 4500-H+, AD Eaton, LS Clesceri, AE Greenberg (Eds.), AWWA, WEF.

APHA, 1995. Standard Methods for the Examination of Water & Wastewater, 19th Edition, Method 2580, AD Eaton, LS Clesceri, AE Greenberg (Eds.), AWWA, WEF.

American Society for Testing and Materials (ASTM) E104 Standard practice for maintaining constant relative humidity by means of aqueous solutions, American Soc. for Testing and Materials.

American Society for Testing and Materials (ASTM) Standard Practice E1982-98, Standard Practice for Open-Path Fourier Transform Infrared (OP/FT-IR) Monitoring of Gases and Vapors in Air; March 1999.

American Society for Testing and Materials (ASTM) Standard Guide E1865-97 (Reapproved 2002), Standard Guide for Open-Path Fourier Transform Infrared (OP/FT-IR) Monitoring of Gases and Vapors in Air; July 1997.

Atmospheric Radiation Measurement Program. 2004. Atmospheric Radiation Monitoring Network: Standard Operating Procedures

Boreal Laser, Inc. 2003. GasFinder2.0 portable system Operation Manual. Ver 0.39, Boreal Laser, Inc, Spruce Grove, Alberta, Canada, 38p.

Cerex Environmental Services Inc. 2006. UV Sentry Open-path Air Monitor End-User Manual, Version 2006329, Cerex Environmental Services, Inc, Atlanta, GA

Foken, T, B Wichura. 1996. Tools for quality assessment of surface-based flux measurements. Agricultural and Forest Meteorol. 78, 83-105.

IMPROVE, Particulate Monitoring Network: Standard Operating Procedures, University of California, Davis.

Innova AirTech Instruments. undated. 1314 Photoacoustic multi-gas analyzer, 1412 Photoacoustic Field Gas-Monitor. Technical Documentation. BE6011-11. 252 p

Lin, L I-K. 1989. A Concordance Correlation Coefficient to Evaluate Reproducibility. Biometrics. 45, 255-68.

Midwest Laboratories, Inc. 2004. Quality Assurance Manual. Ver 6, Midwest Laboratories, Inc, Omaha, NE, 138 p.

SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Applied Meteorology Lab.

SOP G5. 2006. Standard Operating Procedure for the Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450I Pulsed Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Applied Meteorology Lab.

SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Applied Meteorology Lab.

SOP O1. 2006. Emissions Estimation Using Backward Lagrangian Stochastic (bLS) Model. Standard Operating Procedure O1. Purdue Applied Meteorology Lab.

SOP O2. 2006. Emissions Estimation Using Radial Plume Mapping (RPM). Standard Operating Procedure O2. Purdue Applied Meteorology Lab.

SOP W1. 2006. Measurement of Atmospheric Temperature and Humidity with the Viasala Model HMP45C Sensor and Solar Shield. Standard Operating Procedure W1. Purdue Applied Meteorology Lab.

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.

SOP W3. 2006. Measurement of Wetness with the Campbell Scientific Model Resistance Grid. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.

SOP W5. 2006. Measurement of Barometric pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.

SOP E3. 2006. Measurement of Solar Radiation with the LiCOR model 200SL or 200SZ Silicon Pyranometer. Standard Operating Procedure E3. Purdue Applied Meteorology Lab.

US Department of Commerce- Weather Bureau. 1963. Manual of Barometry. Federal Meteorological Handbook No. 7, U.S. Government Printing Office. Washington, D.C.

17. Inspection/Acceptance of Supplies and Consumables

Supplies and consumables for this project consist primarily of calibration supplies. A PAML FOS technician is responsible for accepting, tracking distribution, and maintaining supplies and consumables. Perishable consumables will be labeled on receipt and stored at normal room temperatures both in the PAML laboratory and at the measurement locations in the Instrument Trailer (SOP U4). A FOS technician will maintain a record of the labeling, manufacture date, replacement date, and shelf-life of consumables (using a ”Perishable Consumables” EXCEL spreadsheet similar to that in Appendix D), verify that the perishable consumables are kept at normal room temperature, and replace perishable supplies as necessary. The PQAM is responsible for maintaining certification records of all calibration and calibration verification standards. Calibration checks of the TDLAS (SOP C2), pulsed fluorescence (SOP G5), and multi-gas analyzer (SOP G7) instrument measurements (critical measurements) will be completed using certified standard gases. All atmospheric gaseous measurements will be traceable to dual-analyzed and certified standards from a reputable supplier. Gases will be received according to SOP G2, and NH_3 concentrations will be checked according to SOP G12. Calibration gases for the TDLAS, PFA and PAS include: nominal 4 ppm H_2S (2% accuracy, NIST-traceable) and 50 ppm NH_3 (1% accuracy, NMi-traceable) for single-point in-field calibration checks and 4 ppm H_2S (2% accuracy, NIST-traceable) and 500 ppm NH_3 (1% accuracy, lab-checked according to SOP G12) for multiple-point in-lab calibrations. The shelf life of the NH_3 standard gases is six months. The shelf life of the H_2S standards is one year. Calibration gases for the multi-gas analyzer measurements include:

- 10 ppm methane (1% accuracy traceable to NIST), balance N_2, shelf life 36 months.
- 1 ppm MeOH (2% accuracy traceable to NIST), balance N_2, shelf life 12 months.
- 1 ppm EtOH (1% accuracy traceable to NIST), balance N_2, shelf life 12 months.
- 50 ppm propane (10% accuracy traceable to NIST), balance N_2, shelf life 36 months.
- 500 ppm NH_3 (10% accuracy, checked according to SOP G12), balance N_2, shelf life 6 months.
- 300 ppm and 4 ppm H_2S (3-4% accuracy traceable to NIST), balance air or N_2, shelf life 12 months.

A pure N_2 gas cylinder and CEM zero air cylinder will also be used in the multi-point calibrations as a diluter gas. This gas will be received according to SOP G2 but not concentration checked.

Calibration checks for pH (SOP L1) and redox potential measurements (SOP L3) (non-critical measurements) will be completed using solutions traceable to certified standards from a reputable supplier. Solutions will be received with manufacturer’s calibration assumed to be valid. pH solutions include pH 4 (potassium biphthate), pH 7 (potassium phosphate) and pH 11 (sodium borate) standards traceable to NIST. An additional solution to evaluate the pH probe requires thymol ($C_{10}H_{13}OH$). Redox potential solution is the 230 mV ZoBell’s solution standard. The shelf life of these standards is six months. Water softener resin, with a shelf life of greater than five years, is used to verify the calibration of the sludge depth sensor (SOP L5).

Calibration checks for the relative humidity sensor (SOP W1) require either lithium chloride and potassium sulfate salt packet certified by the Finnish Accreditation Service (shelf life of the packaged salts is six months) or the use of a LiCOR 610 portable dew point generator traceable to NIST standards (NIST, 1996).

In addition, Styrofoam coolers, sealable quart plastic bags, ‘Authorized Return Shipment’ ground shipment labels, ‘blue ice’ for maintaining 4^{o}C sample temperature for manure samples during shipment to the analytical laboratory (SOP M1) will be stocked and tracked to assure adequate supplies for the Corral and Manure Basin locations.

References

NIST. 1996. Report of Calibration**,** Thermoelectric Dew-Point Generator. Technical Note TN 255979, National Inst. of Standards and Technol., Gaithersburg, Maryland 20899.

SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Applied Meteorology Lab.

SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Applied Meteorology Lab.

SOP G2. 2006. Compressed Gas Cylinders, Standard Operating Procedure G2. Purdue Ag Air Quality Lab.

SOP G5. 2006. Standard Operating Procedure for the Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450I Pulsed Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Purdue Ag Air Quality Lab.

SOP G12. 2006. FTIR Verification of Gas Cylinder Composition. Standard Operating Procedure G12. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Applied Meteorology Lab.

SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Applied Meteorology Lab.

SOP L5. 2006. Markland Sludge Gun. Standard Operating Procedure L5. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

SOP M1. 2006. Manure Sampling. Standard Operating Procedure M1. Purdue Ag Air Quality Lab.

SOP W1. 2006. Measurement of Atmospheric Temperature and Humidity with the Viasala Model HMP45C Sensor and Solar Shield. Standard Operating Procedure W1. Purdue Applied Meteorology Lab.

18. Data Acquisition Requirements (Non-Direct Measurement)

US National Weather Service Automated Surface Observation Stations (ASOS) and Automated Weather Observation Stations (AWOS) will be used to substitute for missing or invalid non-critical measurements of air temperature, humidity, barometric pressure and surface wetness (Table 18.1). In addition nearby National Weather Service Doppler Radar (WSR-88D) estimates of precipitation distribution and amount will be used to support project surface wetness measurements. In addition some missing or invalidated measurements may be substituted by valid measurements specified within the NAEMS Barn component QAPP.

Table 18.1 Locations of Supporting NWS Weather Observations

Farm	ASOS/AWOS location code	WSR 88-D Radar Location code
1	KDPL	RAX
2	KLBT	RAX
3	KLAF	IND
4	KCIN & KBNW	DMX
5	KGUY	AMA
6	KGUY	AMA
7	KPSC & KYKM	PDT
8	KJVL	MKX
9	KLAF	IND
10	KAMA	AMA

NWS data will be extracted from either a web-based source such as http://www.uswx.com/ and http://radar.weather.gov/ or from the continuous records collected at PAML by a Local Data Manager program as part of the Internet Data Distribution project of the UNIDATA program University Center for Atmospheric Research (Domenico, 2003). Data provided by the NWS have been quality assured through procedures defined in Federal Meteorological Handbook Nos. 1 and 11 Part A, therefore all measurements made available will be considered valid. On occasion supplementary values of the surface weather are reported on the same hour of the original measurement and if these supplemental reports are replacements of a prior measurement report, they will be used in place of the original reported values where applicable.

References

Domenico, B. 2003. Unidata Internet Data Distribution: An Overview of the IDD. http://www.unidata.ucar.edu/software/idd/overview/idd.html

US National Weather Service. 2005. Federal Meteorological Handbook No. 1 - Surface Weather Observations and Reports, September 2005. US. Dept. of Commerce, National Oceanic and Atmospheric Administration. Office of the Federal Coordinator for Meteorological Support Services and Supporting Research, FCM-H1-2005 (http://www.ofcm.gov/fmh-1/fmh1.htm).

US National Weather Service. 2005. Federal Meteorological Handbook No. 11 - Doppler Radar Meteorological Observations: Part D. WSR-88D Unit Description and Operational Applications. FCM- US. Dept. of Commerce, National Oceanic and Atmospheric Administration. Office of the Federal Coordinator for Meteorological Support Services and Supporting Research, FMH-11D-2006 (http://www.ofcm.gov/fmh11/fmh11D.htm).

US National Weather Service. 2006. Federal Meteorological Handbook No. 11 - Doppler Radar Meteorological Observations: Part A. WSR-88D Unit System Concepts, Responsibilities, and Procedures. FCM- US. Dept. of Commerce, National Oceanic and Atmospheric Administration. Office of the Federal Coordinator for Meteorological Support Services and Supporting Research, FMH-11A-2006 (http://www.ofcm.gov/fmh11/fmh11A.htm).

19. Data Management

The data management program involves collecting, entering, transferring, verifying, validating, summarizing, and reporting the data gathered in this study. These data include descriptive and historical information about each site (e.g. log books and sheets, etc.), all analytical and meteorological data, and summaries and reports. The objective of the data management program is to ensure that the data gathered in the field and laboratory are and remain valid and are not altered (other than appropriate unit conversions) as they are transferred from the field to the periodic and final reports..

Quality assurance of the measurements includes data quality audits. The PQAM will conduct a data quality audit on the data management system at least monthly. Auditing will involve comparing the processed meteorological and analytical data in the spreadsheets with the raw data obtained from the field to ensure that the data are being processed correctly and that invalidated data are not being used incorrectly. Any findings or concerns from the data quality audits will be addressed to the SA and PM. PM is responsible for conducting or assigning the task of conducting the data validation. Data will be assessed for representativeness, completeness, comparability, accuracy and precision as outlined in Section 4.

The DM will distribute only validated, quality-coded data as directed by the SA. All personnel involved in collecting and transferring of measurement and processed data will be trained in all procedures prior to participating in the field operations.

19.1 *Data Analysis*

Emissions calculations using both the RPM and bLS models will be conducted at PAML after careful inspection of the data for validity. Computations of stability, turbulence, and dissipation (among others) will also be conducted at PAML. In addition, data analysis procedures will include statistical representations of the probability distributions for NH_3, H_2S, and VOC concentrations and emissions during varying periods of time defined both temporally and in terms of typical climatological conditions. Concentrations and emissions of NH_3, H_2S, and VOC will be correlated with atmospheric conditions such as stability, wind direction and wind speed. Concentrations and emissions of NH_3, H_2S, and VOC near the lagoons will be correlated with lagoon characteristics such as temperature, pH, redox state, and air-lagoon temperature difference. Concentrations and emissions of NH_3, H_2S, and VOC near the lagoons will be correlated with basin characteristics such as pH, total and volatile solid content, ammonia nitrogen and total nitrogen content. Concentrations and emissions of NH_3, H_2S, and VOC near the corral will be correlated with surface wetness. General techniques to be used include calculation of:

- Means, medians, standard deviations, probability distributions, and standard errors of measurements segregated by ranges of atmospheric or surface conditions.
- Correlations and linear and non-linear regressions between measurement variables with appropriate goodness-of-fit statistics.

- Analysis of variance to determine sources of variability in measurements.
- Significance of differences between probability distributions of measurements.
- Time series analysis of measurements.

It is important to remember however that statistical associations or lack of associations do not indicate causative relationships and provide only supporting evidence for process-based models. At the completion of each quarter, the results of the prior quarter will be presented to the NAEMS participants for review and comment. This will assure that the choices in data reduction are consistent with the needs of the NAEMS researchers.

19.2 *Data tracking*

Data files from each rotating measurement location and the PAML-managed continuous measurement locations will be transferred from field to PAML at the end of each 8 to 20-d sampling period by FOS hand delivery in a ‘data pouch’ with the associated Electronic Data Transfer Form (Appendix D). The data pouch contains two sets of data (that of the most recently-completed measurement period and that of the previous measurement period) to minimize risk of data loss through any accident of raw data files. The ‘data pouch’ includes:

- A set of data for the latest measurement period, including one CD with copies of TDLAS, sonic anemometer (except 16-Hz data), weather, lagoon, GSS, PFA and PAS data from recently-completed measurement period, one 64 Mb flash memory chip with weather/lagoon data, one 256Mb memory stick with field notes, calibration data and control charts from the recently-completed measurement period, one DVD with 16-Hz sonic anemometer data..
- A set of data for the previous measurement period, including one CD with copies of TDLAS, sonic anemometer (except 16-Hz data), weather, lagoon, GSS, PFA and PAS data from previous measurement period.

On arrival at PAML, the PDM will log the data into the laboratory and compare the files received by ‘data pouch’ to those received earlier by ftp. Inconsistencies will be followed up and the data files in the PAML computer will be corrected if indicated. After comparison and inconsistency resolution, the disks will be stored off-site to prevent loss from fire or other accident at PAML. Calibrations, control charts and field notes will be downloaded from the memory stick in the ‘data pouch’ to the appropriate directory.

Data files of chemical analysis of the manure samples from Midwest Laboratories, Inc will be received via email or the World Wide Web (128 bit encrypted) as comma-delineated data that has been verified at the Laboratory according to their Quality Assurance Plan.

19.3 *Data storage on-site and retrieval*

Raw data from the two TDLAS systems at each site (providing PIC values of NH_3) are collected on their respective control and data acquisition computers and daily transferred to the LAN server (Figure 19.2). At the end of each measurement period, the data collected on the two TDLAS computers will be copied onto one CD according to SOP D1.

Raw data from the PAS multigas analyzer at each site are collected on the LAN server computer using hard-wired serial communications and custom software (Figure 19.4). At the end of each measurement period, the data will be downloaded onto CD according to SOP D1.

Raw data from the UV-DOAS units (if validated) at each site will be collected on the LAN server computer using hard-wired serial communications and custom software (Figure 19.1.1). Raw data from the PF analyzer (if UV-DOAS not validated) at each site will be collected on the LAN server computer using hard-wired serial communications and iPort® software (Figure 19.1.2). At the end of each measurement period, the data will be downloaded onto CD according to SOP D1.

Raw data from the 3D sonic anemometers at each site are collected on the LAN server computer. Statistical representations of the raw data (SOP W2) will be computed and stored on the LAN server (Figure 19.2). At the end of each measurement period, the data will be downloaded onto CD according to SOP D1.

Raw data from the GSS (pressure, flow rate, and flow direction) at each site will be stored on the GSS data logger (Campbell Scientific, Inc. CR800). Data will be in comma-delimited format. Measurements will be downloaded every 10 min to the LAN server (Figure 19.1, 19.4). At the end of each measurement period, the data will be downloaded onto CD according to SOP D1.

Table 19.1 On-site computers and data loggers specifications

Computer/ data logger	Use	Input/Output	Storage	Memory	Number
LAN server 3.2 GHz dual processor	Data acquisition of PF, PAS and wind sensors Data transfer from CR1000 and CR800 data loggers Overall database manager DSL communications Runs LoggerNet, iPort, custom sensor communications programs	4-RS232 1-16X DVD+/-RW 3-USB, Ethernet Scanner, Printer CF card reader	200 Gb external HDD 2-120 Gb internal SCSI HDD	1 Gb	1
TDLAS 3.2 GHz dual processor	Data acquisition and control of TDLAS and scanner	3-USB 1-RS232 1-16X DVD+/-RW	120 Gb internal HDD 200 Gb external HDD	1 Gb	2
CR800 data logger	Data acquisition and control of GSS	6 Analog inputs 2 Pulse inputs Serial comm.	4 Mb	4 Mb	1
CR1000 data logger	Data acquisition of weather/lagoon data	16 Analog inputs 2 Pulse inputs Serial comm.	64 Mb flash	2 Mb	1

The meteorological stations at each site will operate according to SOP W6. The meteorological data (excluding wind data) and lagoon/basin characterization data will be collected and stored on the on-site data logger (Campbell Scientific, Inc. CR1000 with compact flash card extended memory) every 5 min. Data will be in comma-delimited format. Raw meteorological (ambient air temperature, relative humidity, barometric pressure, solar radiation, surface wetness, wind components) and lagoon/basin (pH, temperature and redox state) characterization data are stored on the data logger, the data logger compact flash card, and the LAN server (Figure 19.3). The compact flash card from the data logger will be replaced according to SOP W6 and the ‘used’ one will be downloaded at PAML. At the end of each measurement period, the data will be downloaded onto CD according to SOP D1.

Within the instrument trailer, the LAN server computer hard drive will be copied (backed-up) each night onto an attached external hard drive. All raw and processed data for the given day will be automatically ftp-transferred four times a day to a PAML computer. General specifications for the computers in the instrumentation trailer are documented in Table 19.1.

19.4 *Data storage at PAML*

Data received by email or ftp and verified by files transferred at the end of measurement periods on physical disks will be stored on a daily backed-up external hard disk drive. The PAML database computer is a 2.8-GHz dual-processor capable of holding approximately 1 Tb of data: two complete images of the complete database on RAID 6 or RAID 50 Arrays (Table 19.2). A separate computer is attached to the internet to receive daily ftp file downloads from the individual measurement locations (19.2). The post-processing bLS modeling and RPM modeling will be run on at least three additional computers (19.2). The PDM will manage the raw and processed data files. A large portion of the data (meteorological, TDLAS, GSS, PF, PAS, manure analyses) will be maintained electronically in the form of comma-delimited ASCII data. Access to raw or processed file directories will be password or user-group controlled according to need.

Table 19.2 PAML computer specifications.

Computer	Use	Input/Output	Storage	Memory	Number
ftp server 3.2 GHz dual processor	DSL communications	1-16X DVD+/-RW 4-USB, Ethernet, Scanner, Printer	120 Gb internal HDD 200 Gb external HDD	1 Gb	1
3.2 GHz dual processor	Runs all calibration equipment	4-USB, Ethernet 16X DVD+/-RW	120 Gb internal HDD	1 Gb	1
3.2 GHz dual processor	Runs bLS model for all locations	4-USB, Ethernet 16X DVD+/-RW	120 Gb internal HDD	1 Gb	1
3.2 GHz dual processor	Runs RPM model for all locations	4-USB, Ethernet 1-16X DVD+/-RW	120 Gb internal HDD	1 Gb	1
2.8 GHz dual processor	Overall database manager	4-USB, Ethernet 1-16X DVD+/-RW	1 Tb RAID 6 Array or RAID 50 Array (6-8 HDD)	1 Gb	1

Raw tables or graphs used in quality assurance of the data will be printed out and stored in a loose-leaf notebook in the laboratory. PAML staff will collectively keep the following logs: daily notes including site drawings, data analyses conducted and other notations. The logs will also contain measurement activities and monitoring notes. PQAM will keep all calibrations, certifications, results from QC checks and QA documents in a separate filing area. The PQAM will maintain logs of deviations from QA, data validations, records of invalidated data investigations, audit documents and documentation of other QA investigations in a separate loose-leaf notebook. Any other necessary records for documenting the operation of monitoring instruments will also be kept by the PQAM. A third party witness will acknowledge readability and clarity of all site log notes by email. All notes will be contained in a centralized notebook.

All hand entries in any document completed as part of the data collection and validation process will be in indelible ink with any changes or corrections indicated by single line cross-out with initials of individual making the change or correction and date of change or correction indicated. All documents with hand entries will be stored in the appropriate notebook and scanned into image format for electronic storage on completion of document and after any change or correction. All data transferred from hand-written documents to the electronic database (such as sludge depths measured on location, sensor location mapping and path distance determinations) will be entered into the database by duplicate entry with errors revealed by comparison of entries resolved by the PQAM.

Routine analyses of the data will be logged (including names of original files, processing done, and final files created) with results stored in the same directories as the raw and processed data and, where appropriate, notes concerning the results stored in loose-leaf notebooks accessible to all FOS and other staff.

References

Midwest Laboratories, Inc. 2004. Quality Assurance Manual. Ver 6, Midwest Laboratories, Inc, Omaha, NE, 138 p

SOP D1. 2006. Management of Open-Source, Weather, and Lagoon Characterization Data. Standard Operating Procedure D1. Purdue Applied Meteorology Lab.

SOP O1. 2006. Emissions Estimation Using Backward Lagrangian Stochastic (bLS) Model. Standard Operating Procedure O1. Purdue Applied Meteorology Lab.

SOP O2. 2006. Emissions Estimation Using Radial Plume Mapping (RPM). Standard Operating Procedure O2. Purdue Applied Meteorology Lab.

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.

SOP W6. 2006. Weather Data Acquisition and Control Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

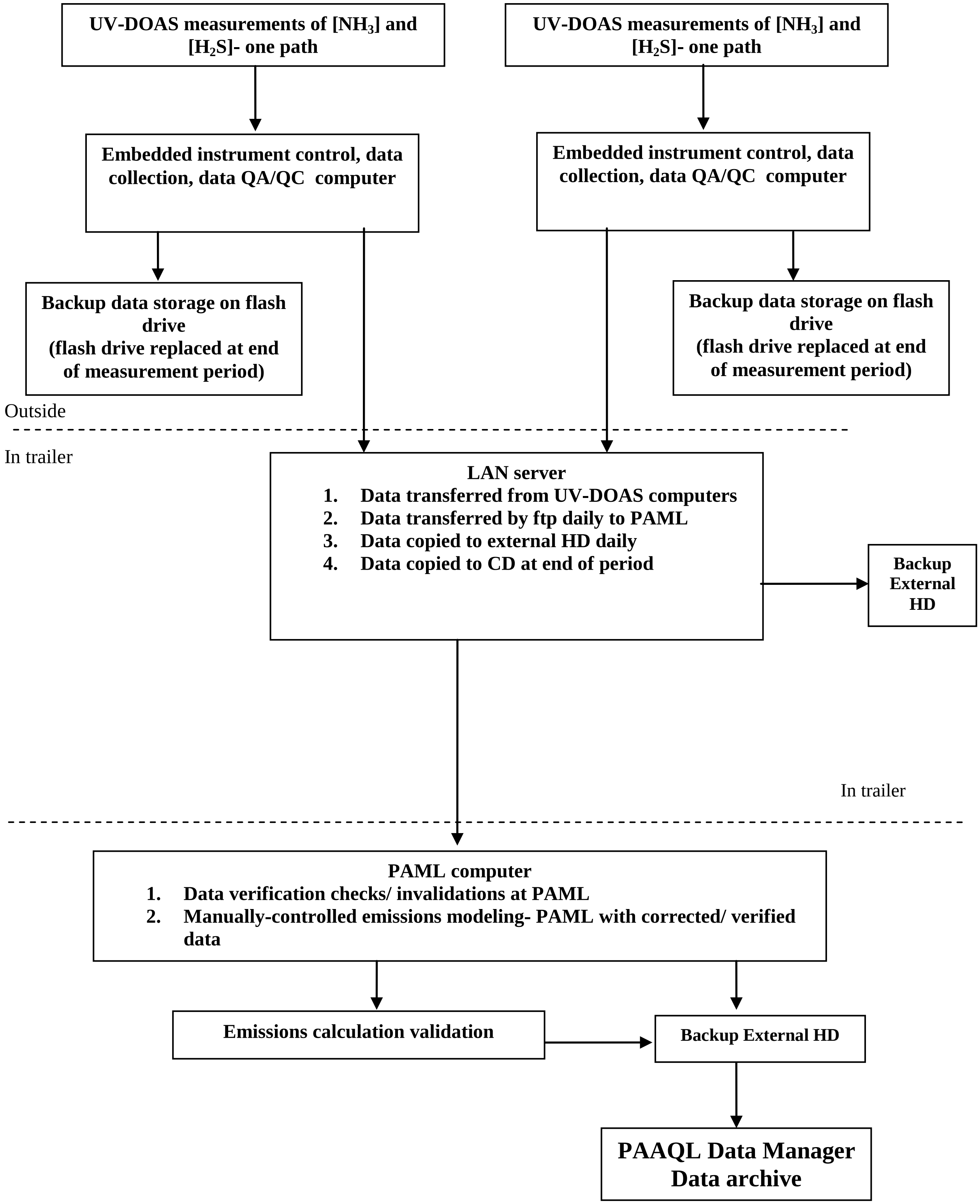


Figure 19.1.1. Data processing and management: UV-DOAS data.

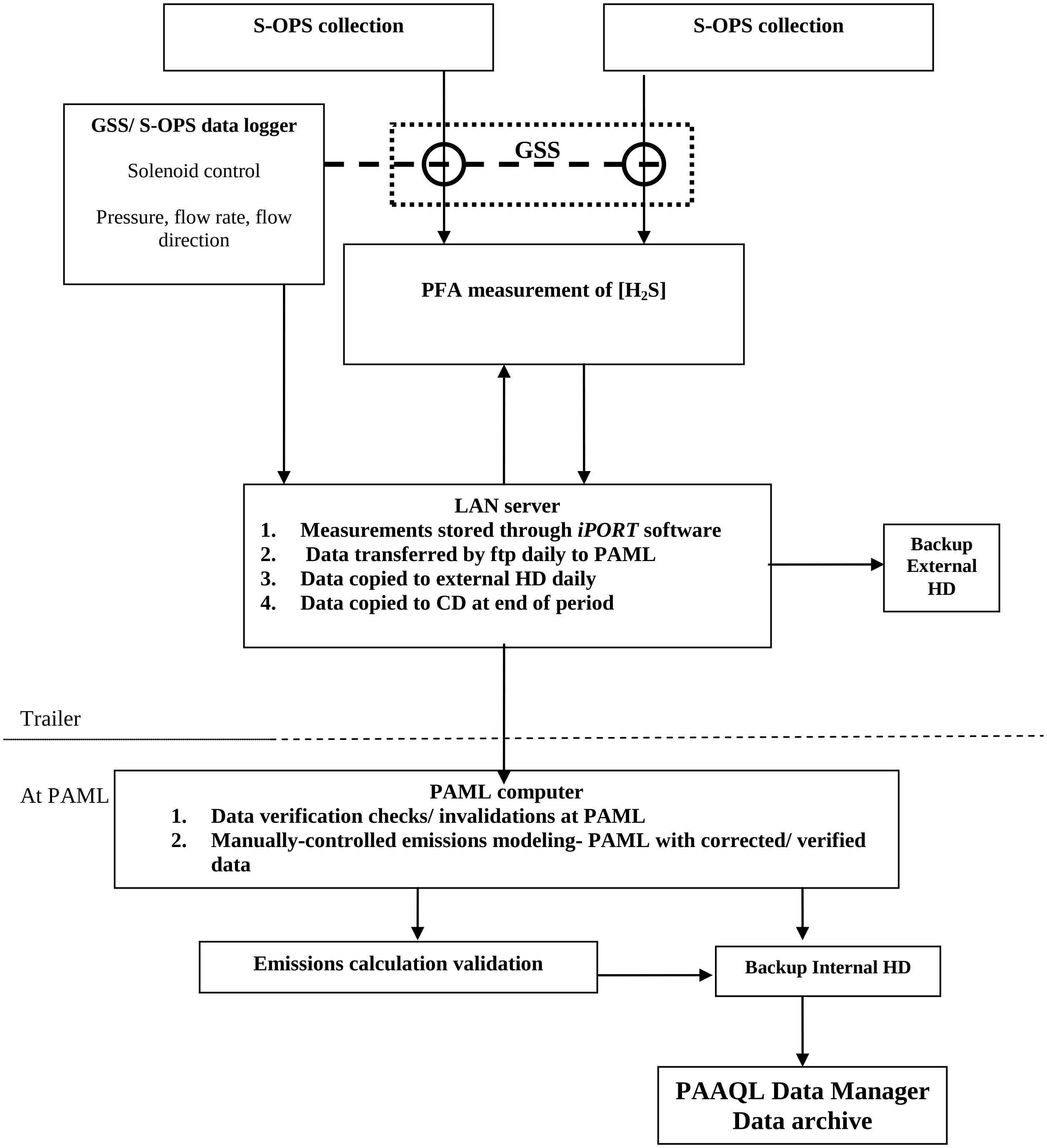


Figure 19.1.2. Data processing and management: PFA data.

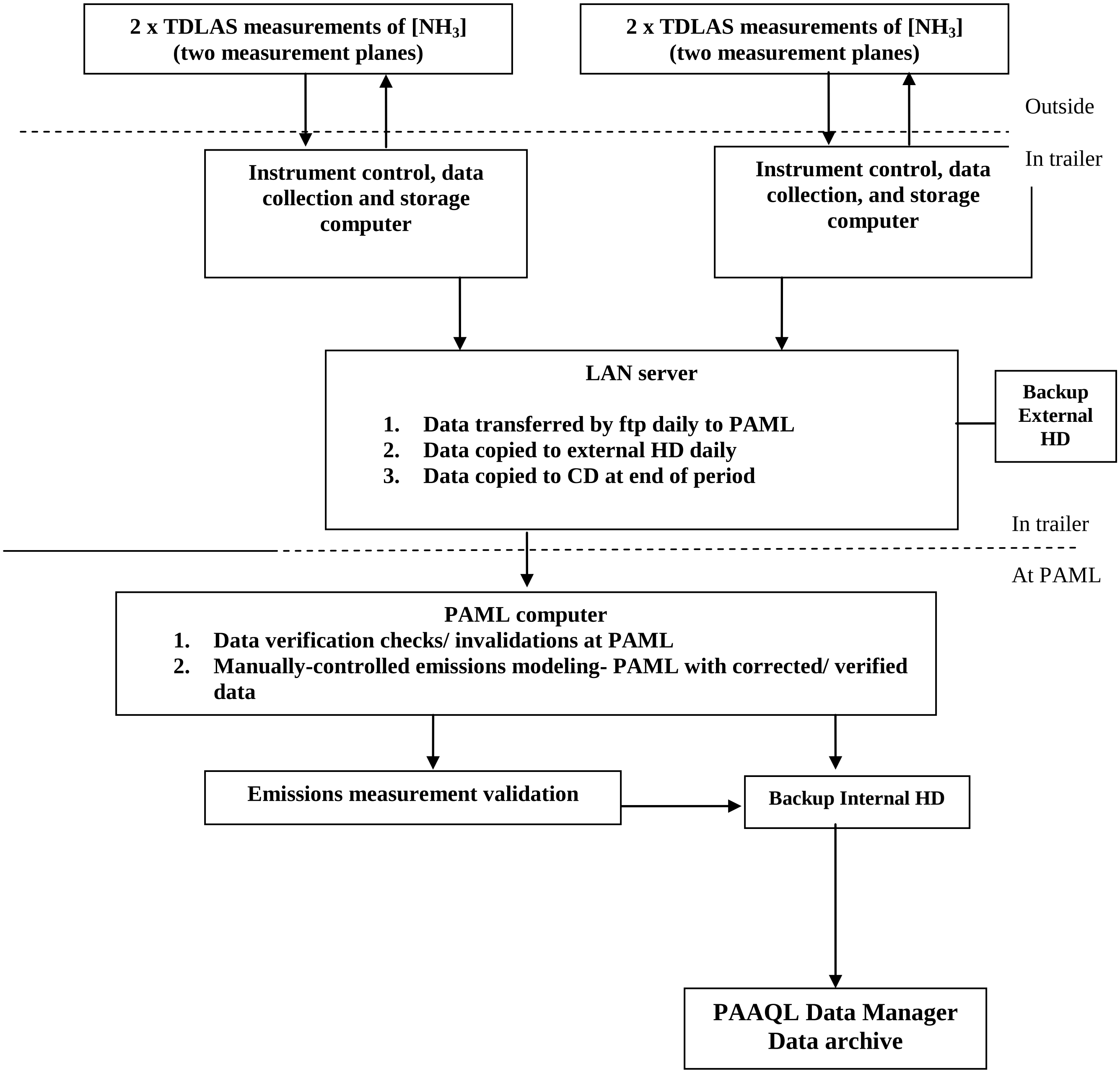


Figure 19.2. Data processing and management: TDLAS data.

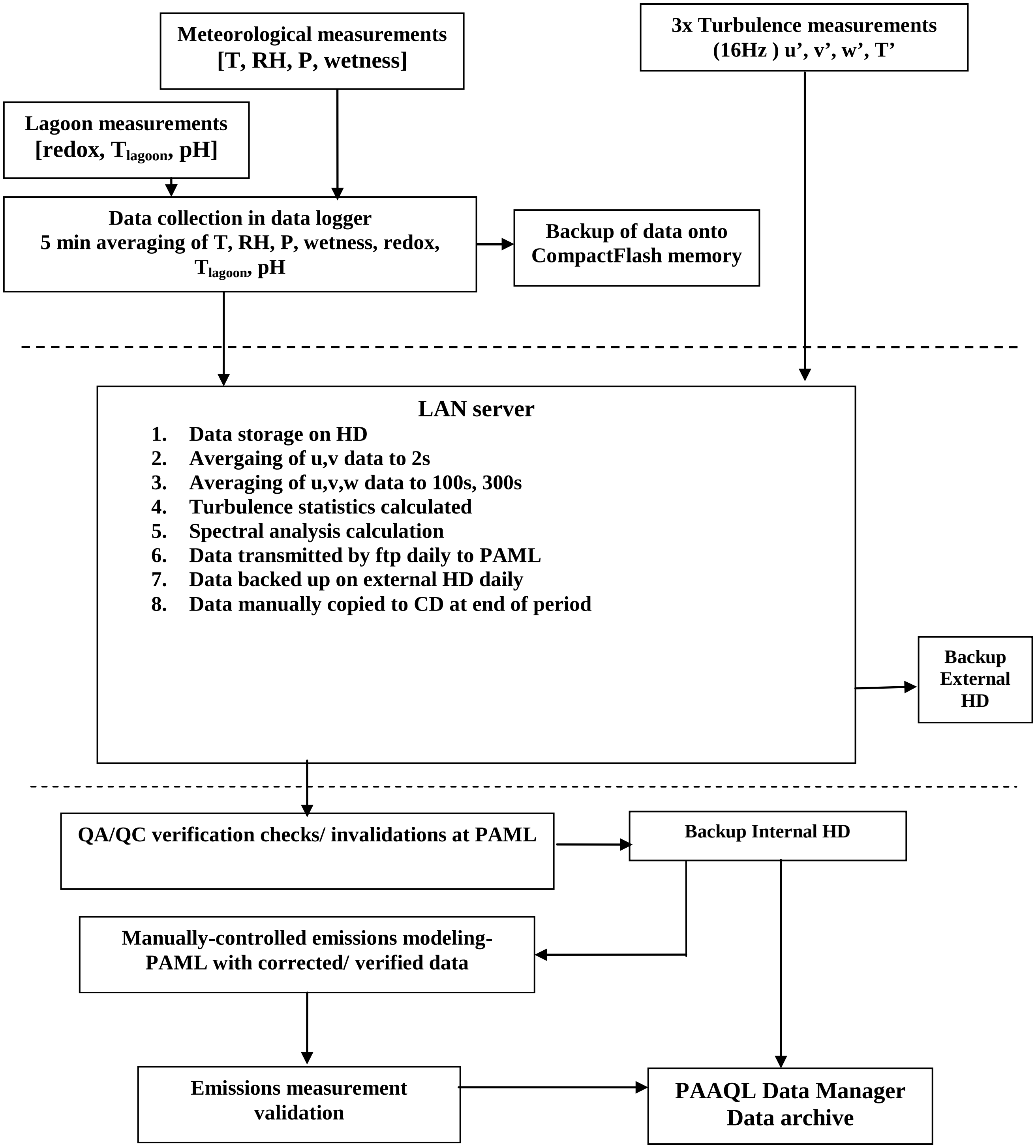


Figure 19.3. Data processing and management: meteorological and lagoon/basin data.

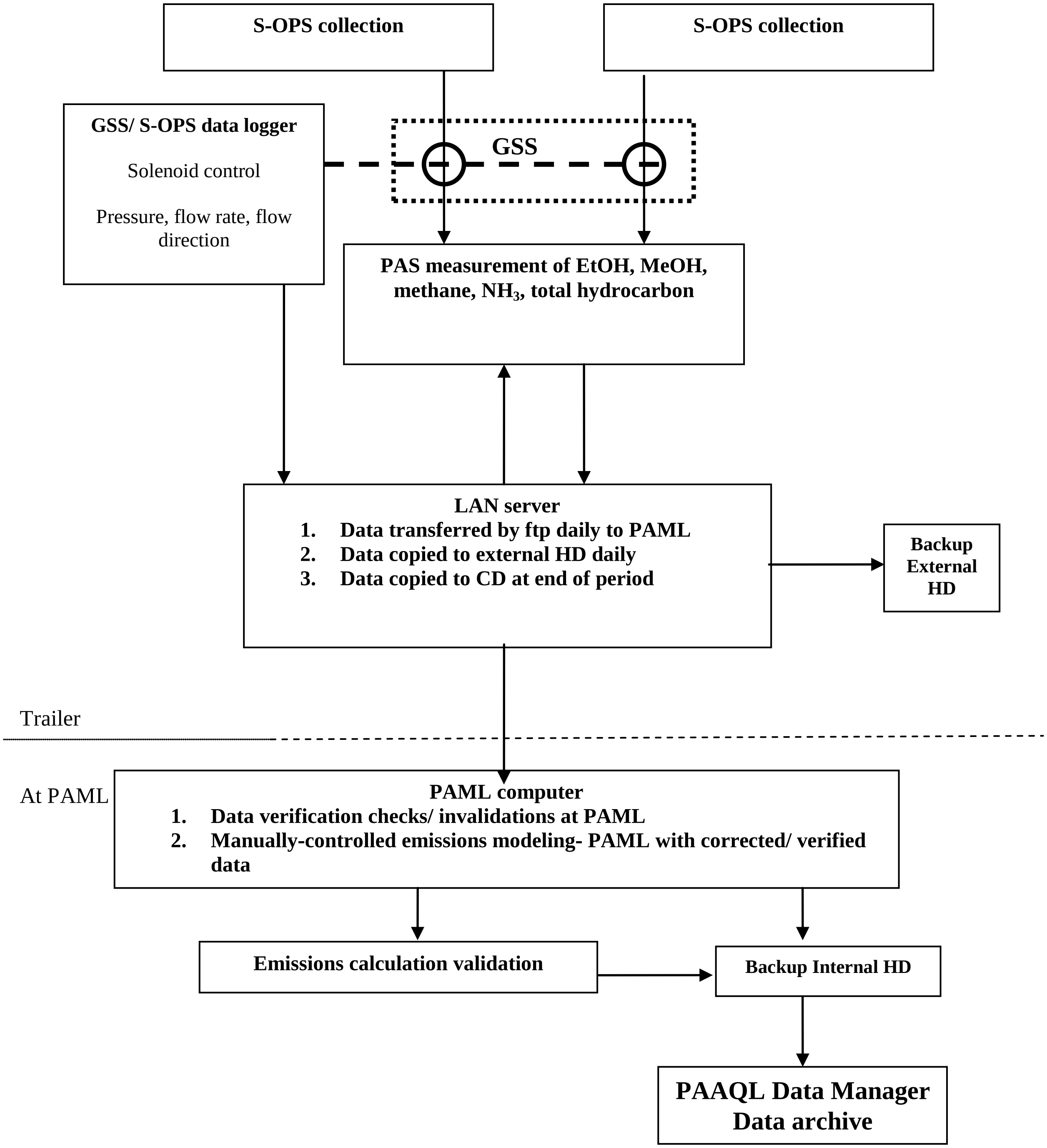


Figure 19.4. Data processing and management: VOC data.

C. Assessment/Oversight

20. Assessments and Response Actions

Quality assurance of the measurements is conducted by external validation of data, performance and technical systems audits, data quality audits, and documentation. New equipment should arrive from the manufacturer in a field-ready state. However, all equipment will be tested for acceptance at PAML according to procedures outlined in the respective SOP. In addition, performance and technical system audits are required to ensure the quality of the measurements throughout the period of the project. A general schedule for the performance, data quality, and technical systems audits is indicated below, however more frequent audits may occur if recurring problems with an instrument are detected.

External technical systems audits will be performed by the EPA or their designate on a schedule coordinated with the PM.

Internal data quality audits will be conducted on data collection, data validation, and data processing. Data will be assessed for representativeness, completeness, comparability, accuracy and precision as outlined in Section 7. The PQAM will perform data quality audits of the data management system at least monthly. Auditing will involve comparing the processed meteorological and analytical data in the spreadsheets with the raw data obtained from the field to ensure that the data are being processed correctly.

The QAM will conduct one internal technical systems audit at each location over the course of the two years in coordination with the PM. The PM will conduct internal technical systems audits at each location each year (due to the PQAM being part of a measurement team). During technical systems audits, the PM or QAM will observe sample collection, equipment operation and calibration verifications of all equipment at the location to verify that the procedures documented in this QAPP are being followed and that any corrective actions previously initiated are being continued. Field documentation will also be reviewed. A checklist identifying items to be included in the technical systems audit are documented in Appendix D. The audit will be documented using forms similar to those in Appendix 15, section 2 of the *USEPA Quality Assurance Handbook for Air Pollution Measurement* (August 1998). Any issues identified during these audits will be documented on the “Audit Finding Form” (Appendix D) and discussed with the appropriate FOS and addressed immediately. If any response actions are taken, the PM will inform the QAM of the reason for the actions and the results, documenting the response on an “Audit Finding Response Form” (Appendix D). Any findings or concerns from the audits will be addressed to the SA and PM. Any necessary response actions will be determined by the SA and PM. Invalidated data may result from a technical systems audit finding. It is not anticipated that immediate shutdown of operations will be needed unless the technical systems audits reveal serious protocol deviation which the FOS cannot correct immediately following the audit. Authority to stop work rests with the SA in consultation with the PM and USEPA Program Manager.

The QAM will be responsible for preparing the portions of any report concerning the results from the internal QAM audits. The PQAM will be responsible for preparing the portions of any report concerning the results from the internal PM audits. The Audit Forms, Audit Finding Form (if applicable), and Audit Finding Response Form (if applicable) must be delivered to the QAM, SA, and PM (as appropriate) within 30 d of audit completion. The generator of the completed forms will retain one copy of the completed forms for his/her file. The QAM will review the audit results and determine if changes to the QAPP (including SOPs) are warranted. If changes are warranted, the QAM will contact the PM and the PM in consultation with the SA and the EPA QAM will determine what changes are appropriate. Field performance audit routines, described below, are also described in each instrument's SOP.

Open-path gas concentration instruments

During the field audits of the performance of open-path concentration instruments (CEREX UVSentry UV-DOAS and Boreal GasFinder2.0 TDLAS), the instruments will be temporarily removed from the lagoon/basin measurement location and positioned near the trailer for alignment with the calibration chambers. Methods and associated SOP for a given audit are indicated in Table 20.1. All field performance auditing activities will be documented in the monitoring site logbooks using forms provided in Appendix D and each respective SOP.

Table 20.1 Performance audit methods for open-path gas concentration instruments.

Sensor	Frequency and location of audit	Audit performed	Method	SOP
UV-DOAS NH_3 concentration	Semiannually in field	System response	Single point calibration with primary standard NH_3 gas concentration; accuracy and precision check	C1
UV-DOAS H_2S concentration	Semiannually in field	System response	Single point calibration with NIST-certified H_2S gas concentration; accuracy and precision check	C1
TDLAS NH_3 concentration	Semiannually in field	System response	Single point calibration with primary standard NH_3 gas concentration; accuracy and precision check	C2

PAS multi-gas analyzer

During the field performance audits of the INNOVA 1413 Multigas Analyzer, the sampling system and analyzer will be audited together by applying the calibration gas at the gas sampling inlet. Methods for the field performance audits to be performed are identified in Table 20.2. The single point calibration verification method is described in SOP G7. All field performance auditing activities will be documented in the monitoring site logbooks using forms provided in Appendix D and SOP G7.

Table 20.2 Performance audit methods for INNOVA 1413 photoacoustic multi-gas analyzer.

Parameter	Frequency and location of audit	Audit performed	Method
NH_3 concentration	Semiannually in field	System response	Single-point calibration verification with primary standard gas concentration
MeOH concentration	Semiannually in field	System response	Single-point calibration verification with NIST-traceable EPA protocol gas concentration
EtOH concentration	semiannually in field	System response	Single-point calibration verification with NIST-traceable methane gas concentration
Water vapor concentration	Semiannually in field	System response	Single-point calibration verification with NIST-traceable dew point generator
CH_4 concentration	Semiannually in field	System response	Single-point calibration verification with NIST-traceable propane gas concentration
THC concentration	Semiannually in field	System response	Single-point calibration verification with NIST-traceable propane gas concentration

Manure characterization sensors

During field performance audits of the manure characterization sensors, the sensors will be temporarily removed from the lagoon and audited in the instrumentation trailer. Field performance audits listed in Table 20.3 will be performed on a semi-annual basis alternating with annual audits at Purdue so that an audit is occurring on each sensor approximately every six months. Methods for the performance auditing of the manure/lagoon sensing equipment are found in SOP L1, L2, L3 and L5. All field performance auditing activities will be documented in the monitoring site logbooks using forms provided in Appendix D and in the respective SOP.

Table 20.3. Performance audit methods for lagoon/basin characterization sensors.

Sensor	Frequency and location of audit	Audit performed	Method	SOP
Redox state	Annually at Purdue	Response	Comparison with certified ZoBell's solution	L3
Temperature	Annually at Purdue	Response	Comparison with unused collocated standard	L2
pH	Annually at Purdue	Response	Comparison with NIST-certified standard buffer solutions	L1
Depth finder	Annually at Purdue	Response	Resin bed test solution	L5

Meteorological sensors

Performance audits of meteorology stations and meteorological sensing equipment are required to ensure the collection of quality meteorological data. Field performance audits listed in Table 20.4 are to be performed on an annual basis alternating with annual performance audits at Purdue so that a performance audit occurs on each sensor approximately every six months. More frequent performance auditing may be conducted when suggested by unusual data.

During the field performance audits of these sensors, the sensors may or may not be temporarily removed from the towers for connection with audit devices. If the sensors are not removed from the towers, a collocated sensor will be used for intercomparisons (as indicated in Table 20.4). Standard Operating Procedures associated with the performance auditing of meteorological sensing equipment are indicated in Table 20.4. All field performance auditing activities will be documented in the monitoring site logbooks using forms provided in each respective SOP. Field performance audits results will be distributed among appropriate PAAQL personnel and included with the final report.

Assurance of parameter accuracy will be determined through performance audits of the meteorological equipment. Performance audits of meteorology stations and meteorological sensing equipment are required to ensure the collection of quality meteorological data. Meteorology stations will be evaluated on a quarterly basis through intercomparisons with unused standard sensors to determine status with respect to the siting criteria previously mentioned in this document. During field performance audits, sensors will be collocated with intercomparison instruments or temporarily removed from the towers for connection with audit devices. Standard Operating Procedures for performance auditing meteorological sensing equipment are described in the individual SOPs. The following performance audits are to be performed on an annual basis. All field performance auditing activities will be documented in the monitoring site logbooks using forms provided in Appendix D and in the respective SOP.

Table 20.4. Summary of performance audit methods for meteorological sensors.

Meteorological sensor	Frequency and location of audit	Audit performed	Method	SOP
Wind Speed (horizontal)	Annually at Purdue	Signal	Comparison with other collocated NIST-traceable wind speed sensors	W2
Ambient Temperature	Annually at Purdue	Response	Comparison with other collocated NIST-traceable sensor	W1
Humidity	Annually at Purdue	Response	Comparison with NIST-traceable sling psychrometer	W1
Solar Radiation	Annually at Purdue	Response	Comparison with other collocated sensor with NIST-traceable calibration	E3
Barometric Pressure	Annually at Purdue	Response	Comparison to NIST-traceable calibrated Fortin barometer	W5

Performance audit samples for the analysis of manure for pH, total and ammonia nitrogen, total solid, and total volatile solids (SOP M2, M3, M4, and M5) will be prepared annually by the QAM and shipped to the commercial laboratory as blind samples.

PF gas analyzer

During the field performance audits of the TFS 450i pulsed fluorescence gas analyzer, the sampling system and analyzer will be audited together by applying the calibration gas at the gas sampling inlet. Methods for the field performance audits to be performed are identified in Table 20.5. The single-point calibration verification method is described in SOP G5. All field or lab performance auditing activities will be documented in the monitoring site logbooks using forms provided in Appendix D and SOP G5.

Table 20.5. Performance audit methods for TFS 450i pulsed fluorescence H_2S analyzer.

Parameter	Frequency and location of audit	Audit performed	Method
H_2S concentration	Semiannually at Purdue	System response	Single-point calibration verification with NIST-certified gas concentration
SO_2 concentration	Semiannually at Purdue	System response	Single-point calibration verification with NIST-certified gas concentration

S-OPS/GSS

Performance audits of the synthetic open-path gas collection and gas sampling system are required to ensure the collection of quality PFA and PAS gas concentration and emission data. Field performance audits listed in Table 20.6 are to be performed on an annual basis, alternating with annual performance audits at Purdue so that a performance audit occurs on each sensor approximately every six months. More frequent performance auditing may be conducted when suggested by unusual data.

Table 20.6. Summary of performance audit methods for S-OPS/GSS.

Sensor	Frequency and location of audit	Audit performed	Method	SOP
GSS mass flow	Annually at Purdue	Response	Comparison with NIST-certified flow meter	C4
GSS air leakage	Annually at Purdue	Response	GSS vacuum test	C4
S-OPS inlet balance	Annually in field	Response	S-OPS inlet flow rate measurement with NIST-certified flow meter	C4
S-OPS air leakage	Annually at Purdue	Response	S-OPS vacuum test	C4

References

APHA. 1995. Standard Methods for the Examination of Water & Wastewater, 19th Edition, Method 4500-H^+, AD Eaton, LS Clesceri, AE Greenberg (Eds.), AWWA, WEF.

APHA, 1995. Standard Methods for the Examination of Water & Wastewater, 19th Edition, Method 2580, AD Eaton, LS Clesceri, AE Greenberg (Eds.), AWWA, WEF.

American Society for Testing and Materials (ASTM) E104 Standard practice for maintaining constant relative humidity by means of aqueous solutions, American Soc. for Testing and Materials.

American Society for Testing and Materials (ASTM) Standard Practice E1982-98, Standard Practice for Open-Path Fourier Transform Infrared (OP/FT-IR) Monitoring of Gases and Vapors in Air; March 1999.

American Society for Testing and Materials (ASTM) Standard Guide E1865-97 (Reapproved 2002), Standard Guide for Open-Path Fourier Transform Infrared (OP/FT-IR) Monitoring of Gases and Vapors in Air; July 1997.

Atmospheric Radiation Measurement Program. 2004. Atmospheric Radiation Monitoring Network: Standard Operating Procedures

Boreal Laser, Inc. 2003. GasFinder2.0 portable system Operation Manual. Ver 0.39, Boreal Laser, Inc, Spruce Grove, Alberta, Canada, 38p.

Cerex Environmental Services Inc. 2006. UV Sentry Open-path Air Monitor End-User Manual, Version 2006329, Cerex Environmental Services, Inc, Atlanta, GA

Foken, T, B Wichura. 1996. Tools for quality assessment of surface-based flux measurements. Agricultural and Forest Meteorol. 78, 83-105.

IMPROVE, Particulate Monitoring Network: Standard Operating Procedures, University of California, Davis.

Innova AirTech Instruments. undated. 1314 Photoacoustic multi-gas analyzer, 1412 Photoacoustic Field Gas-Monitor. Technical Documentation. BE6011-11. 252 p

Lin, L I-K. 1989. A Concordance Correlation Coefficient to Evaluate Reproducibility. Biometrics. 45, 255-68.

SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Applied Meteorology Lab.

SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Applied Meteorology Lab.

SOP C4. 2006. Standard Operating Procedure for the Synthetic Open-Path Sampling System. Standard Operating Procedure C4. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP E3. 2006. Measurement of Solar Radiation with the LiCOR Model 200SL or 200SZ Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP G5. 2006. Standard Operating Procedure for the Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450I Pulsed Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Applied Meteorology Lab.

SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Applied Meteorology Lab.

SOP M1. 2006. Manure Sampling. Standard Operating Procedure M1. Purdue Ag Air Quality Lab.

SOP M2. 2006. Conducting pH Measurements on Manure Samples. Standard Operating Procedure M2. Purdue Ag Air Quality Lab.

SOP M3. 2006. Determining Solids Content of Manure Samples. Standard Operating Procedure M3. Purdue Ag Air Quality Lab.

SOP M4. 2006. Determining Total (Kjeldahl) Nitrogen Content of Manure Samples. Standard Operating Procedure M4. Purdue Ag Air Quality Lab.

SOP M5. 2006. Determining Ammonia Content of Manure Samples. Standard Operating Procedure M5. Purdue Ag Air Quality Lab.

SOP W1. 2006. Measurement of Atmospheric Temperature and Humidity with the Viasala Model HMP45C Sensor and Solar Shield. Standard Operating Procedure W1. Purdue Applied Meteorology Lab.

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.

SOP W3. 2006. Measurement of Wetness with the Campbell Scientific Model Resistance Grid. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.

SOP W5. 2006. Measurement of Barometric Pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.

US Environmental Protection Agency. 1998. Quality Assurance Handbook for Air Pollution Measurement Systems. Office of Air Quality Planning and Standards. Research Triangle Park, NC. EPA-454/R-98-004.

21 Reports to Management

The Quality Assurance Manager will summarize the results of all audits into audit reports that will be documented and archived by the QAM in either hardcopy or electronic formats. These audit reports will include internal technical systems audits conducted by PM and QAM for the field sampling operations, the meteorological data collection, and data quality audits conducted by the PQAM to test the analytical procedures, and data management procedures.

The semi-annual internal technical systems audit reports produced by the PQAM and QAM will include:

- Date of audit
- Location of audit
- Team being audited
- Instruments audited
- Results of each audit
- Signature of auditor and those audited
- Response of team being audited to audit results
- Remediation and corrective actions (if any)

The PM and PDM will summarize the measurement results for the quarterly draft and final reports. Summaries of the audits will be included in the appropriate quarterly report. The quarterly draft and final project reports will contain:

- All valid monitoring data expressed as 30-min and daily values.
- Graphical representations of the location of all measurements taken.
- Numerical and qualitative results of all quality control measures on all measurement systems and will compare them to the applicable acceptance criteria.
- Summaries of the invalidated data and the reason for invalidation as well as the resultant corrective action.

Review drafts of the semi-annual internal technical systems audit reports and quarterly reports will be distributed to the following individuals or agencies:

William Schrock	EPA
Albert J. Heber	PU/ABE
Richard H. Grant	PU/AGR

The final report will contain the following information:

- The report introduction and the monitoring objectives for the project,
- Background information relating the purpose of the monitoring project.
- Descriptions and maps indicating the monitoring location(s).
- Information related to the monitoring methods employed at the monitoring site, the instrumentation used at the site and QA/QC results,
- Field observations during monitoring.

- Data analysis report and meteorological report.
- Emissions calculations by site, time of year, atmospheric conditions, and handling operations.
- Project conclusions.
- Attachments with open path TDLAS and UV-DOAS reprocessing and analysis results, site meteorological data, the initial sampling plans, and a health and safety plan.
- All spectral files and results will be backed up on recordable read only media.

Review drafts of the final report will be distributed to the following individuals or agencies:

William Schrock	EPA
Albert J. Heber	PU/ABE
Juan Carlos Ramirez	PU/ABE
Jiqin Ni	PU/ABE
Richard H. Grant	PU/AGR

The following individuals or agencies will receive final versions of the quarterly and final report.

OAQPS Project Manager	EPA
Albert J. Heber	PU/ABE
Jiqin Ni	PU/ABE
Richard H. Grant	PU/AGR
John Thorne	AARC

D. Data Validation and Usability

22. Data Review, Verification, and Validation

All analytical and meteorological data are reviewed by the PM, PQAM, QAM and the SA to determine if these data meet the QAPP objectives. Decisions to reject or qualify data are made by the PM and the PQAM. The QAM has oversight responsibilities for the PQAM activities.

All manure analysis data received by email or ftp from the commercial laboratory will be provided by the laboratory after verification following the laboratory Quality Assurance Plan. At the time of receipt of each set of analytical results and sample integrity information provided by the commercial laboratory, the chain of custody information documented by FOS and the information from the laboratory are reviewed by the PQAM to verify sample integrity and acceptable sample handling conditions (temperature, time between sampling and analysis, etc.)

All data received overnight by ftp from each monitoring site will be stored in an ‘Unchecked data’ subdirectory of the directory associated with the measurement period until quality-assured by staff scientists at PAML. Data files that have completed quality assurance (described in Section 23) and are validated will be inserted into a ‘Validated data’ directory. Validation of meteorology, lagoon/basin conditions, turbulence, GSS, NH_3 (TDLAS and UV-DOAS) PIC data, VOC (PAS) data and H_2S (PFA or UV-DOAS) PIC data will be conducted and data flags (Section 23) attached. All data will have a data flag associated with it. After validation procedures, data with non-zero data flags need to be assessed to determine the cause of flagging by staff scientists at PAML, in collaboration with similar staff at PAAQL. If flagged values are believed to be mis-flagged (a result of legitimate variability in the sensor response that is erroneously identified as evidence of sensor problems): (1) the filename, erroneous flag(s), cause for removing the flag condition, scientist initials, and date of assessment will be logged into a ‘Data change’ database maintained by the PDM, (2) the PQAM evaluates the legitimacy of the evidence for change in data status from invalid to valid. If after review by the PQAM and PM, the initial assessment is confirmed, then the flags will be changed and the changed data file is renamed with a “-cor” at the end of the file name and placed in the ‘Validated data’ directory.

Comparisons between the measured range of concentration measurements and the range of calibration for the UV-DOAS or PFA, TDLAS, and PAS instruments will be made to assure that the measurements fall within the range of the instrument multi-point calibration. Measurements falling outside the range of calibration concentrations will be verified by the PQAM and flagged as invalid and will not be used for further analysis.

Missing or invalid turbulence, $NH_{3,}$ VOC and H_2S data values will not be estimated to complete a time series. Meteorological measurements (air temperature, barometric pressure) will be estimated to complete a time series if there is a continuous record of NH_3, VOC and H_2S data values since these measurements are needed to run the RPM, bLS and ratiometric models. All other meteorological and lagoon/basin characterization measurements will not be estimated or substituted with nearby barn measurement values (if available at the location) or adjusted NWS values.

Emissions estimates via RPM, bLS, or ratiometric models will be run only on validated data with results containing the appropriate QA flags. The validity of the final emissions calculations will be assessed by the QA flags.

All data received by the data pouch (outlined in Table 9.1) will be stored as backup to the ftp data. This backup data will be compared after the end of the measurement period to the data files received by daily ftp. Comparisons will be initially by file size. If the ftp file and the data pouch file sizes differ for a given day, then the two files will be compared by timestamp record then data value (if necessary) to determine the cause for the difference in file sizes. If the difference is more than a result of end-of-file and beginning of file markers or differences in the number of records included in the file, the discrepancy will be documented reporting the filenames, cause for discrepancy, scientist initials, and date of assessment into a discrepancy database maintained by the PDM. The PDM and DM, in consultation with the SA and PM, will determine if the ftp version of the data file or the backup data file should be used in emissions estimates.

All data transferred from FOS hand-written documents to the electronic database (such as sludge depths measured on location, sensor location mapping and path distance determinations, and chain of custody sheets) will be entered into the database by duplicate entry with errors revealed by comparison of entries and the original document resolved by the PQAM.

Failures in daily QA procedures that indicate a problem with an instrument will be addressed by the PQAM in accordance with the respective SOP and outlined in section 23. Data flags are identified in Section 23 for each measurement. Instrument problems associated with critical measurements will be addressed on-site within three days as outlined in section 23. Instrument problems associated with non-critical measurements will be addressed on-site within one week.

QC checks occurring approximately every 21 d (discussed in section 14) and audits occurring approximately every six months (discussed in sections 16 and 20) provide the basis for data validation. The results of the internal and external technical systems audits, performance audits (Section 20) and QC checks (Section 14) assure proper sample collection, handling, and analytical procedures are being performed according to the QAPP. The records documenting the audits and QC checks will be used to further explain un-resolvable invalidated data and define the interval of valid data from a given instrument. If the performance audits do not explain invalidated data and a trip to the measurement location is needed to resolve the identified problem, the instrument must undergo another performance audit (if equipment repaired) or acceptance check (if equipment replaced). Failures in QC checks of any instrument result in an investigation for evidence for the time of failure in prior data QA flags. If no indication of time of failure is evident, all measurements using the instrument will be flagged invalid back to the last time the instrument was QC checked. If there is an indication of the time of failure from the QA flags, the PQAM in conjunction with the PM will determine the interval of invalid data. All instruments failing a QC check will be removed from the field and sent to the manufacturer for repair on replacement.

All deviations in QAPP or SOP will be documented on a 'Document Deviation Report' Form (Appendix D). The PQAM in consultation with the QAM, PM and SA will determine the resolution of the deviation. Possible resolutions of a deviation include: accept deviation and revise a section of the QAPP or SOP, accept revision (minor) no changes necessary, reject deviation and data, reject deviation but retain data (for instance incomplete replication). All changes in operating protocol must be approved by the EPA prior to activation."

The DM will distribute only validated, quality-coded data as directed by the PM and SA. In this way, the data will be available in a timely manner to appropriate persons. All personnel involved in the study will have the opportunity to review these data before they are incorporated into the final report. Purdue will maintain records of rejected or qualified data for EPA review and must not delete any data without written EPA approval. Invalid data will also be maintained throughout the study period, until as long as deemed necessary by EPA. No data shall be destroyed without EPA's permission.

References

Midwest Laboratories, Inc. 2004. Quality Assurance Manual. Ver 6, Midwest Laboratories, Inc, Omaha, NE, 138 p.

SOP D1. 2006. Management of Open-Source, Weather, and Lagoon Characterization Data. Standard Operating Procedure D1. Purdue Applied Meteorology Lab.

23. Validation and Verification Methods

The purpose of data validation is to detect any data values that may not represent actual conditions at the sampling locations. The PDM will electronically back up all data that are obtained from the field and the laboratory. These backup copies will be maintained until the data are transferred to the dedicated computer and verified. Verification entails a review to ensure that all the data for the collection period are accounted for. Data will be validated and verified by

- comparison with instrumental performance parameters as identified in the applicable SOP or instrument operation manual.
- checking the operations records and changes in the building environment.
- compliance with stated objectives for representativeness, precision, and accuracy defined in section 7 using basic statistical methods (calculation of mean values, standard deviations of the sample, standard error of the means, and coefficient of variation) as well as temporal and spatial analyses.

However, the evaluation process used to find and correct an error may not be defined in this QAPP because not all possible errors and corrections can be anticipated.

If data is determined to be invalid, the person with primary data review responsibilities will inform the PM and a record of the invalid data will be prepared. Both the data reviewer and the supervisor are required to sign the form. Verified, raw data will be maintained on the dedicated computer throughout the study period and for six years after the end of the study by the SA. Purdue will maintain records of rejected or qualified data for EPA review and must not delete any data without written EPA approval. Invalid data will also be maintained throughout the study period, until as long as deemed necessary by EPA. No data shall be destroyed without EPA's permission."

23.1 *Validation of meteorological data*

The meteorological data is validated to ensure that the quality goals of the study are met. Computers are used to assist in validation of meteorological data by determining if the values fall outside a specified range. Validation of each individual measurement is outlined in the respective instrument SOP. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the meteorological data. Validation guidelines for many of the meteorological parameters are provided in USEPA (2000). Invalid flags will be attached to each variable below under the following conditions:

The QA flagging codes for the measurement of wind speed (Table 23.1) and wind direction (Table 23.2) documented in SOP W2 are indicated. If any values of these measurements are flagged with a non-zero data flag, evaluate associated barn measurement location (if available) or nearest NWS weather station for reasonableness: If unreasonable, substitute value from associated barn measurement location (if available) or nearest NWS weather station, if reasonable, document reason for validation of value (with the invalidation flag retained) and retain value for further processing. An unresolved non-zero flag code will result in an unscheduled repair/replacement trip by FOS to the location of the measurement within 2-3 d. These are project critical measurements used in the RPM emissions model.

Table 23.1. Wind speed QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of possible values in period)	Check for power or communications failure, substitute value from one of the two other anemometers if appropriate.
2	Value < 0 m/s or > 50 m/s or value is ±infinity	Check computations, connections, cable condition, lightning damage; repair or replace
4	Spike count >160.	Check connections, cable condition, lightning damage; repair or replace
8	Standard deviation over 24 h > 9 m/s.	Check connections, cable condition, lightning damage; repair or replace
16	5 min value does not vary by 0.5 m/s (1.1 mph) for 12 consecutive hours	Check connections, cable condition, lightning damage; repair or replace
32	5 min value does not vary by 0.1 m/s (0.2 mph) for 3 consecutive hours	Check connections, cable condition, lightning damage; repair or replace
64	> 10% of sampling interval has path obstruction	Check weather conditions (icing), farm activity; repair or replace

Table 23.2. Wind direction QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of possible values in period)	Check for power or communications failure, substitute value from one of the two other anemometers if appropriate
2	Value >360° or less than 0°	Check connections, cable condition, lightning damage; repair or replace
4	Spike count >160.	Check connections, cable condition, lightning damage; repair or replace
8	Standard deviation over 24 h < 0 ° or > 90 ° (bound of computation method).	Check connections, cable condition, lightning damage; repair or replace
16	5 min value does not vary by more than 10° for 18 consecutive hours	Check connections, cable condition, lightning damage; repair or replace
32	5 min value does not vary by more than 1° for 3 consecutive hours	Check connections, cable condition, lightning damage; repair or replace
64	> 10% of sampling interval has path obstruction	Check weather conditions (icing), farm activity; repair or replace

The QA data flagging codes and associated corrective actions for the measurement of air temperature (Table 23.3), relative humidity (Table 23.4), and barometric pressure (Table 23.5) documented in SOP W1 and SOP W5 are indicated. If any values of these measurements are flagged with a non-zero data flag, evaluate associated barn measurement location (if available) or nearest NWS weather station for reasonableness. The location-adjusted NWS barometric pressure (according to SOP W5) and ambient temperature are corrected for altitude differences between location and NWS station and location adjusted ambient humidity is corrected for temperature differences between location and NWS station (according to SOP W1). The reasonableness of the sonic air temperature (SOP W2) at all three heights will be determined by comparison to the ambient virtual temperature determined from the ambient air temperature and the ambient relative humidity. If values are unreasonable, substitute value from associated barn measurement location (if available) or nearest NWS weather station, if reasonable, document reason for validation of value (with the invalidation flag retained) and retain value for further processing.

An unresolved non-zero data flag for these measurements will not result in an unscheduled repair/ remediation trip by FOS staff, but the sensor repair/replacement will be addressed in the next routine site visit. These are project non-critical measurements used in the temperature, water vapor, and pressure correction of gas measurements.

Table 23.3. Temperature QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or data logger communications failure
2	Value < -40°C or > +50°C (bounds of sensor calibration)	Check weather conditions and time series for inconsistencies. Check sensor mount, wiring, casing. Repair or replace.
4	Value > 7°C (16°F) change from the previous hour	Check sensor mount, wiring, casing. Repair or replace.
8	Value does not vary by more than 0.5°C (0.9°F) for 12 consecutive hours	Check sensor mount, wiring, casing. Repair or replace.
16	Value > local record high or < the local low on a monthly average	Check sensor mount, wiring, casing. Repair or replace.
32	Value differs by more than 5°C from the altitude-corrected air temperature from the nearest National Weather Service (NWS) weather station	Check weather conditions and time series for inconsistencies. Check sensor mount, wiring, casing. Repair or replace.
64	No NWS data for nearby stations is available for comparison	None

Table 23.4. Relative humidity QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or data logger communications failure (measurements of other sensors also missing?), sensor wiring.
2	Value < -2% or > 104% (range of the sensor calibration and uncertainty)	Check sensor mount, wiring, casing. Repair or replace.
4	Value standard deviation over one hour> 20%	Check weather conditions and time series for inconsistencies. Check sensor mount, wiring, casing. Repair or replace.
8	Value differs by more than 15% from the temperature-corrected relative humidity from the nearest National Weather Service (NWS) weather station	Check sensor mount, wiring, casing. Repair or replace.
16	No NWS data for nearby stations is available for comparison	None

Table 23.5. Barometric pressure QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or data logger communications failure
2	Value < 600 hPa or > 1100 hPa (i.e. outside the range of the sensor)	Check sensor mount, wiring, casing. Repair or replace as necessary.
4	Difference between the sampling site and local weather station is more than 8 hPa	Check sensor mount, wiring, casing.. Check weather conditions/ time series for inconsistencies. Repair or replace as necessary.
8	No NWS data for nearby stations is available for comparison	None

Table 23.6. Sonic temperature QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of possible values in period)	Check for power or data logger communications failure
2	Value <-40°C or >+50°C	Check connections, cable condition, lightning damage; repair or replace
4	Spike count >160.	Check connections, cable condition, lightning damage; repair or replace
8	Difference between value and calculated T_v >5°C	Check sensor mount, wiring. Repair or replace as necessary.
16	No weather station data available	Repair or replace humidity and temperature probe.

The QA data flagging codes for the measurement of solar radiation documented in SOP E3 are indicated in Table 23.7. No corresponding measurement is made at NWS weather stations. If any values of these measurements are flagged with a non-zero data flag, evaluate associated barn measurement location (if available): If unreasonable, substitute value from associated barn measurement location, if reasonable, document reason for validation of value (with the invalidation flag retained) and retain value for further processing. An unresolved non-zero data flag for these measurements will not result in an unscheduled repair/replacement trip by FOS staff, but the sensor repair/replacement will be addressed in the next routine site visit. This is a project non-critical measurement used in the assessment of general weather conditions.

Table 23.7. Solar radiation QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or data logger communications failure. Check sensor wiring, casing. Repair or replace as necessary.
2	Ratio of sensor measurement to potential irradiance is greater than 0.9	Check sensor wiring. Repair or replace as necessary.
4	Measurements between 10 AM and 2 PM are less than 10% of potential irradiance	Check sensor mount, wiring, casing. Repair or replace as necessary.

The QA data flagging codes and associated corrective actions for the measurement of wetness documented in SOP W3 are indicated in Table 23.8. If flagged with a non-zero data flag, evaluate conditions reported at the nearest NWS weather station for reasonableness: If unreasonable substitute value corresponding to expected state based on weather conditions of nearest NWS weather station, if reasonable document reason for validation of value (with the invalidation flag retained) and retain value for further processing. An unresolved non-zero data flag for these measurements will not result in an unscheduled repair/replacement trip by FOS staff, but the sensor repair/replacement will be addressed in the next routine site visit. This is a project non-critical measurement used in the determination of dew or rain events.

Table 23.8 Wetness QA flagging codes

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or data logger communications failure
2	Values for day and prior day are not consistent with at least one of the past two day's weather conditions	Inspect sensor, repair or replace.

23.2 *Validation of sonic anemometer data*

The QA flagging codes for the sonic anemometer measurements at each height (2 m, 4 m, and 16 m) are indicated in Table 23.9.1. If the value of the 2 m sensor is flagged with a non-zero code, substitute value from the 4 m sensor for the bLS model input. If both the 2 m and 4 m sensor have a non-zero code, then no value is substituted. No equivalent measurements are made at either any associated barn measurement location or a NWS weather station. A non-zero flag code for all wind sensors will result in an unscheduled repair/replacement trip by FOS to the location of the measurement with 2-3 d. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the sonic anemometer data. These are project critical measurements used in the bLS emissions model.

Table 23.9.1 QA flagging codes for individual sonic anemometer components (u', v', w', T_v').

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of records in 5-min period)	Check for power or communications failure
2	Value below minimum or above maximum or value is ±infinity	Check connections, cable condition, lightning damage; repair or replace
4	Spike count >160	Check connections, cable condition, lightning damage; repair or replace
8	Value has variance >10 m^2/s^2 (u, v, w) or 10 C^2 (T)	Check connections, cable condition, lightning damage; repair or replace
16	> 10% of sampling interval has path obstruction	Check weather conditions (icing), farm activity; repair or replace

The individual components of turbulence are inter-correlated. The conditions influencing the validity of the bLS model will be assessed from: 1) checking for stationarity in the time series by comparing the 5-min covariances of u' and w' and w' and T_v' to the 30-min averaged covariances, with invalid data indicated by differences of greater than 30% between the 5-min and 30-min values (Foken and Wichura, 1996), and 2) checking for inhomogeneity by comparing the theoretically derived and measured integral turbulence scales of w' and T_v' (u_* and T_{v*}) to the standard deviation of w' and T_v', with invalid values when the measured and derived values differ by more than 30% (Foken and Wichura, 1996). The QA flagging codes associated with these criteria are found in Table 23.9.2. These are project non-critical measurements used to qualify the bLS model accuracy.

Table 23.9.2 QA flagging codes for combinational components (u', v', w', T_v').

Data Flag	**Reason**	**Corrective action**
0	Value not suspect	None
1	> 10% of sampling interval has path obstruction	Check weather conditions (icing), farm activity; repair or replace
2	$u'w'$ not stationary (30-min period)	Check weather conditions, stability and wind directions
4	$w'T'$ not stationary (30-min period)	Check weather conditions, stability and wind directions
8	σ_u inhomogeneous turbulence in 30-min period	Check weather conditions, stability and wind directions
16	σ_w inhomogeneous turbulence in 30-min period	Check weather conditions, stability and wind directions
32	σ_T inhomogeneous turbulence in 30-min period	Check weather conditions, stability and wind directions

23.3 *Validation of lagoon/basin characterization data*

The lagoon/basin wastewater characterization data is validated to ensure that the quality goals of the study are met. Computers are used to assist in validation of the data by determining if the values fall outside a specified range. Validation of each individual measurement is outlined in the respective sensor SOP.

The QA data flagging codes for the measurement of lagoon pH (Table 23.10), redox potential (Table 23.11), and wastewater temperature (Table 23.12) documented in SOP L1, SOP L2, and SOP L3 are indicated. No value substitution is possible as there are no equivalent measurements made at the measurement location. A non-zero data flag for these measurements will not result in an unscheduled repair/replacement trip by FOS staff, but the sensor repair/replacement will be addressed in the next routine site visit. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the lagoon/basin characterization data. These are project non-critical measurements used to describe the lagoon condition.

Table 23.10. pH QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of possible values in period)	Check for power or communications failure
2	Value > 8.5 or < 6.5	Check connections, cable condition, clogged probe, low solution.; recalibrate
4	Changes by more than 0.5 in 1 h	Check for data flag 4 in lagoon temperature and redox measurements. If yes, ask associated barn measurement team (if applicable for the location) or producer to check if the sensor float is still right side up. If yes then schedule wiring and sensor troubleshooting for next site visit. If no, then ask barn measurement team to right probe float (if applicable).
8	Does not vary from 5.8 to 6.2 over 3 h	Check probe for crack; if yes, repair or replace
16	Does not vary from 7.0 over 3 h	Check cable for damage; if yes, repair of replace

Table 23.11. Redox potential QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of possible values in period)	Check for power or communications failure
2	Value > -20 mV or < -800 mV	Check for contamination or damage; clean or repair
4	Value ≥ 1100 mV	Check for damaged cables, loose connections, clogged or coated probe; repair or clean
8	Value= 0 mV	Check cable for damage, repair or replace

Table 23.12. Wastewater temperature QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or communications failure
2	Value < -40 °C or > +50°C (bound of sensor calibration)	Check cable and connections; repair or replace
4	Value > 5°C (9°F) change from the previous hour	Check for data flag 4 in lagoon pH and redox measurements. If yes, ask associated barn measurement team (if applicable for the location) or producer to check if the sensor float is still right side up. If yes then schedule wiring and sensor troubleshooting for next site visit. If no, then ask barn measurement team to right probe float (if applicable).

The QA data flagging codes for the measurement of lagoon sludge depth documented in SOP L5 are indicated in Table (23.13). These measurements are made manually by the FOS. Values with non-zero data flags cannot be substituted but since eight to nine measurements of sludge depth are made, the invalidated measurements will likely not result in a significant loss of data. It is anticipated that failures of the sensor will be evident by the FOS at the time of measurement and the instrument will be returned to PAML at the time that the FOS return. At that time, the instrument will be tested and a decision for repair or replacement made.

Table 23.13. Sludge depth QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Verify with FOS that the measurement was made.
2	Value > depth of lagoon	Verify with FOS that procedures were adhered to and that sensor has returned with FOS for repair/replacement.

Validation of the manure analyses for pH, total solids content, volatile solids content, ammonia nitrogen and total nitrogen conducted by the commercial laboratory (Midwest Laboratories, Inc.) is certified by the National Environmental Laboratory Accreditation Program (NELAP) to conduct the methodologies on which SOP M2 through SOP M5 are based: Method 9040C (USEPA, 2004), Method 1684 (USEPA, 2001a; Draft version), Method 1687 (USEPA, 2001b) and Method 350.2 (USEPA, 1974).

23.4 *Validation of UV-DOAS data*

The UV-DOAS data will be validated to ensure that the quality goals of the study are met. The UV-DOAS instrument control and data processing control computer will be used to assist in validation of meteorological data by determining if the values fall outside a specified range.

Data will be reviewed and validated by comparison with instrumental performance parameters. Three data validation techniques will be used to assess the validity of data prior to data interpretation and reporting: (1) light levels, (2) signal-to-noise ratio, and (3) lowest acceptable concentration for proper analyzer performance. The procedures outlined in SOP C1 will be followed. Data for each 5-min measurement period also will be evaluated for compliance with stated objectives for representativeness (75% valid measurements during sample period), precision, and accuracy.

Analyzer function and performance procedures found in SOP C1 must be performed to confirm that the measuring system is operating correctly. If function and performance tests indicate the instrument is not operating correctly, data must be flagged with an explanation of the quality issue and a discussion of the impact the deviations have on the quality of the data. Data validation analysis must be applied to each individual pollutant parameter in each field test application since the light levels, standard deviations, and detection limits vary with field test conditions, differences in path lengths, monitoring times, and detection limits.

The minimum requirements for QA and data validation include the following:

1. Valid initial reference and multipoint span calibration;
2. Span/offset check prior to the measurement period;
3. Normal system performance during the measurement campaign as determined by system tests and light levels;
4. Span/offset check following the conclusion of measurements that is within the acceptance parameters;
5. Signal strength and relative single beam intensity;
6. Acceptable correlation coefficient of filtered absorption spectrum to the calculated spectrum (greater than 0.75),
7. Pixel shift of one (approx. 0.07 nm) or less for the alignment of an NH_3 absorption peak from the measured/filtered absorption spectra to the NH_3 reference spectra (for H_2S QA),
8. Low spectrum analysis residual (the un-explained RMS residual from the analytical characterization of the measured/filtered spectrum):

   $$\text{RMS residual}=\frac{\sum_{waveband}\left(FA-EA\right)^2}{\sum_{waveband}\left(FA-\overline{FA}\right)^2}<0.25\text{, and}$$
9. Other validation checks in accordance with operating manuals.

Table 23.14. UV-DOAS NH_3 and H_2S QA flagging codes for each beamline.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or communications failure
2	Value zero	Check alignment; contact PM if aligned for replacement/repair
4	Maximum peak emission<2500 counts	Check for obstructions, check weather records of site and nearby NWS weather station for heavy fog, freezing rain,
8	Integration time >500 ns	Check alignment; contact PM if aligned for replacement/repair
16	Total drift at 270 nm < ±0.002 AU	Contact PM; if flag unresolved- replace/repair
32	Signal at 210 nm > 205 signal at 250 nm	Contact PM; if flag unresolved- replace/repair
64	Dark current ≤±5 counts	Contact PM; if flag unresolved- replace/repair
128	Pixel shift > 1	Check QC spectral feature pixel shift of measurement period, Check alignment, Check spectrum for below MDL NH_3 concentration, check abnormal shape, reprocess spectrum, contact PM if flag unresolved- replace/repair
256	Spectrum correlation coefficient < 0.75	Check alignment, Check spectrum for below MDL NH_3 concentration , Check spectrum for abnoramal shape, Check alignment, Contact PM; if flag unresolved- replace/repair
512	Analysis residual > 0.25	Check spectrum for below MDL NH_3 concentration, Check spectrum for abnormal shape, Check alignment, Contact PM; if flag unresolved- replace/repair

Any data not meeting the data quality objectives will be flagged as invalid for comparison to screening level criteria. Data flags associated with the QA checks are documented in Table 23.14. Subsequently, the root cause of the invalidation will be explored. No equivalent measurements are made at the location. A non-zero flag code will result in an unscheduled repair/replacement trip by FOS to the location of the measurement within 2-3 d. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the UV-DOAS data. These are project critical measurements used in the bLS emissions model.

23.5 *Validation of TDLAS data*

The TDLAS data will be validated to ensure that the quality goals of the study are met. The open path TDLAS instrument control and data processing computer will be used to assist in validation of the TDLAS data by determining if the values fall outside a specified range.

Data will be reviewed and validated by comparison with instrumental performance parameters. Three data validation techniques will be used to assess the validity of data prior to data interpretation and reporting: (1) light levels, (2) signal-to-noise ratio, and (3) lowest acceptable concentration for proper analyzer performance. The procedures outlined in the SOP C2 will be followed. Data for each 10-min measurement period also will be evaluated for compliance with stated objectives for representativeness (75% valid measurements during each sample period), precision, and accuracy.

Analyzer function and performance procedures found in SOP C2 must be performed to confirm that the measuring system is operating correctly. If function and performance tests indicate the instrument is not operating correctly, data must be flagged with an explanation of the quality issue and a discussion of the impact the deviations have on the quality of the data. Data validation analysis must be applied to each individual pollutant parameter in each field test application since the light levels, standard deviations, and detection limits vary with field test conditions, differences in path lengths, monitoring times, and detection limits.

The minimum requirements for QA and data validation include the following:

1. Valid initial reference and multipoint span calibration;
2. Span/offset check prior to the measurement period;
3. Normal system performance during the measurement campaign as determined by system tests and light levels;
4. Span/offset check following the conclusion of measurements that is within the acceptance parameters;
5. Other validation checks in accordance with operating manual

Any data not meeting the MQO will be flagged as invalid. Internally-derived status codes are indicated in the data-logging program data stream output. Data flags associated with these QA checks are documented in Table 23.15. No equivalent measurements are made at the location. The cause for the non-zero data flag will be explored by comparisons of all data flags. An unresolved non-zero flag code will result in an unscheduled repair/replacement trip by FOS to the location of the measurement with 2-3 d. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the TDLAS data. These are project critical measurements used in the bLS emissions model.

Table 23.15. TDLAS NH_3 QA flagging codes for each beamline.

Data Flag	**Reason**	**Corrective action**
0	Value not suspect	None
1	Value missing	Check for power or communications failure
2	Return beam intensity <500 or >12000	Check alignment, clean windows and invalidate measurement.
4	Internal reference linearity $r^2 \leq 0.9$	Contact PM, if unresolved, return for repair/replacement
8	Internal calibration failure	Contact PM, if unresolved, return for repair/replacement
16	Internal temperature <15°C above ambient temperatures	Check for power failure, contact PM; if unresolved, return for repair/replacement

23.6 *Validation of PAS data*

The PAS data is validated to assure that the DQOs of the study are met. Computers are used to assist in validation of the data by determining whether the values fall outside a specified range. Validation of each individual measurement is outlined in SOP G7. The PAS data consists of measurements that are both project critical and project non-critical. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the PAS data.

The project critical measurements include methane and NH_3. The NH_3 is needed (in conjunction with TDLAS NH_3 PIC measurement and the corresponding RPM-calculated NH_3 emissions) to estimate the VOC emissions of methane. The QA data flagging codes for the measurements are indicated in Table 23.16. A non-zero data flag for these measurements will result in an unscheduled repair/replacement trip by FOS staff. No value substitution is possible as there are no equivalent measurements made at the measurement location.

Table 23.16. PAS measurement QA flagging codes.

Data Flag	**Analyte**	**Reason**	**Corrective action**
0	All	Value not suspect	None
1	All	Event mark “R1” from instrument	Power failure and restarted, no action
2	All	Value missing	Check for power or communications failure: other values also missing.
4	All	Value varies < 2 MDL over 1 h	Check for plugged gas sampling line or filter; clean or repair, invalidate measurement if due to plugged lines/filter
8	All	Event mark “F” from instrument	Filter out of alignment, realign filter wheel, invalidate measurement.
16	All	Event mark “X1” from instrument	Operational error; contact manufacturer for repair/replacement, invalidate measurement.
32	All	Event mark “A” from instrument	Over-range of instrument, check other measurements by instrument
64	NH_3	NH_3 value > MDL and > 10 x NH_3 value of corresponding TDLAS path	Check inlet filter for cleanliness, filterwheel for motion/sequence. Replace filter if needed. If filter wheel failure, contact manufacturer for repair/replacement
128	GSS sampling flow rate	Sampling flow rate less than combined analyzer flow (2 L/min) demand	Check S-OPS and GSS inlet filters for cleanliness. Replace filter if needed.
256	GSS pressure	Sample manifold pressure < -50 kPa	Check S-OPS and GSS inlet filters for cleanliness. Replace filter if needed.

The minimum requirements for QA and data validation include the following:

1. Valid initial reference and multipoint span calibration;

2. Span/offset check prior to the measurement period;
3. Normal system performance during the measurement campaign as determined by system tests;
4. Span/offset check following the conclusion of measurements that is within the acceptance parameters;
5. Other validation checks in accordance with operating manual

The project non-critical measurements include the concentration of MeOH and EtOH, used to partially define the composition of NMHC. The QA data flagging codes for these measurements are indicated in Table 23.16. A non-zero data flag for either of these measurements will not result in an unscheduled repair/replacement trip by FOS staff, but the sensor repair/replacement will be addressed in the next routine site visit. No value substitution is possible, as there are no equivalent measurements made at the measurement location.

23.7 *Cross-validation of UV-DOAS and TDLAS data*

Analysis of validated UV-DOAS and TDLAS data files that have been transferred to PAML by ftp will have *four* components. *All* data analysis components provide a higher level of data quality assurance and data reduction. By data, we mean the PIC of air pollutant gases measured by the UV-DOAS and TDLAS. For each set of 24 h of measurements and analysis, a daily check of the prior days measurements will be conducted (by the lead operator at PAML):

1. Determine the statistical properties of the daily data of downwind 30-min [H_2S] and [NH_3] (mean, median, 10th percentile, 90th percentile) and compare to the statistics of the prior records for the same location.
    a. Compare values of open path TDLAS and UV-DOAS when applicable (due to wind direction). Data comparability for NH_3 will be assessed by the collocated UV-DOAS and TDLAS instrumentation. Agreement between the monitoring methods will be considered acceptable if the respective 30-min data agree to within a coefficient of determination of 80%.
    b. Explore causes for extreme values with respect to temperature, wind direction, stability (L), and turbulence.
    c. Identify outliers on log (by 30 min of record) and specify conclusions.
2. Determine the statistical properties of the daily data of upwind 30-min [H_2S] and [NH_3] (mean, median, 10th percentile, 90th percentile) and compare to the statistics of the prior records for the same location.
    a. Compare to values from upwind open path TDLAS when applicable (due to wind direction)
    b. Explore causes for extreme values with respect to temperature, wind direction, stability (L), and turbulence.
    c. Identify outliers on log (by 30-min period) and specify conclusions.
3. Verify that the higher concentrations (mean, median, 90th percentile) occur for the downwind instrument.
4. Verify that the 10th percentile concentrations of upwind and downwind instruments are similar.

Based on these steps, additional data flag values are defined for both TDLAS and UV-DOAS measurements defined in Tables 23.14 and 23.15 according to Table 23.17.

Table 23.17. UV-DOAS / TDLAS cross-validation QA flagging codes.

Data flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (either UV-DOAS or TDLAS)	None, previously documented in individual measurement data flags
2	UV-DOAS value below MDL for TDLAS.	None, previously documented in individual measurement data flags
4	UV-DOAS value suspect - inexplicably below 10th or above 90th percentile of daily TDLAS.	None, track over time and look for trends
8	TDLAS value suspect - inexplicably below 10th or above 90th percentile of daily UV-DOAS.	None, track over time and look for trends

23.8 *Validation of bLS emissions estimates*

Emissions estimates from the WINDTRAX model (SOP O1) will be quality assured by evaluation of two DQI: the calculated Monin Obukov length (L) and the friction velocity. The bLS emissions calculations are made at PAML and DQI values calculated for each 30-min measurement interval. Plots of the apparent plume are saved on the on-site computer. Visual inspection of the plots and measurement period DQI failures will be conducted. After inspection of plots, measurements made during unusual plume plots will be inspected and their validity

Table 23.18 bLS QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for missing UV-DOAS or 2 and 4 m wind measurements
2	Inhomogeneity of turbulence at wind measurement height	None, results of low quality
4	Non-stationarity of turbulence at wind measurements height	None, results of low quality
8	$\lvert L \rvert < 2$ m	None, results invalid
16	$u_* < 0.15$ m/s	None, results invalid
32	2-m wind substituted with 4-m wind	None
64	Value represents mean of multiple PIC measurements	None

assessed. The bLS model will be rerun for all measurement periods at PAML using weather-specific conditions to create the touchdown tables. Periods that fail the DQI will be run, but flagged as invalid. Subsequently, the cause of the invalidation will be explored. Modeling will proceed even when the 5-min data acquisition atmospheric turbulence criteria are not met (Table 23.9), however the model measurement will be flagged for poor data quality (Table 23.18).

Prior studies indicate the emissions estimate is ±36% when period $|L|<2$ m and/or $u_* < 0.15$ m/s (Flesch et al., 2004). Emissions estimates will be classified as invalid when the mean period $|L|<2$ m and/or $u_* < 0.15$ m/s (Table 23.18). See SOP O1 for details. Further validation against the RPM emissions estimates will be conducted according to Method 301 (Section 10.5).

23.9 *Validation of RPM emissions estimates*

Emissions estimates from the RPM model (SOP O2) will be quality assured by evaluation of three DQI: the measured fraction of the plume, the Concordance Correlation Factor (CCF), and the correction factor (A). The RPM emissions calculations will be made on-site as an automated routine with DQI values calculated for each 10-min measurement interval (three complete cycles of the TDLAS scanning system). Plots of the reconstructed plumes will be saved on the on-site computer. The data and plots will be downloaded daily to PAML by ftp (SOP D1) and visual inspection of the plots and measurement period DQI failures will be done. Unusual plume plots and periods which failed the DQI will be manually rerun if the situation indicates a shift in cycles per measurement or shift in measurement period may result in successful emissions calculations.

Modeling will proceed even when only one 10-min mean wind speed measurement height is valid, however the model measurement will be flagged for poor data quality (data flag 1 in Table 23.19). Modeling will also proceed if there are only three valid PIC measurements (the longest pathlength), however the model measurement will be the flagged for poor data quality (Data flag 1 in Table 23.19). Modeling will not proceed if there are no valid TDLAS PIC measurements.

Calculated emission rates will be considered valid when the topmost PIC is less than or equal to 90% of the midlevel PIC (Table 23.19). Under these cases, the measurement plane contains 70% or more of the plume. Prior studies indicate that the emissions error is ±20% when the emissions estimate is based on measurements of the ‘entire’ plume (Hashmonay and Yost, 1999). The Concordance Correlation Factor (CCF) indicates the goodness of fit between measured and predicted PIC. CCF is defined as $CCF = rA$ where r is the Pearson correlation coefficient, and A is a correction factor for the shift in population and location. This shift is a function of the relationship between the averages and standard deviations of the measured and predicted PIC vectors:

$$A = \left[\frac{1}{2} \left(\frac{\sigma_{PIC_P}}{\sigma_{PIC_M}} + \frac{\sigma_{PIC_M}}{\sigma_{PIC_P}} + \left(\frac{\overline{PIC_P} - \overline{PIC_M}}{\sqrt{\sigma_{PIC_P} \sigma_{PIC_M}}} \right)^2 \right) \right]^{-1} \qquad \text{(Equation 23.1)}$$

where σ_{PIC_P} and σ_{PIC_M} are the standard deviations of the predicted and measured PIC vectors respectively, and $\overline{PIC_P}$ and $\overline{PIC_M}$ are the means of the predicted and measured PIC vectors respectively. An $A \geq 0.9$ verifies that the plume positioning is a reasonable fit of the raw data. If $A<0.9$, a longer grouping of measurement cycles should be used (4 instead of the nominal 3) and the algorithm rerun (Table 23.18). A $CCF \geq 0.8$ indicates that the surface concentration plot is a reasonable fit with the raw data. If the $CCF < 0.8$, a longer grouping of measurement cycles should be used (4 instead of the nominal 3) and the algorithm rerun (Table 23.18). These changes in the grouping of measurement cycles will be a post-processing procedure for RPM emissions calculations that fail the A and/or CCF DQI of the automated routine but pass the plume capture fraction DQI. Emissions estimates will be classified as invalid when any of the DQIs are not met. Subsequently, the cause of the invalidation will be explored.

Table 23.19. RPM QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for missing wind or TDLAS measurements, results of poor quality
2	CCF<0.8	Invalidate results, increase number of cycles included in PIC and wind averaging and rerun model.
4	A<0.9	Invalidate results, increase number of cycles included in PIC and wind averaging and rerun
8	15 m TDLAS PIC > 8 m TDLAS PIC or 8 m TDLAS PIC > 1 m TDLAS PIC	No calculation, Invalid plume conditions
16	15 m TDLAS PIC > 0.9 of 8 m TDLAS PIC	No calculation, Invalid plume conditions
32	2 m wind invalid, substituted 4 m wind	None
64	4 m wind invalid, substituted 16 m wind	None
128	16 m wind invalid, substituted 4 m wind	None
512	2 of 3 wind measurements invalid	Invalidate results, no wind profile

23.10 *Reconciliation of Validated RPM and bLS emissions estimates*

If the UV-DOAS and TDLAS systems are used to measure NH_3, it is anticipated that validated emissions calculations from the RPM method and the bLS method will not be the same. Consequently, a means of evaluating the ‘true’ emission must be made. If the correction factor for the bLS emission calculation is between 1.10 and 0.90 that of the RPM calculation method, as determined in the validation study (Section 10.7), then the bLS and RPM calculations will both be considered of equal accuracy. Consequently:

- If there is a significant difference between the validated RPM and bLS NH_3 emissions; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S emissions will be determined using the ratio of H_2S to NH_3 concentrations determined by the UV-DOAS measurements multiplied by the RPM NH_3 emissions calculation.
- If the difference between the validated RPM and bLS NH_3 emissions is not significant; the NH_3 emissions for the basin will be the average of the two emissions calculations and the H_2S emissions will be based on the bLS model results. If the RPM emissions calculation of NH_3 is valid but the bLS calculation is invalid; the NH_3 emissions for the basin will that computed from the RPM model and the H_2S emissions will be determined using the ratio of H_2S to NH_3 concentrations determined by the UV-DOAS measurements multiplied by the RPM NH_3 emissions calculation.

Emission measurements will be weighted according to the results of the bLS/ RPM comparison study described in Section 10.7 and a statistical representation (mean and standard deviation) of the emission estimates made. Using these statistics, outlying emissions calculations can be identified and evaluated as to cause, and emission measurement confidence can be determined.

If the correction factor for the bLS emission measurement is more than 1.10 or less than 0.90 that of the RPM measurement method, then the bLS method will be used differently for lagoon/ basin and corral measurements. At the lagoon/ basin locations, the bLS model will not be considered valid even when the DQI for the bLS method are satisfied. The RPM emission rate for NH_3 will be the true emission while the emission rate of H_2S will be based on the ratio of UV-DOAS NH_3 and H_2S PIC measurements will be used in combination with the TDLAS NH_3 PIC and RPM measured emission using Equation 10.1. Since only bLS emissions calculations are made at the corral location, all bLS emission estimates that pass the DQI will be considered valid and will be qualified at a reduced accuracy in accordance with the validation experiment.

23.11 *Validation of PFA data*

The PFA data is validated to assure that the DQOs of the study are met. Computers are used to assist in data validation by determining whether the values fall outside a specified range. Validation of each individual measurement is outlined in SOP G5. The PFA data consists of H_2S measurements that are project critical. The minimum requirements for QA and data validation include the following:

1. Valid initial reference and multipoint span calibration
2. Span/offset check prior to the measurement period
3. Normal system performance during the measurement campaign as determined by system tests and light levels
4. Span/offset check following the conclusion of measurements that is within the acceptance parameters
5. Other validation checks in accordance with operating manual

The H_2S measurements are needed (in conjunction with TDLAS NH_3 PIC measurement and the corresponding RPM-calculated NH_3 emissions) to estimate the H_2S emissions. The QA data flagging codes for the measurements are indicated in Table 23.20. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the PF data. A non-zero data flag for these measurements will result in an unscheduled repair/replacement trip by FOS staff. No value substitution is possible as there are no equivalent measurements made at the measurement location.

Table 23.20. PF measurement QA flagging codes.

Data Flag	Analyte	Reason	Corrective action
0	All	Value not suspect	None
1	All	Value missing	Check for power or communications failure: other values also missing.
2	Reaction chamber and converter	Reaction chamber out of range (43-47^oC) or converter temperature out of range (300-400^oC)	Operational error. Contact manufacturer for repair/replacement, invalidate
4	H_2S and SO_2	Does not vary more than 2 ppb over 1 h	Check other measurements by instrument, contact manufacturer for repair/replacement, invalidate
8	Pressure	Pressure outside of range (400-1000 mmHg)	Check for plugged gas sampling line or filters or inlet filters; clean or repair, invalidate measurement if due to plugged line/filter.
16	Sample flow rate	Flow rate outside of range (0.35-1.4 L/min)	Check for plugged gas sampling line or filters or inlet filters; clean or repair, invalidate measurement if due to plugged line/filter.
32	Lamp intensity or voltage	Lamp voltage outside of range (20-100) Lamp intensity outside of range (500-1200)	Operational error. Contact manufacturer for repair/replacement, invalidate
64	GSS sampling flow rate	Sampling flow rate less than 2 L/min	Check S-OPS and GSS inlet filters for cleanliness. Replace filter if needed.
128	GSS pressure	Sample manifold pressure < -50 kPa	Check S-OPS and GSS inlet filters for cleanliness. Replace filter if needed.

23.12 *Cross-validation of PAS and TDLAS data*

Analysis of validated PAS and TDLAS data files that are transferred to PAML by ftp will have four components. All data analysis components provide a higher level of data quality assurance and data reduction. By data, we mean the PICs of air pollutant gases measured by the TDLAS that are nearest to the S-OPS system on the two sides of the source, and the PAS measurements from the S-OPS-sampled air. For each set of 24 h of measurements and analysis, a daily check of the prior day's measurements will be conducted (by the lead operator at PAML). Cross-validation will consist of the calculation of the statistical properties of the daily data of valid 30-min [NH_3] concentrations (mean, median, 10th percentile, 90th percentile) and a comparison of resulting values. Agreement between the monitoring methods will be considered acceptable if the respective PAS 30-min data agree to within a coefficient of determination of 80% of the TDLAS data. Where agreement is not indicated, data analysts will explore causes for extreme values with respect to temperature, wind direction, stability (L), and turbulence and identify outliers on log (by 30 min of record) and specify conclusions. Based on these steps, additional data flag values are defined for both TDLAS and PAS measurements according to Table 23.17.

Table 23.17. PAS / TDLAS cross-validation QA flagging codes.

Data flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (either TDLAS or PAS values missing)	None- previously documented in individual measurement data flags
2	TDLAS value below MDL for PAS	None
4	TDLAS value suspect - inexplicably above daily 90th percentile or below daily 10th percentile.	None, track over time and look for trends
8	PAS value suspect - inexplicably above daily 90th percentile or below daily 10th percentile.	None, track over time and look for trends

References

American Society for Testing and Materials (ASTM) E104 Standard practice for maintaining constant relative humidity by means of aqueous solutions, American Soc. for Testing and Materials.

Atmospheric Radiation Measurement Program. 2004. Atmospheric Radiation Monitoring Network: Standard Operating Procedures

Boreal Laser, Inc. 2003. GasFinder2.0 portable system Operation Manual. Ver 0.39, Boreal Laser, Inc, Spruce Grove, Alberta, Canada, 38 p.

Cerex Environmental Services Inc. 2006. UV Sentry Open-path Air Monitor End-User Manual, Version 2006329, Cerex Environmental Services, Inc, Atlanta, GA.

Foken, T, B Wichura. 1996. Tools for quality assessment of surface-based flux measurements. Agricultural and Forest Meteorology 78, 83-105.

IMPROVE, Particulate Monitoring Network: Standard Operating Procedures, University of California, Davis.

Innova AirTech Instruments. undated. 1314 Photoacoustic multi-gas analyzer, 1412 Photoacoustic Field Gas-Monitor. Technical Documentation. BE6011-11. 252 p

Lin, L. I-K. 1989. A Concordance Correlation Coefficient to Evaluate Reproducibility. Biometrics. 45, 255-68.

Midwest Laboratories, Inc. 2004. Quality Assurance manual. Ver 6, Midwest Laboratories, Inc, Omaha, NE, 138 p.

Miller, WJ. 2002. Redox chemistry of six anaerobic swine lagoons in eastern North Carolina. MS thesis, North Carolina State University, 167 p.

SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Applied Meteorology Lab.

SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Applied Meteorology Lab.

SOP G5. 2006. Standard Operating Procedure for the Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450I Pulsed Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic Multi-gas Analyzer. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1.

SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP O1. 2006. Emissions Estimation Using Backward Lagrangian Stochastic (bLS) Model. Standard Operating Procedure O1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP O2. 2006. Emissions Estimation Using Radial Plume Mapping (RPM). Standard Operating Procedure O2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W1. 2006. Measurement of Atmospheric Temperature and Humidity with the Viasala Model HMP45C Sensor and Solar Shield. Standard Operating Procedure W1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W3. 2006. Measurement of Wetness with the Campbell Scientific Model Resistance Grid. Standard Operating Procedure W3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W5. 2006. Measurement of Barometric pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer. Standard Operating Procedure W5. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP E3. 2006. Measurement of Solar Radiation with the LiCOR model 200SL or 200SZ Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

US Environmental Protection Agency. 1974. Method 350.2 – Nitrogen, Ammonia (Colorimetric, Titrimetric, Potentiometric Distillation Procedure). Online at www.umass.edu/tei/mwwp/acrobat/epa350_2NH3titration.pdf, Accessed 1/19/2006.

US Environmental Protection Agency. 2000. Meteorological Monitoring Guidance for Regulatory Modeling Applications. Office of Air Quality Planning and Standards. Research Triangle Park, NC. EPA-454/R-99-005.

US Environmental Protection Agency. 2001a. Method 1684 – Total Fixed and Volatile Solids in Water, Solids, and Biosolids. Office of Water, Office of Science and Technology, Washington, DC. EPA-821/R-01-015 (CD).

US Environmental Protection Agency. 2001b. Method 1687 – Total Kjeldahl Nitrogen in Water and Biosolids. Office of Water, Office of Science and Technology, Washington, DC. EPA-821/R-01-004 (CD).

US Environmental Protection Agency. 2004. Method 9040C (Rev. 3) pH Electrometric Measurement. Online at www.epa.gov/sw-846/pdfs/9040c.pdf. Accessed 3/7/2006.

24. Reconciliation with User Requirements

Since there are no specific DQOs for the study, explicit evaluation of the meeting of the DQOs is not possible. The two general DQO identified in section 7 provide the criteria to evaluate how well the project has met the intended use as specified by the ACA. Data (measurement or calculation) are flagged as invalid based on data validation checks, performance audits, technical system audits, or QC checks. All data is retained.

The first DQO for the study is to provide mean daily lagoon/ basin emission calculations for each farm waste storage area under study that are within 30% of the true values for each measurement period. This DQO is derived from the emissions model errors associated with the measurements used in the study and not from statistical analysis of previous measurements due to the very limited duration of previous lagoon/ basin emissions measurements. The quality of the measurements and calculated emissions of NH_3, H_2S and VOCs (THC, methane, MeOH and EtOH) will be assessed by:

- A review of the data including the review of systematic invalidation of data as indicated in the quality assurance reports.
- Inspection of summary statistics (number of samples, mean concentration, median concentration, standard deviation, coefficient of variation, and probability distributions) generated for all measurements within a day of a measurement period and for each quarter of year for emissions characteristics of the area sources.
- Statistically compare the daily emissions by operation type to determine influence of season, climate/operation type on emissions. Determine the typical daily emissions for each operation type and season using the predefined measurement errors.

The second DQO is the completeness criteria for the study: Valid samples of NH_3, H_2S, THC, methane, MeOH and EtOH) emissions during each quarter will consist of 75% of 10 d of valid measurements or 7.5 d. Since there is no way to rerun the periods of measurement, invalid data directly impacts the final completeness DQO. An evaluation of the completeness of the data for the determination of typical emissions for the represented operations will qualify the analyses of daily emissions above.

References

US Environmental Protection Agency, 2005. Animal Feeding Operations Consent Agreement and Final Order: Notice, Part IV, Environmental Protection Agency, Federal Register 70(19):4958-4877.

Appendix A- Measurement Quality Objectives

Tables reporting the MQO for each parameter needed in the study follow.

Table A1. Measurement Quality Objectives - Ambient temperature (Thermistor in CSI Model HMP45C hygrometer).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Degrees C		
Shelter temperature	Daily	-40 - +60°C		Sensor mounted in solar radiation shelter and kept at ambient environmental conditions
Equipment -thermistor	Purchase specification	Accuracy ±0.5 °C across -40 - +60°C	USEPA 454/R-99-005	Sensor is part of a instrument.
Detection	Purchase specification	0.1 °C	Manufacturer manual	Platinum resistance thermistor
Completeness 1/2h data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling for approx. 21 d/quarter to assure 90% of 10 d
Local primary standard	Purchase specification	±0.01 °C	Manufacturer calibration certificate	NIST certified standard immersion thermometer
Calibration	On receipt Annual	Accuracy ±0.5 °C across -40 - +60°C, NIST traceability	USEPA 454/R-99-005 SOP W1	Invalidate data to last acceptable calibration. Contact PM for replacement of sensor head with HMP 41 sensing element and recalibrate. If continued problems, decommission and return to manufacturer for repair and contact PM for replacement or repair.
Performance evaluation	Daily	-40 to +60°C , 1) hourly SD > 2°C, 2) < 5°C change from previous hour 3) varies > 0.5°C over 12 consecutive hours 4) within 3°C of nearby NWS measurement	SOP W1	Data automatically flagged, assess weather conditions Check sensor mount, wiring, casing; repair or replace
Precision	Annual	0.3 °C	Manufacturer manual	Contact PM for replacement of sensor head with HMP 41 sensing element and recalibrate. If continued problems, decommission and return to manufacturer for repair and contact PM for replacement or repair.
Accuracy	Annual	Accuracy ±0.5 °C across -40 - +60°C	SOP W1	Contact PM for replacement of sensor head with HMP 41 sensing element and recalibrate. If continued problems, decommission and return to manufacturer for repair and contact PM for replacement or repair.

Table A2. Measurement Quality Objectives- Parameter: Relative Humidity of ambient air (Hygrometer in Campbell Scientific, Inc. CSI HMP45C hygrometer; Vaisala, Inc.).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Percent relative humidity		Determined from temperature measurements.
Shelter temperature	daily	-40 - +60°C	Manufacturer manual	Sensor mounted in solar radiation shelter and kept at ambient environmental conditions
Equipment -RH sensor	Purchase specification	±2% over 10-90% RH; ±3% over 90-100% RH	Manufacturer manual	Sensor is part of an instrument.
Detection	Purchase specification	0.3%	Manufacturer manual	Capacitive chip
Completeness 1/2h data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Transfer standard	Purchase specification	Less than one year old	Batch purity certified by FINAS	Salts
Calibration - Salt solution calibration check	On receipt Annual	RH within 3% of theoretical values	ASTM E104 Manufacturer manual	Invalidate data to last acceptable calibration. Contact PM for replacement of sensor head with HMP 41 sensing element and recalibrate. If continued problems, decommission and return to manufacturer for repair and contact PM for replacement or repair.
Performance evaluation	Daily Hourly Hourly	-2%<RH≤104% Standard deviation< 20% within 10% of nearby NWS measurement	SOP W1	Data flagged
Accuracy	Annual	5%	USEPA 454/R-99-005 SOP W1	Contact PM for replacement of sensor head with HMP 41 sensing element and recalibrate. If continued problems, decommission and return to manufacturer for repair and contact PM for replacement or repair.

Table A3. Measurement Quality Objectives- Parameter: Barometric pressure of ambient air (Campbell Scientific, Inc. CS110 aneroid barometer, Setra, Inc.).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	hPa		
Shelter temperature	daily	-40 - +60°C	Manufacturer manual	Instrument kept in a un-conditioned enclosed box.
Equipment -pressure sensor	Purchase specification	800-1100 hPa Accuracy ±3 hPa	USEPA 454/R-99-005	
Detection	Purchase specification	0.5 hPa	USEPA 454/R-99-005	
Completeness 1/2h data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Local primary standard		NIST traceability	Fortin barometer	
Calibration -multipoint	On receipt Annually	≤2 hPa ≤2 hPa	USEPA 454/R-99-005 SOP W5	Return to manufacturer for repair Back-correct data record for shift (>2 to ≤6 hPa) Back-correct data record for shift, Contact PM for replacement, repair (>6h Pa) Invalidate data to last acceptable calibration. Contact PM for replacement, repair
Performance evaluation	Daily	600 to 1100 hPa within 4 hPa of NWS measurement	SOP W5	Data flagged
Accuracy	Semi-annual	±2 hPa	SOP W5	

Table A4. Measurement Quality Objectives- Parameters: Wind speed and direction (Model 81000 RM Young ultrasonic anemometer).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Speed: m/s Direction: deg.		
Shelter temperature	Daily	-50 - +50^{o}C	Manufacturer manual	Instrument mounted un-enclosed in the ambient environment
Equipment -3D sonic anemometer	Purchase specification	Speed: ±0.2 m/s + 5 % observed Direction: ±5 degrees	USEPA 454/R-99-005	
Detection	Purchase specification	Speed: 0.1 m/s Direction: 1 degree	USEPA 454/R-99-005	
Completeness 5 min data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Calibration Intercomparison of three sensors Intercomparison of at least three sensors	Beginning/end of meas. period or 20d, whichever comes first On receipt / Every six months	Difference between sensors <0.2 m/s Difference between sensors <0.2 m/s Sensor calibration with NIST traceability	SOP W2	Invalidate data to last acceptable calibration or evident failure in data record. Contact PM for replacement Return to manufacturer for repair
Performance evaluation - zero check - range and variability	Daily Beginning/end of meas. period or 20d, whichever comes first Daily	Zero check yields <0.3 m/s Wind speed: 0 - 45 m/s, varies by >0.1 ms^{-1} in 3 consecutive hours, varies by > 0.5 ms^{-1} in 12 consecutive hours, SD < 9 m/s Wind direction : 0° -360°, SD between 0 and 90 degrees.	SOP W2 USEPA 454/R-99-005	Data flagged Documented on calibration form Data flagged
Accuracy		Speed: ±0.2 m/s Direction: ±5 degrees		

Table A5. Measurement Quality Objectives- Parameter: Surface wetness (AC resistance grid plate).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Wet or Dry		
Equipment - wetness grid	Purchase specification	Detect wetness with resistance change	Manufacturer manual	Instrument mounted un-enclosed in the ambient environment
Detection		threshold of visual wetness	Manufacturer manual	
Completeness 5 min data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Verification	On receipt At end of study	Resistance change on wetting	Manufacturer manualSOP W3	Return to manufacturer for repair
Performance evaluation (Wetting)	At beginning of each measurement period	Resistance change on wetting	SOP W3	Invalidate data to last acceptable evaluation. Substitute with external weather information.
	Daily	Dry condition: <0.3124 mVDC Wet condition: >6.1881 mVDC		Data flagged Check continuity of sensor and cleanliness of surface and retest
	Daily	Must match wetness state from NWS or other external source in at least one of the past 2 d		-Sensor cleaned if dirty -if continued problem, contact PM for replacement/ return to manufacturer for repair
Accuracy	On receipt At end of study	Resistance change on wetting	SOP W3	Check continuity of sensor and cleanliness of surface Return to manufacturer for repair

Table A6. Measurement Quality Objectives- Parameter: Solar radiation (LiCOR 200SB silicon photodiode radiometer).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	W/m^2		
Equipment - radiometer	Purchase specification	±5% of observed	USEPA 454/R-99-005	
Detection	Purchase specification	10 W/m^2	USEPA 454/R-99-005	
Completeness 1/2h data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Calibration	On receipt Annual	±5% response of unused sensor, NIST traceability	USEPA 454/R-99-005 Intercomparison with unused sensor SOP E3	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement or repair and PM for replacement.
Performance evaluation - Ratio of measured to potential values	Daily	<0.9 of potential irradiance	SOP E3	Data flagged. Invalidate data to last acceptable measurements.
- Value check	Daily between 10AM-2PM	>100 W/m^2	SOP E3	Inspect sensor and cable and clean sensor at next visit to site. If problem persists, decommission and contact manufacturer for replacement or repair and PM for replacement.
- Zero check	At beginning of each measurement period or 21 d whichever comes first	<0.01 mV		Inspect sensor and cable. If problem persists, decommission and contact manufacturer for replacement or repair and PM for replacement.
Accuracy	Annual	±5% of unused sensor	SOP E3	Check for cleanliness of surface Return to manufacturer for repair

Table A7. Measurement Quality Objectives- Parameter: pH of lagoon/basin (Campbell Scientific, Inc. CSIM11 pH sensor; Innovative Sensors, Inc).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	pH unit		Correction using lagoon/basin temperature measurement
Shelter temperature	daily	0°C to +80°C	Manufacturer specification	
Equipment -pH sensor	Purchase specification	0 – 14 pH units accuracy 0.1%, ±0.1 pH unit	Manufacturer specification	
Completeness 1/2h data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Transfer Standards at pH 4.01, 7, 11 buffers	Every 6 mos.	NIST traceability	Manufacturer specification	Replace
Calibration 2-point Probe stability 2-point Probe stability	On receipt Beginning/end of meas. period or 20d, whichever comes first	±0.1 pH units. ±0.05 pH units ±0.3 pH units ±0.05 pH units.	APHA 4500-H+ Manufacturer specification SOP L1 Manufacturer specification	Return to manufacturer for replacement Invalidate data to last acceptable calibration, Return to manufacturer for repair or replacement
Performance evaluation	Beginning/end of meas. period or 20d, whichever comes first Daily	Accuracy ±0.3 pH units. Probe stability: ±0.05 pH units. Abrupt changes	SOP L1 Manufacturer specification	Data flagged; if at beginning of period, replace probe, if at end of period, invalidate data to last acceptable calibration check. Data flagged, check sensor
Accuracy	Every six months	±0.2 pH units.	SOP L1	Check for cleanliness Return to manufacturer for repair

Double junction Response time 95% of reading in 10s
Drift < 2 mV/week

Table A8. Measurement Quality Objectives- Parameter: Redox potential of lagoon/basin (Campbell Scientific, Inc. CSIM11-ORP sensor; Innovative Sensors, Inc).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	mV		Correction using lagoon/basin temperature measurement
Shelter temperature	daily	0° to +70°C		
Equipment -redox sensor	Purchase specification	-800 to +1100 mV	Manufacturer manual	
Completeness ½ h data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Transfer standard 230mV	Every 6 mos.	NIST traceability	Manufacturers specification SOP L3	
Calibration (standard solution-230mV)	On receipt	≥ |10 mV|	APHA 2580	Return to manufacturer
	Beginning/end of measurement period	≥ |30 mV|	SOP L3	Data flagged; if at beginning of meas. period replace sensor, if at end correct values throughout period
		≥ |50 mV|		Invalidate data to last acceptable calibration. Contact PM for replacement / return to manufacturer for repair
Performance evaluation (standard solution)	Beginning/end of measurement period	≥ |30 mV|	SOP L3	Data flagged; if at beginning of meas. period replace sensor, if at end correct values throughout period
		≥ |50 mV|		Data flagged, Replace sensor
	Daily	Abrupt changes		Data flagged, check sensor
Accuracy	Every six months	±0.1% of full range	SOP L3	Check for cleanliness Return to manufacturer for repair

Table A9. Measurement Quality Objectives- Parameter: Temperature of lagoon/basin (Thermistor).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Degrees C		
Shelter temperature	daily	-35° to +50°C		Sensor is exposed in ambient wastewater
Equipment -submersible thermistor	Purchase specification	-38 ^{o}C to 53 ^{o}C Accuracy ±0.9 ^{o}C.	Manufacturer manual	
Detection	Purchase specification	0.1 ^{o}C	Manufacturer manual	
Completeness 1/2h data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Local primary standard	Purchase specification	±0.01 ^{o}C	Manufacturer calibration certificate	NIST certified standard immersion thermometer
Calibration	On receipt Every 6 mos.	±0.5 ^{o}C ±0.5 ^{o}C	USEPA 454/R-99-005 Water bath SOP L2	Invalidate data to last acceptable calibration. Contact PM for replacement, replace sensor
Performance evaluation	Daily	>5 ^{o}C change from prior ½ h period	SOP L2	Data flagged
Precision		±0.2 ^{o}C	SOP L2	
Accuracy		±0.9 ^{o}C	SOP L2	

Table A10. Measurement Quality Objectives- Parameter: Lagoon solids depth (acoustic depth finder).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	m		
Shelter temperature	daily	-20 °C - +50°C	Manufacturer specification	
Equipment -submersible acoustic depth finder	Purchase specification	Accuracy: ±0.001 m	Manufacturer specification SOP L5	
Detection	Purchase specification	0.001 m- 0.01 m	Manufacturer specification	Dependent on resolution of length measure used.
Completeness	Each site visit	90%		
Calibration: Test solution	On receipt Annually	±0.001 m	Manufacturer specification SOP L5	Calibration in a water+resin solution with visual depth indication Contact PM for replacement Return to manufacturer for repair
Performance evaluation -Calibration check	Bi-annual	+/- 0.5% full scale	SOP L5	Data flagged Dependent on resolution of length measure used.
Precision		±0.01 m	SOP L5	Dependent on resolution of length measure used.
Accuracy		±0.2% full scale	SOP L5	Dependent on resolution of length measure used.

Table A11. Measurement Quality Objectives for the TDLAS measurement of NH_3 (Boreal Laser, Inc. GasFinder2®).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard units	All data	Ppm		
Shelter temperature	Daily	-40 - +50°C	Manufacturer specification	Maintain instrument case at above dew point temperature. Record temperature of case. Flag all measurements made when instrument case temperature is less than the dew point temperature
Equipment -open path tunable diode laser	Purchase spec.	Accuracy: +/-10%	Manufacturer specification	Current operational limits of open-path technology
Detection	Purchase spec.	NH_3: 5ppm-m	Manufacturer spec.	
Completeness 10 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	500 ppm NH_3 EPA Protocol Gas Mixture N_2	CFR 40 Pt 75 App. A Section 5.1.4 EPA-600/R-97/121.	
Calibration -single point -multipoint	On receipt Beginning/end of meas. period or 21 d, whichever is first. Every 6 mos.	10% NH_3	EPA/625/R-96/010b SOP C2	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement or repair
Performance evaluation -return beam intensity -background check -linearity	Daily Daily Daily	Signal strength Zero values $r^2>0.9$	EPA/625/R-96/010b SOP C2	Data flagged Clean windows or align Decommission and contact manufacturer for replacement or repair Decommission and contact manufacturer for replacement or repair
Precision -Direct assay of calibration gas	Beginning/end of meas. period or 20d, whichever is first	10%	EPA/625/R-96/010b Myers, et al. (2000) SOP C2	Contact PM or manufacturer for remediation and repeat calibration. If problem unresolved, decommission and contact manufacturer for replacement or repair
Accuracy -Direct assay of calibration gas	Beginning/end of meas. period or 20d, whichever is first	10%	EPA/625/R-96/010b Myers, et al. (2000) SOP C2	Contact PM or manufacturer for remediation and repeat calibration. . If problem unresolved, decommission and contact manufacturer for replacement or repair

Table A12. Measurement Quality Objectives for the UV-DOAS measurement of NH_3 (Cerex UVSentry®).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppb		
Shelter temperature	daily	-40 - +50°C	Manufacturer spec.	Maintain transmitter and receiver instrument cases at above dew point temperature.
Equipment -open path UV-DOAS	Purchase spec.	Accuracy: +/-10%	Manufacturer spec.	Current operational limits of open-path technology
Detection	Purchase spec.	500 ppb m	Manufacturer spec.	
Completeness 5 min data	10 d within quarter	75%		No remediation possible. Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Transfer standards		C_6H_6 and SO_2 in 'lollipop' H_2S, NH_3 cylinders	EPA/625/R-96/010b SOP C1	
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	50 ppm, 500 ppm NH_3 in N_2,(primary standard) 50 ppm, 500 ppm H_2S in N_2 (NIST certified EPA protocol gases	CFR 40 Pt 75 App. A Section 5.1.4 EPA-600/R-97/121.	
Calibration -single point with interference -Spectral feature match -multipoint with interference	On receipt Beginning/end of meas. period or 20d, whichever is first Every six months Every six months	Within 10% of NH_3 conc. (alone and with H_2S) Peaks of C_6H_6 and SO_2 in 'lollipop' 2 pixels or less, corr. Coeff>0.9. Within 10% of NH_3 conc. (alone and with H_2S)	EPA/625/R-96/010b SOP C1	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation -Baseline stability -Single beam ratio -Dark current correction	 Daily Daily Daily	Total drift at 270 nm < ±0.002 AU Signal at 210 nm > 205 signal at 250 nm +/-5 counts	EPA/625/R-96/010b SOP C1	Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of meas. period or 20d, whichever is first	10%	EPA/625/R-96/010b SOP C1	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay ,calibration gas	Beginning/end of meas. period or 20d	10%	EPA/625/R-96/010b SOP C1	Decommission and contact manufacturer for replacement and repair

Table A13. Measurement Quality Objectives for the UV-DOAS measurement of H_2S (Cerex UVSentry).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppb		
Shelter temperature	daily	-40 - +50^{o}C	Manufacturer spec.	Keep transmitter, receiver cases > dew point.
Equipment -open path UV-DOAS	Purchase spec.	Accuracy: ±10%	Manufacturer spec.	Current operational limits of open-path technology
Detection	Purchase spec.	2000 ppb-1m	Manufacturer spec., experimental result	
Completeness 5 min data	10 d within quarter	75%		No remediation possible. Sampling occurs for up to 21 d to assure 75% of 10 d in each quarter
Transfer standards		C_6H_6 and SO_2 in 'lollipop' H_2S , NH_3 cylinders	EPA/625/R-96/010b SOP C1	
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	50 ppm and 500 ppm NH_3 in N_2 (primary standard, 1% acc.), 50 ppm and 500 ppm H_2S in N_2: EPA protocol NIST-certified, 1% acc.	CFR 40 Pt 75 App. A Section 5.1.4 EPA-600/R-97/121.	
Calibration -single point with interference -Spectral feature match -multipoint with interference	On receipt Beginning/end of meas. period or 20d, whichever is first Every six months Every six months	Within 10% of H_2S conc. (alone and with NH_3) Shift in peaks of C_6H_6 and SO_2 in 'lollipop' ≤ 2 pixels, correlation coeff>0.9. Within 10% of H_2S conc. (alone and with NH_3)	EPA/625/R-96/010b SOP C1	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation -Baseline stability -Single beam ratio -Dark current correction	Daily Daily Daily	Total drift at 270 nm < ±0.002 AU Signal at 210 nm > 205 signal at 250 nm +/-5 counts	EPA/625/R-96/010b SOP C1	Data flagged Contact PM for remediation Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of meas. period or 20d, whichever is first	10%	EPA/625/R-96/010b SOP C1	Contact PM for remdiation, If unresolvable, decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of meas. period or 20d,	10%	EPA/625/R-96/010b SOP C1	Contact PM for remdiation, If unresolvable, decommission and contact manufacturer for replacement and repair

Table A14. Measurement Quality Objectives for the INNOVA 1412 measurement of NH_3.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppm	Manufacturer spec.	All data will be in engineering units
Shelter temperature	daily	-25 ˚C to 55˚C	Manufacturer spec.	Operating temperature: 5˚C -40 ˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±1%	Manufacturer spec.	
Detection	Purchase spec.	0.2 ppm	Manufacturer spec.	On 977 nm wavelength
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	100 ppm NH_3 in N_2, ±1% traceable to NMi standard N_2	NMi standard	
Calibration Single point- Multi Point-	On receipt Span gas calibration, beginning/end of every meas. period. After every 6 months	100 ppm NH_3 in N_2 100 ppm NH_3 in N_2 0.5, 1, 10 and 100ppm NH_3 in N_2	SOP G7	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source, sample filter, pump, measurement chamber, RS 232, chopper and filter wheel.	SOP G7	Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of every meas. period.	5% of the Full scale	SOP G7	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period.	±5%	SOP G7	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Table A15. Measurement Quality Objectives for the INNOVA 1412 measurement of MeOH.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Ppm		All data will be in engineering units
Shelter temperature	daily	-25 ˚C to 55˚C	Manufacturer spec.	Operating temperature: 5˚C -40 ˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±2%	Manufacturer spec.	
Detection	Purchase spec.	0.08 ppm	Manufacturer spec.	On 936 nm wavelength
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	1 ppm MeOH in N_2, ±2% accuracy. N_2		
Calibration Single point- Multi Point-	On receipt Span gas calibration Beginning/end of every meas. period After every 6 months	1ppm MeOH in N_2 1ppm MeOH in N_2 0.1, 0.5 and 1ppm MeOH in N_2	SOP G7	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source, sample filter, pump, measurement chamber, chopper and filter wheel.	SOP G7	Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of every meas. period	5% of the Full scale	SOP G7	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period	±5%	SOP G7	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Table A16. Measurement Quality Objectives for the INNOVA 1412 measurement of EtOH.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppm	Manufacturer spec.	All data will be in engineering units
Shelter temperature	daily	-25 ˚C to 55˚C	Manufacturer spec.	Operating temperature: 5˚C -40 ˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±2%	Manufacturer spec.	
Detection	Purchase spec.	0.06 ppm	Manufacturer spec.	On 974 nm wavelength
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	1 ppm EtOH in N_2, ±2% accuracy. N_2		
Calibration Single point- Multi Point-	On receipt Span gas calibration Beginning/end of every meas. period After every 6 months	1ppm EtOH in N_2 1ppm EtOH in N_2 0.1, 0.5 and 1ppm EtOH in N_2	SOP G7	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source, sample filter, pump, measurement chamber, chopper and filter wheel.	SOP G7	Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of every meas. period	5% of the Full scale	SOP G7	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period	±5%	SOP G7	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Table A17. Measurement Quality Objectives for the INNOVA 1412 measurement of THC (referenced to propane).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppm	Manufacturer spec.	All data will be in engineering units
Shelter temperature	daily	-25 ˚C to 55˚C	Manufacturer spec.	Operating temperature: 5˚C -40 ˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±1%	Manufacturer spec.	
Detection	Purchase spec.	0.02 ppm	Manufacturer spec.	On 987 nm wavelength
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	50 ppm propane in N_2, ±1% accuracy, traceable to NIST standard. N_2		
Calibration Single point- Multi Point-	On receipt Span gas calibration Beginning/end of every meas. period After every 6 months	50ppm propane in N_2 50ppm propane in N_2 0.1, 1, 10 and 50 ppm propane in N_2	SOP G7	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source, sample filter, pump, measurement chamber, chopper and filter wheel.	SOP G7	Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of every meas. period	1% of the Full scale	SOP G7	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period	±1%	SOP G7	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Table A18. Measurement Quality Objectives for the INNOVA 1412 measurement of methane.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppm	Manufacturer spec.	All data will be in engineering units
Shelter temperature	daily	-25 ˚C to 55˚C	Manufacturer spec.	Operating temperature: 5˚C -40 ˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±1%	Manufacturer spec.	
Detection	Purchase spec.	0.4 ppm	Manufacturer spec.	On 969 nm wavelength
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	10 ppm Methane in N_2, ±1% accuracy, traceable to NIST standard. N_2		
Calibration Single point- Multi Point-	On receipt Span gas calibration Beginning/end of every meas. period After every 6 months	10ppm Methane in N_2 10ppm Methane in N_2 0.5, 1, 10 ppm Methane in N_2	SOP G7	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source, sample filter, pump, measurement chamber, chopper and filter wheel.	SOP G7	Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of every meas. period	5% of the Full scale	SOP G7	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period	±5%	SOP G7	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Table A19. Measurement Quality Objectives- Parameters: 3D turbulence components (Model 81000 RM Young ultrasonic anemometer)

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	m/s		
Shelter temperature	daily	-50 - +50°C	Manufacturer spec.	Sensor is exposed to ambient weather conditions
Equipment -3D sonic anemometer	Purchase spec.	U,V,W =0.2 m/s	Manufacturer spec.	
Detection	Purchase spec.	W, V, W: 0.01 m/s	Manufacturer spec.	
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Calibration Intercomparison with two other used sensors Intercomparison with unused sensor	On receipt Beginning/end of meas. period or 20d, whichever comes first. Every 6 mos.	Deviation in value from mean of three sensors of 0.2 m/s	SOP W2	Return to manufacturer for repair or replacement
Performance evaluation 1) spikes 2) obstructions 3) stationarity 4) homogeneity 5) spectral turbulence structure	30 min 5 min 5 min 15 min daily	1) If spike <100 values/30 min, substitution with mean value 2) Internally flagged 3) invalidated if diff. betw. 5 min and 30 min values >30% 4) theoretical and derived values differ by >30%, data invalidate 5) Numerous tests	Foken and Wichura (1996) SOP W2	1)Data flagged as spiked 2) Data already flagged 3 and 4)Data flagged invalid 5)Data flagged suspect
Precision		0.05 m/s for 0 to 5 m/s, 1% of reading from 5 to 30 m/s, 3% of reading from 30 to 40 m/s.	Manufacturer spec.	This value is not measurable for turbulent flow. Value represents steady mean flow.
Accuracy		0.02 m/s	Manufacturer spec.	This value is not measurable for turbulent flow. Value represents steady mean flow.

Table A20. Measurement Quality Objectives- Parameters: Sonic Temperature (Model 81000 RM Young ultrasonic anemometer).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	^{o}C		
Shelter temperature	Daily	-50 - +50^{o}C	Manufacturer specification	Sensor is exposed to ambient weather conditions
Equipment -3D sonic anemometer	Purchase specification	±2^{o}C	Manufacturer specification	
Detection	Purchase specification	0.01^{o}C	Manufacturer specification	
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Calibration	On receipt Yearly	±2^{o}C ±2^{o}C	Intercomparison with air temperature, SOP W2	Return to manufacturer for repair
Performance evaluation -Path obstruction -Spikes -mean value	 30 min 15 min 15 min	Values < 5 standard deviations of the mean Value < 3 ^{o}C from hygrometer value	SOP W2	Data flagged
Precision			Manufacturer spec.	
Accuracy		±2^{o}C	Manufacturer specification	Sensor accuracy is low but not critical since deviations in temperature are of interest

Table A21. Measurement Quality Objectives for pH measurements of manure samples.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	pH units		Correction using sample temperature measurement.
Shelter temperature	Daily	0˚C to +100˚C	Manufacturer spec.	
Equipment	Purchase spec.	0 – 14 pH units, Accuracy = ±0.02%	Manufacturer spec.	
Detection	Purchase spec.	0.02 pH units	Manufacturer spec.	
Completeness	Per sample period or 90 d (corrals)	75%		
Transfer Standards: pH 4, 7 and 10	Purchase spec.		Manufacturer spec.	Replace
Calibration -(2 points)	Before and after each batch of samples	±0.05 pH units	SOP M2 USEPA 9040C, Rev. 3, November 2004.	Contact PM for replacement Return to manufacturer for repair or replacement.
Performance evaluation				If yes ,Correct measured pH values
-calibrations	Before and after each batch of samples	±0.05 pH units	SOP M2	If No, measure the pH of the sample
- time between collection and analysis	Each shipped sample	Duration of sample to analysis < 1 weeks	SOP M2	Verification by chain of custody document If exceeded, invalidate sample
- temperature of sample in shipping	Each shipped sample	Samples shipped at <4°C	SOP M2	If exceeded, invalidate sample
Precision				
Accuracy		±0.05 pH units	USEPA 9040C, Rev. 3, November 2004.	Check for cleanliness Return to manufacturer for repair

Table A22. Measurement Quality Objectives for determining total solids contents of manure samples.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	mg/L		
Shelter temperature	Daily	4 ˚C	USEPA Method 1684, Draft – January 2001	Refrigerate the sample at 4˚C up to the time of analysis to minimize microbiological decomposition. Make the sample at room temperature before analysis.
Detection Limits	Method Spec.	Approx. 3 mg/L,	USEPA Method 1684, Draft – January 2001	
Completeness	Per sample period or 90 d (corrals)	75%		
Calibration -analytical Balance		±10% (i.e. ±0.2 mg at 2 mg) and ±0,5% (i.e. ±5 mg at 1000 mg)	USEPA Method 1684, Draft – January 2001	If it does not match the acceptance criteria, recalibrate.
Performance evaluation -Initial Precision and Recovery (IPR) - Ongoing Precision and recovery (OPR)	Before and every ten samples	Compare the values with the corresponding limits for initial precision and recovery in the mentioned table	USEPA Method 1684, Draft – January 2001	If the values do not match with the mentioned tables, system performance is unacceptable, correct the problem and repeat the test.
- time between collection and analysis	Each shipped sample	Duration of sample to analysis < 1 weeks	SOP M3	Verification by chain of custody document If exceeded, invalidate sample
- temperature of sample in shipping	Each shipped sample	Samples shipped at <4°C	SOP M3	If exceeded, invalidate sample
Precision -KHP spike[1]		80-110% of KHP spike	USEPA Method 1684, Draft – January 2001	If the values do not match with the mentioned tables, system performance is unacceptable, correct the problem and repeat the test.
Accuracy		Unstated	USEPA Method 1684, Draft – January 2001	

1: KHP spike: NaCl-potassium hydrogen phthalate solution with 200 mg/l total solid, 81.0 mg/L volatile solids.

Table A23. **Measurement Quality Objectives for determining total Kjeldahl nitrogen (TKN) content of manure.**

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	mg N/gram (wet weight basis)	SOP M4	
Shelter temperature	daily	4 ˚C	USEPA Method 1687 Draft January 2001	Samples should be kept at 4 ˚C and should not be hold for more than 28 d.
Detection	Purchase spec.	Approx 0.05 mg/L	40 CFR part 136, SOP M4	The method has a working range of approximately 0.5 – 10 mg N/gram. Concentration value that corresponds to the instrument signal in range of 2.5 to 5
Completeness	Per sample period or 90 d (corrals)	75%		
Calibration Standards Nicotinic acid spikes	Purchase spec.		SOP M4	Five concentrations of nicotinic acid in 5g of blank sand with 250 mL NH_3-free water such that the organic nitrogen concentration of the precision and recovery is one to five times the MDL
Balance Calibration (2 mg and 1000 mg using class "S" weights)		±10% at 2 mg and ±0.5% at 1000mg	USEPA Method 1687 Draft January 2001	If values are not within these limits, recalibrate the balance.
Calibration verification standard solution	Once per every ten analysis	100% ±5%	SOP M4	If standard does not meet acceptance criteria, identify problem and correct, including possible recalibration of the system.
Performance evaluation - Initial Precision and Recovery (IPR)	Before and one sample in 10 analyzed)	check for residual chlorine	USEPA Method 1687 Draft January 2001	Samples should be checked for residual chlorine and treated with sodium thiosulfate, if necessary, during collection. Samples should be preserved with 2 mL Conc. H_2SO_4.
- Ongoing Precision and recovery (OPR)		90% - 110%		If OPR outside range, resolve. If % recovery or RPD of TKN in the MS samples falls outside designated range while the % recovery in the Precision and recovery sample is within acceptable range- problem is matrix-related.
- Matrix spikes (MS)		80% to 120% with Relative percentage difference (RPD) ≤ 20%		
Precision	Beginning of analysis	±10%, 0.2 mg N/liter	SOP M5, USEPA method # 350.2	Based on 24 analysts at 16 laboratories
Accuracy	Beginning of analysis	±0.02 mg N/ liter	USEPA method # 350.2	Based on 24 analysts at 16 laboratories

Table A24. Measurement Quality Objectives for determining ammonia content of manure.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	mg NH_3/gram (wet weight basis)	SOP M5	
Shelter temperature	daily	4 ˚C	USEPA method # 350.2	Samples should be kept at 4 ˚C with 2 mL of Conc. H_2SO_4, and should not be hold for more than 28 d.
Detection	Purchase spec.	Approx 0.05 mg/L	40 CFR part 136, SOP M5	The method has a working range of approximately 0.5 – 10 mg NH_3-N/L. Concentration value that corresponds to the instrument signal in range of 2.5 to 5
Completeness	Per sample period or 90 d (corrals)	75%		
Calibration Standards Ammonium chloride spikes Balance Calibration (2 mg and 1000 mg using class “S” weights)	Purchase spec.	±10% at 2 mg (i.e. ±0.2mg) and ±0.5% at 1000mg (i.e. ±5mg).	SOP M5	Five concentrations of ammonium chloride in 5g of blank sand with 250 mL NH_3-free water such that the ammonia concentration of the precision and recovery is one to five times the MDL If values are not within these limits, recalibrate the balance.
Calibration verification standard solution	Once per every ten analysis	100% ±10%	SOP M5	If standard does not meet acceptance criteria, the problem must be identified and corrected, including possible recalibration of the system.
Performance evaluation -If Aqueous Sample - Ongoing Precision and Recovery (OPR) - Matrix spikes (MS)	10% (one sample in 10 analyzed)	check for residual chlorine 90% - 110% 80% to 120% with Relative percentage difference (RPD) ≤ 20%	USEPA Method 1687 Draft January 2001 SOP M5 SOP M5	Samples should be checked for residual chlorine and treated with sodium thiosulfate, if necessary, during collection. Samples should be preserved with 2 mL Conc. H_2SO_4. If OPR outside range, resolve. If % recovery or RPD of TKN in the MS samples falls outside designated range while the % recovery in the Precision and recovery sample is within acceptable range- problem is matrix-related.
Precision	Beginning of every analysis	±10%, 0.2 mg N/liter	SOP M5 USEPA method # 350.2	Based on 24 analysts at 16 laboratories
Accuracy	Beginning of every analysis	±0.02 mg N/ liter	USEPA method # 350.2	Based on 24 analysts at 16 laboratories

Table A25. Measurement Quality Objectives for the TEC 450i measurement of H_2S.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Ppb	Manufacturer spec.	All data will be in engineering units
Shelter temperature	daily	0 ˚C to 45˚C	Manufacturer spec.	Operating temperature: 15˚C -35˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±1%	Manufacturer spec.	
Detection	Purchase spec.	2.0 ppb	Manufacturer spec.	
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	4 ppm H_2S in N_2, ±2% traceable to NIST CEM Zero gas- air	NIST standard	
Calibration Single point- Multi Point-	Span gas calibration, beginning/end of every meas. period. On receipt After every 6 months	0.5 ppm H_2S in N_2 or air 0, 0.5, 1, 2 and 3 ppm H_2S in N_2 or air	EQSA-0486-060 EMTIC TM-006C SOP G5	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source lamp, sample flow and pressure, instrument temperatures, RS 232.	EQSA-0486-060 EMTIC TM-006C SOP G5	Data flagged Contact PM for remediation
Precision -Direct assay of zero gas	Beginning/end of every meas. period.	5% of full scale	EQSA-0486-060 EMTIC TM-006C SOP G5	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period.	±10%	EQSA-0486-060 EMTIC TM-006C SOP G5	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Appendix B
Standard Operating Procedures

Table B1. List of NAEMS Open-source SOPs.

Code	Title
C1	Open-Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UV Sentry Ultraviolet Differential Optical Absorption Spectrometer
C2	Measurement of Ammonia with the Boreal Laser GasFinder Tunable Diode Laser Absorption Spectrometer (TDLAS)
C3	Operation of the Thermo Electron Model 146C Multi-gas Diluter
C4	Synthetic Open Path Sampling System
D1	Management of Open-source, Weather, and Lagoon-characterization Data
E3	The Measurement of Solar Radiation with the Licor Model 200SL or 200SZ Silicon Pyranometer
G2	Compressed Gas Cylinders
G5	Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450I Pulsed Fluorescence Analyzer
G7	Use of the INNOVA 1412 Photoacoustic Multi-Gas Monitor
G11	Operation of the Environics® Computerized Gas Dilution System
G12	FTIR Verification of Gas Cylinder Concentration
L1	Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor
L2	Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor
L3	Measurement of Lagoon Redox State with the Campbell Scientific CSIM11 ORP Sensor
L5	Measurement of Lagoon Sludge Depth with Markland Model 10 Portable Sludge Gun
M1	Manure Sampling
M2	Conducting pH Measurements on Manure Samples
M3	Determining Solids Content of Manure Samples
M4	Determining Total (Kjeldahl) Nitrogen Content of Manure Samples
M5	Determining Ammonia Content of Manure Samples
O1	Emissions Estimation Using the Thunder Beach Scientific Windtrax Backward Lagrangian Stochastic Model
O2	Emissions Estimation Using the ARCADIS Radial Plume Mapping Model
Q1	Use of Control Charts for Performance Monitoring of Gas Analyzers and Analytical Instruments
S7	Producer Collaborations at Open-source Monitoring Sites
U4	Open-source Instrument Trailer
U5	The Installation of Open-source Measurement Equipment for Lagoon Sites
U6	The Powerware 9125 Uninterruptible Power Supply
U7	The Instrument Trailer and Installation of Open-Source Measurement Equipment (Corrals)

W1	Measurement of Atmospheric Temperature and Humidity with the Vaisala Model HMP45C Sensor and Solar Shield
W2	Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer
W3	Measurement of Wetness with the Campbell Scientific Model Resistance Grid
W5	The Measurement of Barometric Pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer
W6	Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware

Appendix C
Site Monitoring Plans

Table C1. List of NAEMS Site Monitoring Plans.

Farm No. (Table 6.3)	Location Code	Location Classification
1	NC4A	Southeast Swine Sow Lagoon
2	NC3A	Southeast Swine Finisher
3	IA3A	Midwest Finisher Basin
4	IN5A	East Dairy Lagoon
5	OK3A	West Swine Finisher Lagoon
6	OK4A	West Swine Sow Lagoon
7	WA5A	Northwest Dairy Basin
8	WI5A	Midwest Dairy Lagoon
9	IN4A	Midwest Swine Sow Lagoon
10	TX5A	West Dairy Corral

Appendix D
Forms

Perishable Consumables Tracking Form

Material	**Use**	**Shelf Life (months)**	**Manufacture date**	**Dispose-of date**	**Container labeled date**	**FOS responsible**
4.01 pH buffer (potassium biphthalate)	pH sensor calibration	6				
7.00 pH buffer (potassium phosphate)	pH sensor calibration	6				
10.00 pH buffer (sodium borate/sodium carbonate)	pH sensor calibration	6				
Potassium biphthalate (KHP)	pH sensor calibration	36				
Thymol ($C_{10}H_{13}OH$)	pH sensor calibration	24				
1M KCl solution or reagent grade KCl	Redox sensor calibration	6				
ZoBell’s Solution Redox Standard	Redox sensor calibration	6				
A Gas cylinder: Pure N_2 (or equivalent)	UV-DOAS, TDLAS, PAS sensor calibration	36+				
A58L Disposable gas cylinder: 50 ppm H_2S (1% accuracy traceable to NIST), balance N_2 (or equivalent)	UV-DOAS sensor calibration	6				
A58L Disposable gas cylinder: 50 ppm NH_3 (1% accuracy traceable to NMi), balance N_2 (or equivalent)	UV-DOAS, TDLAS sensor calibration	6				
CL Gas cylinder: 50 ppm Propane (1% accuracy traceable to NIST), balance N_2 (or equivalent)	PAS sensor calibration	*36*				
CL Gas cylinder: 10 ppm Methane (1% accuracy traceable to NIST), balance N_2 (or equivalent)	PAS sensor calibration	36				
CL Gas cylinder: 1 ppm EtOH (2% accuracy traceable to NIST), balance N_2 (or equivalent)	PAS sensor calibration	12				

CL Gas cylinder: 1 ppm HAc (2% accuracy traceable to NIST), balance N_2 (or equivalent)	PAS sensor calibration	12				
CL Gas cylinder: 500 ppm H_2S in N_2 (or equivalent)	UV-DOAS sensor calibration	12				
CL Gas cylinder: 500 ppm NH_3 in N_2 (or equivalent)	UV-DOAS, TDLAS sensor calibration	12				
CL Gas cylinder: 50 ppm NH_3 (1% accuracy traceable to NMi), balance N_2 (or equivalent)	PAS sensor calibration	12				
Lithium chloride salt	Humidity sensor calibration	6				
Potassium sulfate salt	Humidity sensor calibration	6				

Maintenance List for NAEMS Open Source Measurements

Location: _____________ Date:________________

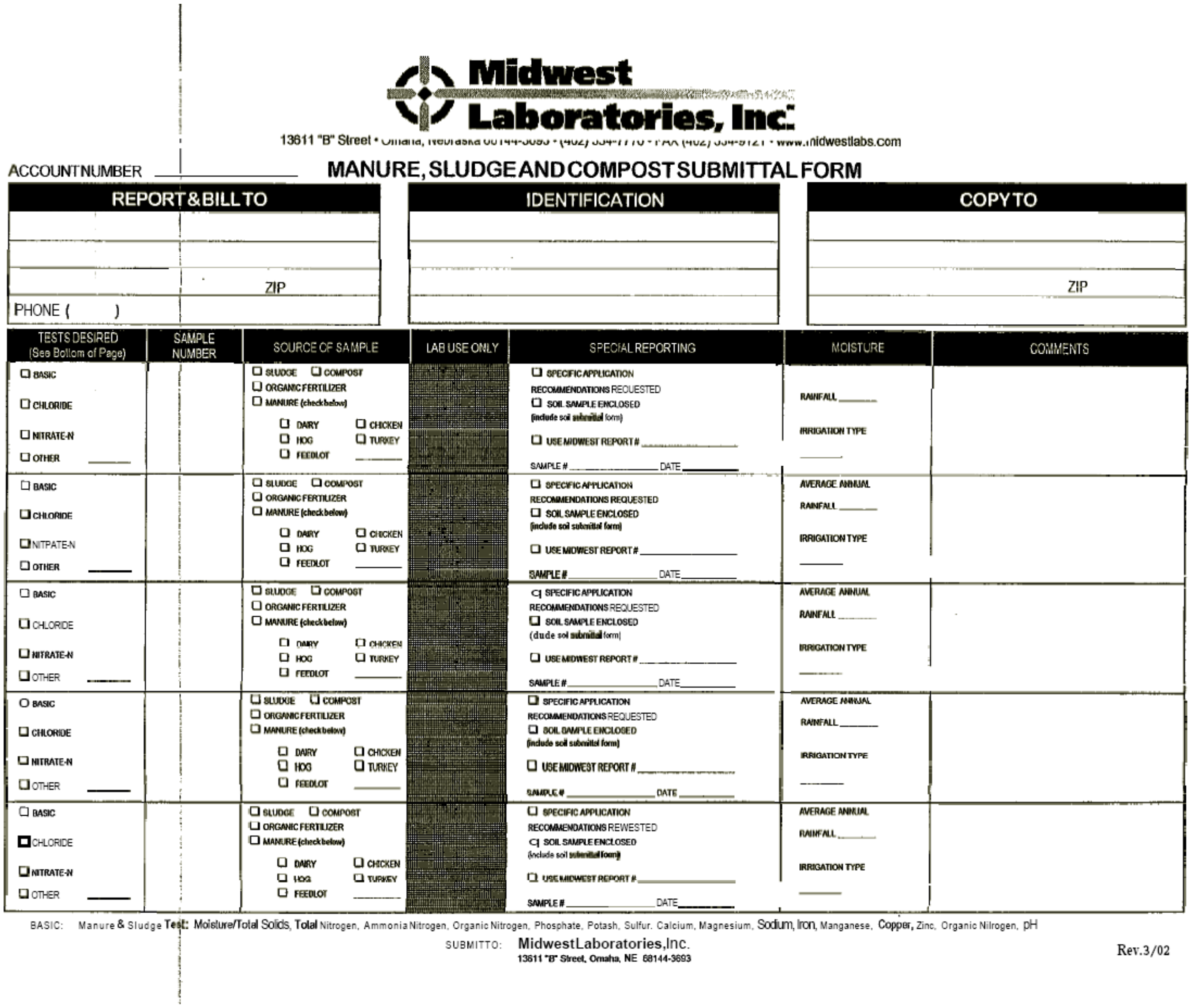
	Interval (d)	Notes[1]
Check integrity of trailer antenna cable feed-through	Start of period	
Check cable connections at antennae	Start of period	
Check cable connections at computers	Start of period	
Check cable connections at GSS/CR580 datalogger /computer	Start of period	
Check cable connections at TEC 450i/switch/computer	Start of period	
Check cable connections at TEC 146i/computer	Start of period	
Check trailer power feed cable connections	Start of period	
Check trailer ground rod connections	Start of period	
Check UPS, GFCI trips	Start of period	
Check ground rod connection at weather station	Start of period	
Check ground rods at towers	Start of period	
Check power connection at 15-m tower retroreflectors, GFCI OK on outlets	Start of period	
Check power connection at 7-m tower retroreflectors, GFCI OK on outlets	Start of period	
Check power connection at 2-m tower retroreflectors, GFCI OK on outlets	Start of period	
Check power connection at 2-m ground retroreflectors, GFCI OK on outlets	Start of period	
Check ground rods at towers	Start of period	
Replace dessicant in NEMA box	Start of period	
Lagoon cable floats: intact and spaced correctly?	Start of period	
Flag cable path for lagoon sensors	Start of period	
Flag tubing path for S-OPS extension tubing	Start of period	
Check power cable connections at TDLAS modem/power units	Start of period	
Check sonic cable integrity and connector connections	Start of period	
Check sonic power unit connections	Start of period	

Check under road tubing path for integrity and uncrushed tubing	Start /End of period	
Check integrity of calibration cylinder/analyzer/diluter/chamber tubing	Start /End of period	
Check tubing connections of calibration cylinders/diluter/analyzers/chamber	Start /End of period	
Check cable integrity of all meteorological sensors	Start /End of period	
Check cable integrity of lagoon sensors	Start/End of period	
Check connections in NEMA box to datalogger	Start /End of period	
Check signal cable connections at TDLAS units (rubber seal present)	Start/End of period	
Check cable connections from scanner units (weather-tight seal at connectors)	Start/End of period	
All towers, tripods, & mast look vertical?	Start/End of period	
All towers, tripods, & mast intact?	Start/End of period	
Sonic anemometers mounted & oriented correctly?	Start/End of period	
Check tower: bolts all present & tight?	End of period	
All tools & equipment put away?	End of period	
S-OPS and S-OPS extension tubing intact?	End of period	
Clean/Check Retro-reflector windows	End of period	
Check integrity of NEMA box	End of period	
Clean sonic heads	As needed	
Replace inlet filters (inlet flow test check)	As needed	
Check/Replace gas sampling filters	As needed	
Check/Clean pyranometer	As needed	
Check/Clean T/RH shield	As needed	
Check/Clean wetness grid	As needed	
Replace pH probe reference sol	6 mos	
Replace pH probe QCCS sol	3 mos	
Replace redox probe reference sol (if needed)	6 mos	
Replace redox probe ZoBell’s sol	3 mos	
Replace redox probe 0.1M KCl sol	3 mos	

1: If additional space needed, use back of page, then attach additional pages.

Name(FOS): ____

Example Chain of Custody Form



Midwest Laboratories, Inc.

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ACCOUNT NUMBER ____________

MANURE, SLUDGE AND COMPOST SUBMITTAL FORM

REPORT & BILL TO	IDENTIFICATION	COPY TO
ZIP		ZIP
PHONE ( )		

TESTS DESIRED (See Bottom of Page)	SAMPLE NUMBER	SOURCE OF SAMPLE	LAB USE ONLY	SPECIAL REPORTING	MOISTURE	COMMENTS
☐ BASIC ☐ CHLORIDE ☐ NITRATE-N ☐ OTHER ______		☐ SLUDGE ☐ COMPOST ☐ ORGANIC FERTILIZER ☐ MANURE (check below) ☐ DAIRY ☐ CHICKEN ☐ HOG ☐ TURKEY ☐ FEEDLOT ______		☐ SPECIFIC APPLICATION RECOMMENDATIONS REQUESTED ☐ SOIL SAMPLE ENCLOSED (include soil submittal form) ☐ USE MIDWEST REPORT # ______ SAMPLE # ______ DATE ______	RAINFALL ______ IRRIGATION TYPE ______	
☐ BASIC ☐ CHLORIDE ☐ NITRATE-N ☐ OTHER ______		☐ SLUDGE ☐ COMPOST ☐ ORGANIC FERTILIZER ☐ MANURE (check below) ☐ DAIRY ☐ CHICKEN ☐ HOG ☐ TURKEY ☐ FEEDLOT ______		☐ SPECIFIC APPLICATION RECOMMENDATIONS REQUESTED ☐ SOIL SAMPLE ENCLOSED (include soil submittal form) ☐ USE MIDWEST REPORT # ______ SAMPLE # ______ DATE ______	AVERAGE ANNUAL RAINFALL ______ IRRIGATION TYPE ______	
☐ BASIC ☐ CHLORIDE ☐ NITRATE-N ☐ OTHER ______		☐ SLUDGE ☐ COMPOST ☐ ORGANIC FERTILIZER ☐ MANURE (check below) ☐ DAIRY ☐ CHICKEN ☐ HOG ☐ TURKEY ☐ FEEDLOT ______		☐ SPECIFIC APPLICATION RECOMMENDATIONS REQUESTED ☐ SOIL SAMPLE ENCLOSED (include soil submittal form) ☐ USE MIDWEST REPORT # ______ SAMPLE # ______ DATE ______	AVERAGE ANNUAL RAINFALL ______ IRRIGATION TYPE ______	
○ BASIC ☐ CHLORIDE ☐ NITRATE-N ☐ OTHER ______		☐ SLUDGE ☐ COMPOST ☐ ORGANIC FERTILIZER ☐ MANURE (check below) ☐ DAIRY ☐ CHICKEN ☐ HOG ☐ TURKEY ☐ FEEDLOT ______		☐ SPECIFIC APPLICATION RECOMMENDATIONS REQUESTED ☐ SOIL SAMPLE ENCLOSED (include soil submittal form) ☐ USE MIDWEST REPORT # ______ SAMPLE # ______ DATE ______	AVERAGE ANNUAL RAINFALL ______ IRRIGATION TYPE ______	
☐ BASIC ☐ CHLORIDE ☐ NITRATE-N ☐ OTHER ______		☐ SLUDGE ☐ COMPOST ☐ ORGANIC FERTILIZER ☐ MANURE (check below) ☐ DAIRY ☐ CHICKEN ☐ HOG ☐ TURKEY ☐ FEEDLOT ______		☐ SPECIFIC APPLICATION RECOMMENDATIONS REQUESTED ☐ SOIL SAMPLE ENCLOSED (include soil submittal form) ☐ USE MIDWEST REPORT # ______ SAMPLE # ______ DATE ______	AVERAGE ANNUAL RAINFALL ______ IRRIGATION TYPE ______	

BASIC: Manure & Sludge Test: Moisture/Total Solids, Total Nitrogen, Ammonia Nitrogen, Organic Nitrogen, Phosphate, Potash, Sulfur, Calcium, Magnesium, Sodium, Iron, Manganese, Copper, Zinc, Organic Nitrogen, pH

SUBMIT TO: Midwest Laboratories, Inc.
13611 "B" Street, Omaha, NE 68144-3693

Rev.3/02

NAEMS Site Audit Form: Open sources

Site: Auditor(s):
Date:
Researchers present during visit:

<u>Characteristics of producer collaboration and cooperation</u>:
Is producer providing the following data?
Animal inventory and weight Yes _____ No ______
Animal diet? Yes _____ No ______
Record of production (e.g. wt of marketed animals, milk) Yes _____ No ______
Record of sludge removals Yes _____ No ______
Record of pump outs Yes _____ No ______
Record of water consumption Yes _____ No ______
Occurrence of special activities, e.g., generator tests, building cleaning, power failures, etc.? Yes _____ No ______

Installed equipment:

Instrument	Serial number	Instrument	Serial number
TDLAS-1		Solar Radiation	
TDLAS-2		T/RH probe	
PAS		2 m Sonic	
CR1000 Data logger		4 m Sonic	
Barometer		16 m Sonic	
Wetness sensor		Lagoon temp.(1)	
CR800 Data logger		Lagoon pH (1)	
GSS Mass flow controller		Lagoon redox (1)	
GSS temperature		Lagoon temp. (2)	
GSS flow direction		Lagoon pH (2)	
CR Relay driver		Lagoon redox (2)	
NH_3 regulator		H_2S regulator	
Zero air regulator		Organics regulator	

Gas cylinders:

	Cylinder number	Date of expiration	Remaining Pressure
Zero Air			
Nom. 500 ppb NH_3			
Nom. 1 ppm MeOH, 1 ppm EtOH			
Nom. propane_____, methane ________			
Nom. 4 ppm H_2S			

Data Management

Is manual entry log book being maintained? Permanent ink?

Are electronic field notes being maintained?

All files under one folder in the LAN Server PC?

Automatic data and files backup system functioning?

Computer	**Last external backup**	**Errors in backup?**
LAN server		
TDLAS-1		
TDLAS-2		

Are the second set of data from prior measurement period stored in fireproof box or stored away from instrument shelter (e.g. on campus)?

Instrument Trailer

Cleanliness and orderliness:

SOPs up to date and available? Yes _____ No _______

Trailer environmental control: Temp. ________, RH ___________
Security:

Electrical power protection:

Gas Sampling System:

Gas sampling inlet clean and oriented correctly?
Date of last leak test:
Visual appearance:
Mass flow sensor:
Flow rate (minimum = 3.6 L/min) = ________ L/min
Has response time been tested? Yes _____ No ______

Towers and tripods:

Tall towers secure and stable?

Retro tripods secure and stable?

Meteorology mast secure and stable?

Layout Inspection:

Check location of sensors match SMP and site setup records:

Vulnerability of sampling lines to mechanical damage:

Vulnerability of power lines to mechanical damage:

Equipment protection (from animals, workers):

Maintenance:

	Frequency	Most recent	Notes
Replace dessicant in NEMA box	Each period		
Clean sonic heads	As needed		
Replace gas sampling filters	As needed		
Clean Pyranometer	As needed		
Clean T/RH shield	As needed		
Clean wetness grid	Each period		
Clean Retroreflector windows	As needed		
Clean TDLAS windows	As needed		
Check tubing and connections	Each period		
Clean pH probe	Each period		
Clean redox probe	Each period		
Check integrity of NEMA box	Each period		
Check integrity of trailer antenna cables feed-through	Each period		
Check cable connections at CR1000 datalogger	Each period		
Check cable connections at CR800 datalogger			
Check cable connections at computers	Each period		
Check cable connections at antennae	Each period		
Check RF antennae	Each period		
Check UPS connections at TDLAS/scanner units	Each period		

Inspect cables and cable connectors for damage

	Power	Signal	Notes
TDLAS<>scanner			
Scanner<>power/ modem box			
TDLAS/scanner computer			
TDLAS/scanner modems inside			
CR1000		▨	
CR1000 modem inside			
CR1000 modem outside			
Sonic modems inside			
Sonic modems outside			
Pyranometer	▨		
T/RH	▨		
wetness grid	▨		
Retroreflectors		▨	
TEC 450i			
Innova 1412			
Lagoon pH probe	▨		
Lagoon redox probe	▨		
Lagoon temp.	▨		
2 m sonic	▨		
4 m sonic	▨		
16 m sonic	▨		
LAN computer			
Internet connection			
Trailer power		▨	
CR800			
GSS Pressure sensor			
GSS T/RH			
GSS MFC			
GSS flow direction			

Communications

Instrument	Serial/Ethernet communications OK?	Notes
Powerware UPS		
Power switch		
Internet modem		
Innova 1412		
TEC450i		
TDLAS-1		
TDLAS-2		
CR1000 Datalogger		
2 m Sonic		
4 m Sonic		
16 m Sonic		
CR800 Datalogger		

Calibration Verification Records:

Are all cal. gas cylinders valid (not expired?) Yes _____ No _______
Regulators operational? Yes _____ No _______

Instrument	Last calibration verification date		Results of most recent verification	Notes
	QAPP	Actual		
TEC450i H_2S	Period start/end			
TDLAS-1 NH_3	Period start/end			
TDLAS-2 NH_3	Period start/end			
PAS NH_3	Period start/end			
PAS Methane	Period start/end			
PAS MeOH	Period start/end			
PAS EtOH	Period start/end			
PAS THC	Period start/end			
Lagoon redox	Period start/end			
Lagoon pH	Period start/end			
Lagoon temp	Period start/end			

Instrument	Last calibration verification date		Results of most recent verification	Notes
	QAPP	Actual		
Solar radiation	Period start/end			
RH	6 mos.			
Temperature	6 mos.			
Barometer	Period start/end			
Wetness	Period start/end			
2 m sonic	Period start/end			
4 m sonic	Period start/end			
16 m sonic	Period start/end			
Mass flow meter				

Control charts available for gas analyzers?

TDLAS-1 Yes _____ No _______
TDLAS-1 Yes _____ No _______
Innova 1412 Yes _____ No _______
TEC 450i Yes _____ No _______

Calibration verification records available in shelter?

TDLAS-1 Yes _____ No _______
TDLAS-1 Yes _____ No _______
Innova 1412 Yes _____ No _______
TEC 450i Yes _____ No _______
Sonic -1 Yes _____ No _______
Sonic -2 Yes _____ No _______
Sonic -3 Yes _____ No _______
pH probe-1 Yes _____ No _______
redox probe-1 Yes _____ No _______
pH probe-2 Yes _____ No _______
redox probe-2 Yes _____ No _______

NAEMS Audit Finding Form: Open sources

Site Audited: ____

Audit Date: ____

Audit Title: ______________________Audit #:_______________Finding #_________

Finding:

Discussion:

QA Lead Signature:____________________ Date: ______________________

Audited site

Signature: ___________________________ Date: ______________________

NAEMS Audit Finding Response Form: Open Sources

Site Audited: ____

Audit Date : _________________________________

Audit Title: ______________________Audit #:_______________Finding #_________

Finding:

Cause of the Problem:

Actions taken or planned for correction:

Responsibilities and timetable for the above actions:

Prepared by:__________________________ Date: ______________________

Signed by: ___________________________ Date: ______________________

QA officer

Reviewed by: ________________________________ Date________________

Remarks:

Is this audit finding closed?_________________when?____________________________

File with QA coordinator. Sent copy to auditee.

Document(s) Deviation Report Form

Date: Author:

Deviation in (SOP / QAPP / SMP)?

Description of Deviation:

Resolution:

Accept deviation, minor, do not modify document	Accept deviation, major, modify document
Reject deviation, invalidate results	Reject deviation, modify document

If document modification, Document(s) modified : ____________________________

Date of modification(s) : ___________________________

Initials: PQAM: __________, QAM: __________, PM: __________, SA: __________

EPA Approval: _______________________________Date: __________________

SOP C1

UV-DOAS Calibration Sheet

UV-DOAS Serial Number ___________________

		Certified Gases		**Measured Analyte**				
Date	**Time**	**Analyte: Gases present**	**Conc.**	**Mean**	**SD**[1]	**Accuracy**[2]	**RSD**	**Operator**
mm/dd/yy	**hh:mm**		**ppm-m**	**ppm-m**	**ppm-m**	%	%	
		NH_3						
		H_2S						
		NH_3: NH_3+H_2S						
		H_2S: NH_3+H_2S						

[1] Standard deviation

[2] Accuracy = 100% * (Measured concentration – Certified concentration) / (Certified concentration)

SOP C1

UV-DOAS QA Sheet

UV-DOAS Serial Number ___________________

Date	**Time**	**Dark current correction check**	**±5 counts?**	**Spectral feature match**	**<2 pixels?**	**R**[1]	**>0.90?**	**Baseline stability drift at 270 nm**	**<+/- 0.002AU?**	**Beam energy at 250 nm**	**Beam energy at 210 nm**	**210 nm energy /250 nm energy**	**<20%?**	**Operator**
mm/dd/yy	**hh:mm**	**# counts**	Y/N	**pixels**	Y/N			AU						

1: R is correlation coefficient

If <u>No</u> is answer any of the above questions, Remediation is needed.

SOP C2

TDLAS Single Point Calibration Verification Log

Trailer: (EAST/WEST/FIXED)
Site: _______________

TDLAS Serial number _____________ Operator________________________
Date (MM/DD/YYYY):______________________
Calibration verification filename ():________________________

Calibration cylinder# (_____________) concentration: _____________ppm
Diluted chamber calibration gas concentration: _______________ppm

Trail[1]	TEST	Valid measurement times[2]		TDLAS mean measurement			
		Start	End	Mean	SD	RSD	Bias
	Background						
1	Calibration gas						
	Background						
2	Calibration gas						
	Background						
3	Calibration gas						
	Background						
4	Calibration gas						
	Background						

1: Only one good trial is needed (comments needed if more that one is conducted)
2: Valid measurement times represent the time after 10 min of flow.

Comments:

SOP C4 Appendix B NAEMS open GSS Acceptance Form

GSS S/N ____________________

Date: _______________________

Operator: ____________________

	Solenoid 2	**Solenoid 3**	**Solenoid 5**	**Solenoid 7**
Sample flow test				
Outlet Mass Flow (L/min)				
Pressure (kPa)				
Pass/Fail				
GSS Leak test				
Mass Flow (L/min)				
Corrected Mass flow (L/min)				
Pressure (kPa)				
Corrected Pressure (kPa)				
Pass/Fail				
No flow test				
Mass Flow (L/min)				
Pressure (kPa)				
Max flow test				
Outlet Mass Flow (L/min)				
Pressure (kPa)				

Comments:

SOP C4 Appendix C

NAEMS open S-OPS Acceptance Form

Date: _____/____/_____ GSS S/N _________________

Location: ____________________ FOS: ____________________

	Solenoid 2	Solenoid 3	Solenoid 5	Solenoid 7
Max flow test				
Inlet Mass Flow (L/min)				
Outlet Mass Flow (L/min)				
Pressure (kPa)				
Pass/Fail				
S-OPS/ GSS Leak test				
Mass Flow (L/min)				
Corrected Mass flow (L/min)				
Pressure (kPa)				
Corrected Pressure (kPa)				
Pass/Fail				
S-OPS S/N				

Comments:

SOP C4 Appendix D

Synthetic Open-Path System Inlet Flow Verification Form

S-OPS S/N ____________________ Date: ______/______/______

FOS: ________________________

Inlet	**S-OPS inlet flow rate** **(L/min)**	**Deviation**[1]	**Action** **(clean, replace..)**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Mean			

1: Deviation= (Inlet flow-Mean flow)/Mean flow

SOP C4 Appendix E

S-OPS/ GSS Bag Test (System Adsorption)

S-OPS: ________________ Date: ____/_______/________

GSS S/N: ______________ FOS: ___________________

Gas: H2S Analyzer: TFS 450i s/n:						
			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

Gas: Methane Analyzer: Innova 1412 s/n:						
			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

SOP C4 S-OPS/ GSS Bag Test (System Adsorption) (Continued)

S-OPS: __________________ Date: _____/______/________

GSS S/N: ________________ FOS: ____________________

Gas: Methanol Analyzer: Innova 1412 s/n:

			Diluter/Cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

Gas: Ethanol Analyzer: Innova 1412 s/n:

			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

SOP C4 S-OPS/ GSS Bag Test (System Absorption) (Continued)

S-OPS: __________________ Date: _____/______/________

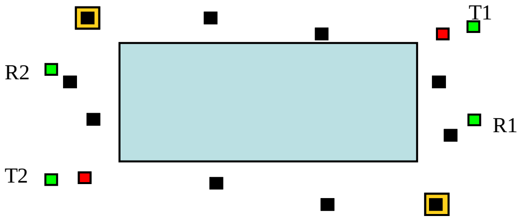
GSS S/N: ________________ FOS: ____________________

Gas: Propane		**Analyzer: Innova 1412 s/n:**				
			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

Gas: Ammonia		**Analyzer: Innova 1412 s/n:**				
			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

SOP C4 Appendix F

Lagoon/Basin Site Open-path Sensor Installation Report



Location: _______________________

Date: ______/______/_______

FOS: _________________________________

NEAR S-OPS extension tubing

S-OPS Path #1 start location (T1) ______Deg (N) ______._____Min Lat.

______Deg (N) ______._____Min Long.

S-OPS Path #1 end location (R1) ______Deg (N) ______._____Min Lat.

______Deg (N) ______._____Min Long.

Distance between Path #1 outlet tube and GSS manifold (extension tubing): _______ m

Height of path#2 above lagoon berm : ________________________ m

---

FAR S-OPS extension tubing

S-OPS Path #2 start location (T2) ______Deg (N) ______._____Min Lat.

______Deg (N) ______._____Min Long.

S-OPS Path #2 end location (R2) ______Deg (N) ______._____Min Lat.

______Deg (N) ______._____Min Long.

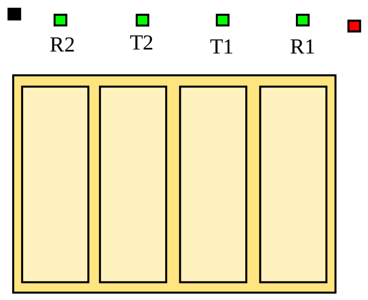
Distance between Path #2 outlet tube and GSS manifold (extension tubing): _______ m

Height of path #2 above lagoon berm : ________________________ m

---

Notes:

Corral Site Open-path Sensor Installation Report



Location: ________________________

Date: ______/______/_______

FOS: ___________________________________

NEAR S-OPS extension tubing

S-OPS Path #1 start location (T1) ______Deg (N) ______._____Min Lat.

______Deg (N) ______._____Min Long.

S-OPS Path #1 end location (R1) ______Deg (N) ______._____Min Lat.

______Deg (N) ______._____Min Long.

Distance between Path #1 outlet tube and GSS manifold (extension tubing): _______ m

Height of path#2 above lagoon berm : ________________________ m

---

FAR S-OPS extension tubing

S-OPS Path #2 start location (T2) ______Deg (N) ______._____Min Lat.

______Deg (N) ______._____Min Long.

S-OPS Path #2 end location (R2) ______Deg (N) ______._____Min Lat.

______Deg (N) ______._____Min Long.

Distance between Path #2 outlet tube and GSS manifold (extension tubing):________ m

Height of path #2 above lagoon berm: ________________________ m

---

Notes:

Appendix F **Flow Direction Sensor Calibration**

GSS S/N ____________________

Date: _______________________

Operator: ____________________

	Solenoid 2	**Solenoid 3**	**Solenoid 5**	**Solenoid 7**
Flow	▨	▨	▨	▨
Sample flow rate (L/min)				
Reverse Flow rate (L/min				
Δ Flow (L/min)				
Sensor Response	▨	▨	▨	▨
Sample flow				
Reverse Flow				
Δ response				
Pass/Fail				

SOP D1
Electronic Data Chain of Custody form

Location of measurements: _________________________

Period represented: From Date (MM/DD /YYYY) _________ time (GMT: 24h clock) _____: _____

To Date (MM/DD/YYYY) _________ time (GMT: 24h clock) _____: _____

Data preparation/ copying done by: _____________________________________

<u>Calibration conducted during period</u>

TDLAS1: s/n ________	Date (MM/DD/YYYY) _________	time (GMT: 24h clock) _____: _____
	Date (MM/DD/YYYY) _________	time (GMT: 24h clock) _____: _____
TDLAS2: s/n ________	Date (MM/DD/YYYY) _________	time (GMT: 24h clock) _____: _____
	Date (MM/DD/YYYY) _________	time (GMT: 24h clock) _____: _____
TEC 450i: s/n ________	Date (MM/DD/YYYY) _________	time (GMT: 24h clock) _____: _____
	Date (MM/DD/YYYY) _________	time (GMT: 24h clock) _____: _____
Innova 1412: s/n ______	Date (MM/DD/YYYY) _________	time (GMT: 24h clock) _____: _____
	Date (MM/DD/YYYY) _________	time (GMT: 24h clock) _____: _____

Notes:

Data Receipt

Received: Date (MM/DD/YYYY) _____________________ time (GMT: 24h clock) _____: _____

Physical condition of TDLAS1/TDLAS2/WXL/H2S/GSS data CD	(Excellent / Good / Fair / Poor)
Physical condition of WXL flash memory chip	(Excellent / Good / Fair / Poor)
Physical condition of 16Hz sonic data DVD	(Excellent / Good / Fair / Poor)
Physical condition of Backup DVD (excl 16Hz data)	(Excellent / Good / Fair / Poor)
Physical condition of memory stick	(Excellent / Good / Fair / Poor)

Received by: _____________________________________

SOP G2 and G11: Gas Cylinder Labels

Gas ______________________________
Concentration _____________________
Initial Pressure _________________psi
CGA No. ________________________
Cylinder No. ______________________
Date Received ____________________
Expiration Date ___________________
Date:___________Pressure:________psi
Date:___________Pressure:________psi
Date:___________Pressure:________psi
Date:___________Pressure:________psi
Date:___________Pressure:________psi

Return To: General Stores

From: Rich Grant
Department of Agronomy
215 LSPS

Date:

Return label for gas cylinders:

Calibration date:__________________
Next calibration due date:__________
Calibrated by:_____________________

Sample calibration label.

SOP L1

Inspection and Maintenance Log
INNOVATIVE SENSORS MODEL CSIM11 pH SENSOR

Serial Number _____________

Date (DMY)	Condition		Action taken	Calibration done?	Acceptance done?	Person assessing
	Glass electrode	Cable				

SOP L1

Acceptance Log

INNOVATIVE SENSORS MODEL CSIM11 pH SENSOR

Serial Number _____________

Date (DMY)	Condition		T (ºC)	QCCS reference check (mV)	Time to stable QCCS reading (min)[1]	pH reading in QCCS check		Calibration done?	Action taken	Analyst
	Glass electrode	Porous junction				30-s	2-min			

[1] Should be ±1 mV in less than 1 min

[2] Both 30-s and 2-min readings should be 4.00±0.05 pH units (at 25°C) and agree within ±0.05 pH units.

SOP L1

pH Quality Assurance Log

INNOVATIVE SENSORS MODEL CSIM11 pH SENSOR

Serial number ______________________

Beginning or end of measurement period?	Date (DMY) & Time	T (^{o}C)	Buffer pH	Nernst temp comp. (mV)	Expected potential of pH buffer (mV)	Probe measurement		pH Error (Expected vs. calculated)	Action (Adjust, Replace)	Analyst
						mV	Calculated pH			
			7							
			4							
			10							
			7							
			4							
			10							
			7							
			4							
			10							

SOP L2

Model 107 Thermistor Calibration Form

Serial Number ______________________________

Calibration Date D-M-Y	Calibration Time hh:mm		Temperature(°C)			Action (Adjust, Replace)	Analyst
	Begin	End	Expected	Measured	Offset (Table 1)		

SOP L3

Acceptance Log

INNOVATIVE SENSORS MODEL CSIM11 ORP SENSOR

Serial Number _____________

Date & Time	**Condition**		**KCl reference check (mV)**	**Time to stable reading (min)[1]**	**Calibration done?**	**KCl reference check (mV)**	**Action**	**Analyst**
	Pt sensing element	**Porous junction**						

[1] Should be stable within ±1 mV in less than 10 min

SOP L3

Calibration form

Redox Sensor - CSIM11-ORP sensor for SOP L3

Serial Number _____________

Date & Time	**T (°C)**	**Redox standard ORP (mV)**			**Action (Retest, Replace)**	**Analyst**
		(Expected)	**Measured**	**Error (Expected-measured)**		

SOP L5

Markland Model 10 Sludge Gun Calibration Form

Serial Number ________________ Date (DD-MM-YYYY) _________________________

Person Calibrating ____ Action: (Accept / Adjust / Replace)

Actual depth of resin layer (mm)	Measured Depth (mm)
	Trial #1
	Trial #2
	Trial #3
	Trial #4
	Trial #5
	Trial #6
	Trial #7
	Trial #8
	Trial #9
Mean	
Standard Deviation (Precision)	
Accuracy (Measured depth – Actual depth)	

SOP L5

Sludge Depth Field Data Form

Location: ___________________________________

Sensor serial number ____________________

Date (D-M-Y)	Time (EST)	**Bottom Depth (m)**			**Sludge Depth (m)**			Comments	Persons measuring
		Avg Cable Marker # (A)	Avg Distance to Waterline (B)	Avg Bottom Depth (A – B)	Avg Cable Marker # (C)	Avg Distance to Waterline (D)	Avg Depth to Sludge Layer (C – D)		
									/
									/
									/
									/
									/
									/

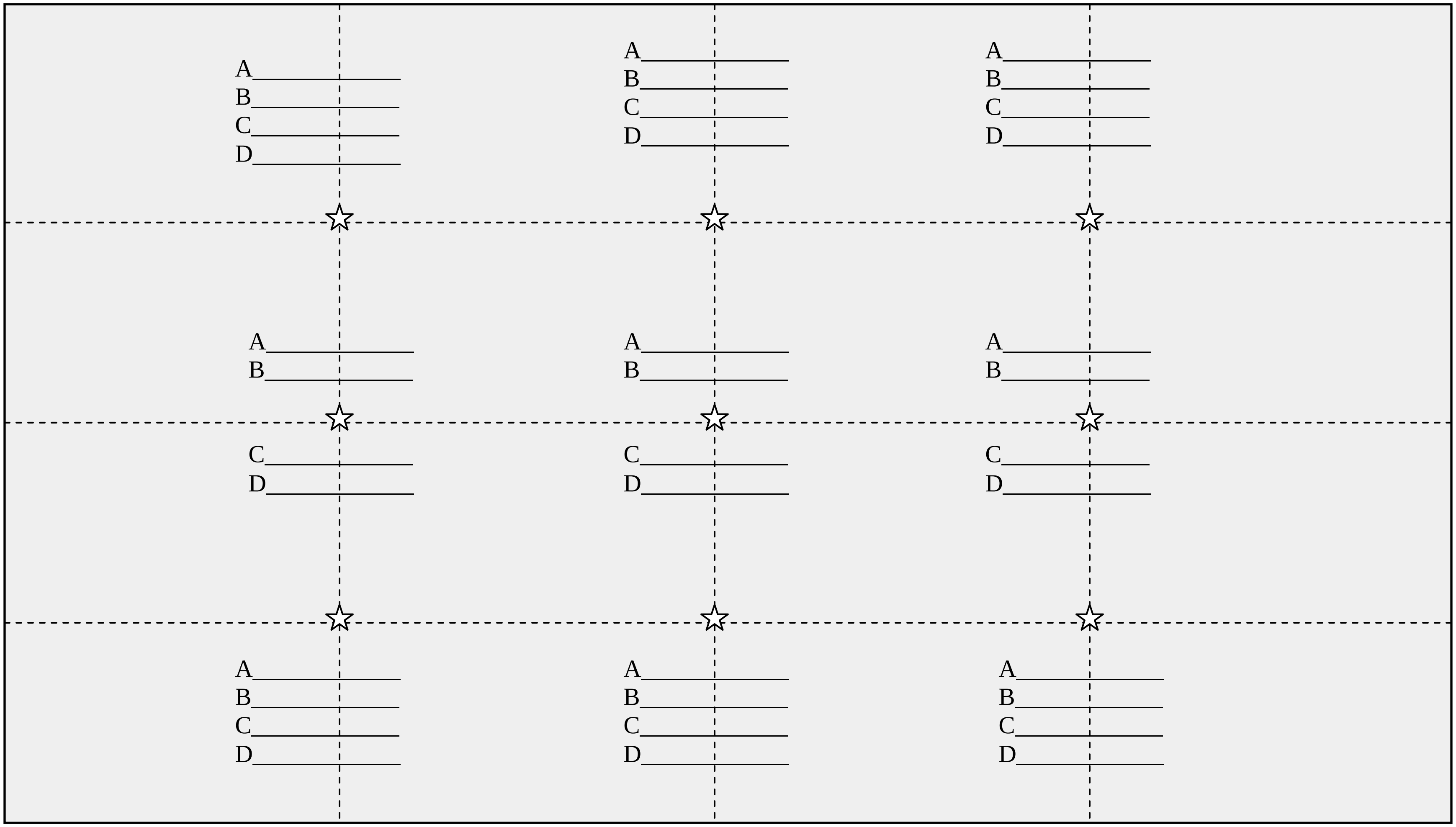
SOP L5

Depth Plot Worksheet

Location: ________________________________ Date: ____________________ Operator: __________________________________

Sensor serial number _____________

☆ Denotes approximate measurement locations



A_____________
B_____________
C_____________
D_____________

A_____________
B_____________
C_____________
D_____________

A_____________
B_____________
C_____________
D_____________

A_____________
B_____________
C_____________
D_____________

A_____________
B_____________
C_____________
D_____________

A_____________
B_____________
C_____________
D_____________

A_____________
B_____________
C_____________
D_____________

A_____________
B_____________
C_____________
D_____________

A_____________
B_____________
C_____________
D_____________

Site Information Form for Lagoons and Basins SOP S7 (Table 1)

Category	Information
Farm name	
Address, phone	Contact Person:
Livestock Producer	Biosecurity: time since farm visit, d:
	Willing to provide production information?
	Cooperative and enthusiastic participant?
	How long has the farm been in operation under current owner?
	Able to provide feed and water consumption data? Sample analysis records?
	Willing to possibly test abatement technologies after the NAEMS?
	Describe management style (tools used, etc.):
Convenience	Distance from university, miles:
	Phone, internet, and electric power available? 240 VAC?
	Lodging nearby for research team?
Facilities	Generally describe rations:
	Animal breed:
	Describe feed delivery system
	Describe waste collection, handling, treatment and storage systems
	Rate lagoon maintenance from 1 to 5 (1 is cleanest):
	Any emission control measures at facility?
Surroundings	Describe surrounding landscape and topography (hills, flat, etc.)
	Describe other pollution sources within one mile:
	Distance to nearest land application sites
	Distance from public road. Type of road (gravel or paved).

Site Information Form for Lagoons and Basins SOP S7 (Table 2)

Descriptive parameters	**Unit 1**	**Unit 2**	**Unit 3**
Livestock type			
Year of facility construction			
Separation distance from barn fans, ft			
Type of storage (basin, lagoon or tank)			
Stage of lagoon (1st, 2nd, 3rd)			
Manure contributors to unit			
Animal 1 type (sows, cows, etc.)			
Animal 1 average weight (lb)			
Animal 1 inventory (# head)			
Animal 2 type (sows, cows, etc.)			
Animal 2 average weight (lb)			
Animal 2 inventory (# head)			
Animal 3 type (sows, cows, etc.)			
Animal 3 average weight (lb)			
Animal 3 inventory (# head)			
Manure collection (flush, scrape, PPR)			
Source flush or recharge water (if any)			
Lagoon loading frequency, hours			
Minimum space surrounding unit, ft			
Volumetric loading rate, lb/d-ft^3			
Surface loading rate, lb/d-ft^2			
Obstructions within 3X height of unit?			
If yes, what kind? (e.g. trees, barns)			
Height of worst obstruction, ft			
Distance from worst obstruction, ft			
Type of cover (crust, straw, none, etc.)			
Are solids separated from influent?			
Odor control: (digester, additives)			
Sludge removal cycle, years			
Last time sludge removed (e.g., 1999)			
Agitation prior to pumpout?			
Manure removal frequency, d			
Pump out (contractor or producer)			
Type of liner (clay, plastic, etc.)			
Volume, cubic ft			
Surface area, square feet			
Berm slope (e.g. 3:1, 3.5:1, 4 :1, etc.)			
Maximum side length, ft			
Minimum side length, ft			
Actual freeboard, ft			
Inner berm height, ft			
Outer berm height, ft			
Liquid depth, ft			
Sludge depth, ft			
Number of inlets (show on drawings)			
Shape (rectangular, oval, etc.)			

Dairy Corral Site Information Form SOP S7

(Email to Al Heber, Purdue University: heber@purdue.edu)

Table 1. Dairy Corral Site Selection Criteria

Category	Information
Farm name	
Address, phone	
Livestock Producer	Provide production and herd management information (DC305)?
	Cooperative and enthusiastic about study?
	Willing to make some nonconsequential changes for the test?
	Willing to train herdspersons about importance of test?
	Able to provide feed and water consumption data per cow group?
	Willing to possibly test abatement technologies after the NAEMS?
	Describe management style (tools used, etc.):
Convenience	Distance to site from university, miles:
	Cell phone signal?
	Phone, internet, electric power available?
	Lodging nearby for research team?
corrals	Generally describe rations (including forages and purchased feeds)
	Describe feed delivery system.
	Describe waste collection, handling, treatment and storage systems
	Rate corral hygiene from 1 to 5 (1 is cleanest).
Surroundings	Describe surrounding landscape and topography.
	Describe other pollution sources within one mile of site;
Farm	Describe all facilities on the site (# hd, size, age);
	Distance to nearest land application sites.
	On-site heifer growing program?

Table 2. Characteristics of test site and corrals **SOP S7**

Descriptive parameters.	**Type 1**	**Type 2**	**Type 3**
Breed			
Inventory (cow capacity)			
Average mass, lb			
Year(s) of construction			
Overall site width (E-W dist), ft			
Overall site length (N-S dist), ft			
Heifer growing program?			
Corrals			
Type (yearlings, lactation, hosp, etc.)			
Number			
Corral orientation			
Corral width, ft			
Corral length, ft			
Corral area, ft^2			
Apron width, ft			
Apron length, ft			
Apron cleaning (flush, scrape, vac)			
Maintenance technique (scr, harrow)			
Maintenance frequency (d)			
Shade height, ft			
Shade length, ft			
Shade width, deg.			
Side slope, %			
Cross slope, %			
Cow lane width, ft			
Cow lane length, ft			
Windbreak			
Height, ft			
Length, ft			
Lagoon			
Length, ft			
Width, ft			
Depth, ft			
Berm height, ft			
Number of stockpiles			
Weeping pad area, ft^2			
Number of separators			
Number of silage bunkers			
Number of hay barns			
Parlor			
Width, ft			
Length, ft			
Sidewall height, ft			
Roof ridge height, ft			
Type of ventilation			

Number of air outlets in ridge			

Table 2. Characteristics of test site and corrals (continued)

Descriptive parameters.	**Type 1**	**Type 2**	**Type 3**
Type of sidewall inlets			
Air circulation fans in ceiling			
Misting?			
Exit lane drenching?			
Holding time, min			
Wash cows?			
Milking frequency, times daily			
Parlor occupancy, # cows			
Holding pen			
Manure removal (flush, hand wash)			
Manure removal frequency			
Width, ft			
Length, ft			
Sidewall height, ft			
Roof ridge height, ft			
Type of ventilation (NV, MV)			
Number of air outlets in ridge			
Type of sidewall inlets			
How is feed weighed?			
How is manure loads weighed?			
How are animals weighed?			
Number of pumps to monitor			
Access around property for sensors?			

Producer Event/Change Form SOP S7

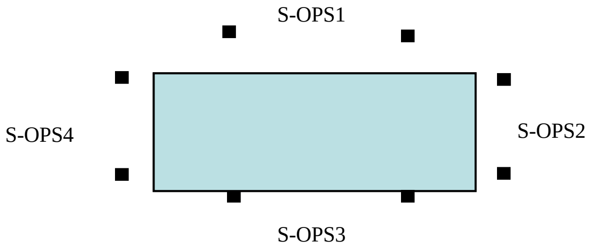
In order for the Purdue Air Quality group to do its job, they need to know about events/changes around the lagoon, basin, or corral that affect airflow or air emissions. A few jotted notes here will help them not make mistakes when analyzing the data. Thank you for your cooperation!

[Examples of changes include (but are not limited to): major water leaks, power interruptions, sludge removal, pump outs, and diet changes.]

Description of event/change	**Start time/date**	**End time/date**	**Contact person**

Research staff contact information:
Name(s):____
Office phone: __________________________
Cell phone: __________________________

Synthetic Open-Path System (S-OPS) Placement Form SOP C4



Location: ______________________

Date: ______/______/_______

FOS: ________________________________

Indicate North direction on map

Synthetic Open Path system (S-OPS1) End of line:_Deg (N) _____Min______Sec

Synthetic Open Path system (S-OPS2) End of line:_Deg (N) _____Min______Sec

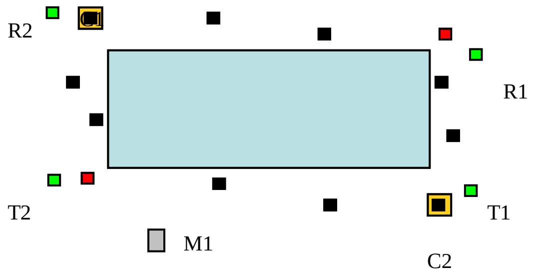
Synthetic Open Path system (S-OPS3) End of line:_Deg (N) _____Min______Sec

Synthetic Open Path system (S-OPS4) End of line:_Deg (N) _____Min______Sec

S-OPS	**Height above berm (m)**	**Distance from berm (m)**	**Length of path (m)**	**Number of inlets**	**Length of sampling line from S-OPS to pump (m)**	**Orientation of path (N-S, NE-SW, etc.)**
1						
2						
3						
4						

Notes:

Site Open-path Sensor Installation Report SOP U5



Location: ______________________

Date: _______/_______/________

FOS: ________________________________

Crank-up tower 1 location (C1) _______Deg (N) ______Min_______Sec

Crank-up tower 2 location (C2) _______Deg (N) ______Min_______Sec

Mast location (M1) _______Deg (N) ______Min_______Sec

UV-DOAS 1 transmitter location (T1) _______Deg (N) ______Min_______Sec

UV-DOAS 1 receiver location (R1) _______Deg (N) ______Min_______Sec

Distance between transmitter and receiver: _____________________ m

Height of path 1 above lagoon berm : _______________________ m

UV-DOAS 2 transmitter location (T2) _______Deg (N) ______Min_______Sec

UV-DOAS 2 receiver location (R2) _______Deg (N) ______Min_______Sec

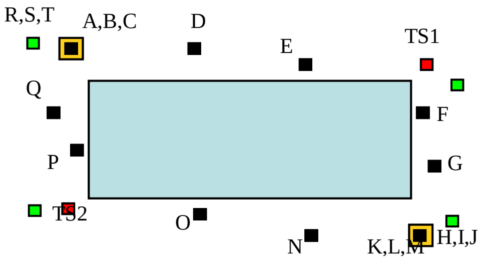
Distance between transmitter and receiver: _____________________ m

Height of path 2 above lagoon berm : _______________________ m

Notes:

Site Open path sensor Installation Report SOP U5

(Continued)



Location: _______________________

Date: _______/_______/________

FOS: __________________________________

TDLAS/scanner 1 location (TS1) _______Deg (N) ______Min_______Sec

	---------------- Location -----------------------				
Retro-reflector	Deg (N)	Min	Sec	Distance from TDLAS (m)	Actual height above berm (m)
A					
B					
C					
D					
E					
F					
G					
H					
I					
J					

Inspection Checklist Form SOP U5

(Cables)

Date: ___________________

Item	All OK	One Bad	Repaired or Replaced Unit # or Description	Note #
Retro-reflector Cables (15-m/Tower)				
Retro-reflector Cables (7-m/Tower)				
Retro-reflector Cables (1- m/Tower)				
Retro-reflector Cables (1-m 2/3)				
Retro-reflector Cables (1-m 1/3)				
UV-DOAS Power Cable (Transmitter)				
UV-DOAS Power Cable (Receiver)				
TDLAS Power Cable				
Meteorological Unit Power Cable				
Lagoon Sensor Data Cables				
Sonic Anemometer Cables (16-m)				
Sonic Anemometer Cables (4-m)				
Sonic Anemometer Cables (1-m)				

All notes to be documented on back of form and note # referenced to the appropriate entry!

Name: ____

Inspection Checklist Form SOP U5

(Continued)

(Hardware)

Date: ____________________

Item	**OK**	**Problem**	Note #
GFCI Trip and Power OK?			
Lightning Rod OK?			
Ground Wire OK?			
Mast Stakes			
Crank Up Tower Guys Wires Tight?			
Crank Up Tower Base Bolts All Present & Tight?			
All Towers, Tripods, & Mast Look Vertical?			
All Towers, Tripods, & Mast Intact?			
Sonic Anemometers Mounted & Oriented Correctly?			
Lagoon Cable Floats Intact And Spaced Correctly?			
All Heater Cables Look OK, Mounted Securely?			
All Other Sensor Cables Look Intact			
Meteorological Boxes Weather Tight?			
Desiccant Fresh In Meteorological Boxes?			

<u>All notes to be documented on back of form and note # referenced to the appropriate entry!</u>

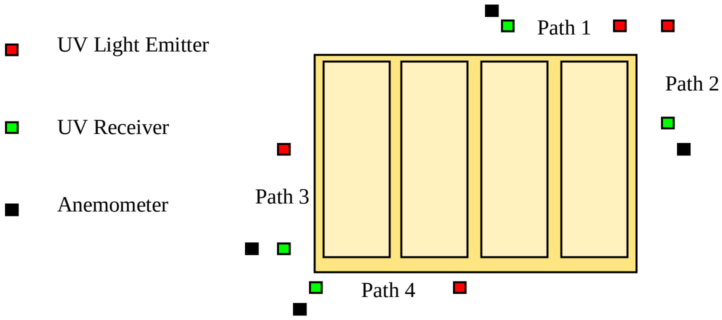
Name: ____

SOP U7

Site Open path sensor Installation Report (Corrals)

Location: ______________________

Date: ______/______/_______



Path #1

UV-DOAS light emitter location (T1) ______Deg (N) _____Min______Sec

UV-DOAS receiver location (R1) ______Deg (N) _____Min______Sec

Sonic Anemometer location (A1) ______Deg (N) _____Min______Sec

Distance between transmitter and receiver: _____________________ m

Path#2

UV-DOAS light emitter location (T2) ______Deg (N) _____Min______Sec

UV-DOAS receiver location (R2) ______Deg (N) _____Min______Sec

Sonic Anemometer location (A2) ______Deg (N) _____Min______Sec

Distance between transmitter and receiver: _____________________ m

Path#3

UV-DOAS light emitter location (T3) ______Deg (N) _____Min______Sec

UV-DOAS receiver location (R3) ______Deg (N) _____Min______Sec

Sonic Anemometer location (A3) ______Deg (N) _____Min______Sec

Distance between transmitter and receiver: _____________________ m

Path#4

UV-DOAS light emitter location (T4) ______Deg (N) _____Min______Sec

UV-DOAS receiver location (R4) ______Deg (N) _____Min______Sec

Sonic Anemometer location (A4) ______Deg (N) _____Min______Sec

Distance between transmitter and receiver: _____________________ m

Name:

Inspection Checklist Form

Date: ___________________

Item	All OK	One Bad	Repair or Replaced Unit # Or Description	Note #
GFCI Trip and Power OK?				
Lightning Rod OK?				
Ground Wire OK?				
Mast Stakes				
UV-DOAS Power Cable (Transmitter)				
UV-DOAS Power Cable (Receiver)				
Meteorological Unit Power Cable				
Sonic Anemometer Cables				
All Other Sensor Cables Look Intact				
Meteorological Boxes Weather Tight?				
Desiccant Fresh In Meteorological Boxes?				
Tower Bolts All Present & Tight?				
All Towers, & Mast Look Vertical?				
All Towers, & Mast Intact?				
Sonic Anemometers Mounted & Oriented Correctly?				
All Tools & Equipment Put Away?				

All notes to be documented on back of form and note # referenced to the appropriate entry!

Name: ____

SOP W2

AUDIT FORM

SOP W2 RM YOUNG MODEL 81000 3-DIMENSIONAL SONIC ANEMOMETER

Date/time Yymm/dd hhmm	Bias in U (m/s)	Bias in V (m/s)	Bias in W (m/s)	Auditor

SOP W3

Calibration Check Form: Campbell Scientific Resistance Grid Wetness Sensor

Instrument Serial Number:_________________________________ Location:__________________________________

Date (D-M-Y)	Time		Resistance (ohms)		Action Taken (Adjust, Replace)	Analyst
	Begin	End	Dry	Wet		

Calibration Record: Setra 278 Barometric Pressure Sensor SOP W5

Instrument Serial Number:________________________________ Location:_________________________________

Date (D-M-Y) Time: Begin-End	Temp. (^{o}C)	Manometer pressure (in. Hg)	Hg Temp. correction (in. Hg)	Pressure					Difference		Action*	Analyst
				Corrected			Measured					
				in. Hg	mb	hPa**	mb	hPa	mb	hPa		

* Sensor adjustment or replacement made after the measurement, if necessary. If action is taken, next entry should show result of re-calibration following that action.

**1hPa = 0.02953 in Hg

SOP W6
CR1000 Data logger Calibration Form

Instrument Serial Number:_________________________________

Date (MM/DD/YYYY): ____/_____/_____ Calibrator: ______________________________

Begin time (HrHr:MinMin) _____________ End time (HrHr:MinMin) _____________

For 5VDC input, factory accuracy: ±6.3 mV

SE Channel	Recorded voltage Mean value	Error (5-mean)	Within factory accuracy (±6.3 mV)? (Y/N)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
12			
13			
14			
15			
16			