Appendix B

SMPs

SMP IA3A
SITE MONITORING PLAN FOR FINISHER SWINE BASIN IN IOWA

SMP IA3A
SITE MONITORING PLAN FOR FINISHER SWINE BASIN IN IOWA

The Midwestern finisher basin facility is located in Greene County, IA. The elevation at the farm is 351 m (1151 ft). The magnetic compass variation at this location is 03^{o}E. The farm consists of two barns and a manure basin (Fig. 1). The facility has a capacity of 3840 finishers in four units. The construction of the facility was completed in 1998.

Logistics

Measurements will be made once per quarter for two years by one of the rotating measurement teams from Purdue Applied Meteorology Laboratory in W. Lafayette, IN. The farm is located 75 km (47 mi) – an approximately 1.5-h drive – NW of the nearest airport (Des Moines, IA).

Climate (Table 1)

The climate for the area is represented by the Des Moines, IA National Weather Service weather station, which is approximately 75 km (47 mi) SE of the farm. The area typically receives an annual average of 783 mm (31 in) of precipitation (NCDC, 1981). The prevailing winds are from the S from May through October, and NW from November through April (Table 1, Fig. 2). The maximum chances of days with precipitation are during the spring (Table 1). Mean monthly wind speeds range from 4 m/s (9 mph) to 6 m/s (13 mph) (NCDC, 1998). Relative humidity (RH) ranges from 79% in the morning to 60% in the afternoon, while air temperatures range from 18^{o}C (58^{o}F) to 6^{o}C (40^{o}F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is given in Table 1.

Farm Operations Characteristics (Table 2)

Manure from the 2-ft deep pits in each of the four barns is transferred approximately once every ten weeks to the basin, through two inlets (Fig. 2). The basin is W of the barns (Fig. 3). The concrete circular basin has a diameter of 55 m (180 ft). The basin sides are approximately 1.5 ft above ground level (agl), and extend 6.5 ft below ground level. While the basin is circular, the measurements are described below as on the N, E, S, and W ‘sides’ of the basin, referring to measurements made to the N, E, S and W. Manure is surface-applied on adjacent fields every other year, and on fields up to 2 mi from the basin on the alternate years.

Surrounding Sources

The nearest identifiable NH_3 or H_2S emission source is a two-barn finisher farm two miles to the W of the farm site. No other basin, lagoon, or barn sources of NH_3 or H_2S emission are within one mile of the farm. Manure is surface-applied in alternating years on adjacent fields, and on fields up to 2 mi from the basin.

Monitoring Plan

The NH_3 emissions from the basin will be monitored using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the basin will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, and the backward Lagrangian Stochastic model (SOP O1). VOC emissions will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and air sampled using the S-OPS (SOP C4) and analyzed by the INNOVA (SOP G7). Data will be collected on the LAN server in the trailer (SOP D1, SOP U5).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes around the basin. Two towers will be located at the NW and SE "corners" of the basin (SOP U5) (Fig. 4). The scanning TDLAS instruments will be mounted at 1-m height above the basin rim on anchored tripods (SOP U5) at the NE and SW corners. The 1.5-ft (approx 0.5-m) height of the basin rim results in the TDLAS/scanners being about 1.5 m abl. Retro-reflectors at the approximate 1/3 and 2/3 distance down the basin 'sides' will also be mounted at 1 m above basin rim height on anchored tripods (SOP U5) (Fig. 4). The TDLAS laser beam is eye-safe.

Two S-OPS paths will be used to measure the synthetic PIC of VOC and H_2S near the basin rim height on two sides of the basin. Since the prevailing winds are S or NW depending on the time of year, the S-OPS will be positioned to the N and S of the basin (Fig. 4).

Volatile organic compounds, including methane, methanol, ethanol, and total VOC, will be measured using an INNOVA 1412 multi-gas photoacoustic analyzer (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the basin (Fig. 4).

Hydrogen sulfide will be measured using pulsed-florescence (SOP G5) from air sampled through the S-OPS paths upwind and downwind of the basin (Fig. 4).

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be located 10 m to the SW of the basin and 66 m W of the barns (Fig. 4). The meteorological measurement data will be collected on the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2-m height, and on the NW corner tower (Fig. 4) at 4-m and 16-m heights abl (Fig. 4) (SOP U5).

The farm is located in rolling terrain (Fig. 5). The barns 12 m to the E of the basin have an approximate ridge height of 5 m (16 ft) agl, resulting in a fetch ratio (rise: run) to the E for the nearest TDLAS beamline of 1:3 or better. Crops are grown to the N, S and W of the basin. The area to the N alternates between corn and soybeans, while that to the W and S varies between wheat, soybean, and corn. Crops approximately 10 m (currently) to the N, S, and W of the basin will have a height ranging from 1 m (soybeans, wheat) to 3 m (corn). Since measurements are at

1.5 m abl or higher, the soybean and wheat crops would not affect the air flow at beamline or anemometer measurement heights. The fetch for the TDLAS and S-OPS beamlines to the S of the basin is 1:17 or better when cropped with corn. The fetch for TDLAS beamlines to the W of the basin is 1:6 or better when cropped with corn. The fetch for the S-OPS and TDLAS to the N of the basin is 1:3 or better when cropped with corn. To the N, the current year crop is soybeans, so under typical rotation 2007 will be in corn and 2008 in soybeans. The 2-m anemometer has a prevailing wind upwind fetch of 1:36 and 1:33 for the NW and S winds, respectively, and 1:22 for the E winds coming from the barns. The 4-m anemometer fetch in all directions except E winds is greater than 1:100; for the E wind, fetch is 1:78. Consequently, all wind measurements should be relatively unaffected by upwind conditions.

Configuration specifics:

The TDLAS/ scanners are located to the NE and SW of the basin, mounted at 1 m above basin height on anchored tripods (Fig. 4). The tower-mounted TDLAS retro-reflectors are mounted on fixed towers located SE and NW of the basin (Fig. 4). A description of the position of each measurement path, with photographs showing the views corresponding to the locations and directions indicated in Fig. 1 follows:

N side of basin

- TDLAS/scanner 9 m S of fenceline and 12 m NW of NW corner of northernmost barn.
- Three retro-reflectors mounted on a tower 23 m S of the fenceline and 79 m W of the barns, with a path length of 75 m.
- TDLAS retro-reflectors will be located 25 m and 45.5 m W of the TDLAS/ scanner on the NE corner, mounted at 1 m above basin rim height using anchored tripods.
- Beam paths are approximately 3 m from the basin at their closest point.
- 50-m length S-OPS path beginning at the TDLAS/scanner and ending 19 m S of the fence and 59 m W of the northernmost barn.
- Nearest point from S-OPS path to basin is 3 m.

Location of N side TDLAS beam path looking W towards the 15-m TDLAS retro-reflector tower. Basin rim is on left.

E side of basin

- TDLAS/scanner 9 m S of fenceline, 12 m NW of NW corner of northernmost barn.
- Three retro-reflectors mounted on a tower 12 m W of the barns and 84 m S of the fenceline (halfway between barns 3 and 4) with an 80.5-m path length.
- TDLAS retro-reflectors will be located 27 and 48 m S of the TDLAS/ scanner at the NE corner and mounted at 1 m above basin

Location of E side TDLAS beam path, looking N towards the location of the 15-m TDLAS retro-reflector tower. Basin rim is on right.

rim height using anchored tripods. Retro-reflectors are located halfway between barns 2 and 3, and 3 and 4.
- Beam paths are approximately 1 m from the berm at their closest point.

S side of basin

- 50 m length S-OPS path E-W along the TDLAS path lines with closest point 9 m S from the basin.
- S-OPS path begin 11 m W of barns.at 1 m above basin rim height and ends along the TDLAS path lines 62 m W of the barns.
- TDLAS/scanner at the SW basin corner, 79 m W of the barns and 75 m S of fenceline.

S side of basin. Basin rim is on left.

- TDLAS retro-reflectors will be located 22 m and 44 m E from the TDLAS/scanner. The retro-reflectors are mounted at 1 m above basin rim height on anchored tripods.
- Three retro-reflectors are mounted on a tower 11 m W of the barns and 84 m S of the fenceline (halfway between barns 3 and 4) with a 71 m path length.
- TDLAS beam paths are approximately 9 m from the basin at their closest point.

W side of basin

- TDLAS/scanner is located 79 m W of the barns and 75 m S of the fenceline.
- Three retro-reflectors are mounted on a tower 23 m S of the fenceline and 79 m W of the barns with a 60.5-m path length.
- TDLAS retro-reflectors will be located 18 m and 36 m N from the TDLAS/scanner. The retro-reflectors are mounted at 1 m above basin rim height on anchored tripod.

W side of basin. Basin rim is on left.

- TDLAS beam paths are approximately 12 m W of basin rim.

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2), with data from the three sonic anemometers (SOP W2) and TDLAS measurements (SOP C2). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above rim height) are less than 1 m/s. The wind speeds (at a 7-m height) at Des Moines, IA were 1.1 m/s or less 2.8% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m abl) are greater than 11 m/s. Wind speeds (at 7-m height) at

Des Moines, IA were 11.1 m/s or more 1.4% of the time between 1981 and 1990 (NCDC, 1998).

3) The TDLAS path-integrated concentration (PIC) measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane on all four 'sides' of the basin ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

It is anticipated that the TDLAS upwind concentration measurements will be valid even when the winds are from the NNE to SSE, since the fetch is better than 1:3 and the distance to the beam line is ten times the diameter of the fan. We expect channeling of the flow along the barn axis, causing many of the NNE to SSE winds to align to an E wind.

VOC and Hydrogen sulfide emissions from the lagoon will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and air sampled using the S-OPS (SOP C4, Fig. 4) and analyzed by PF (SOP G5). Restrictions on the use of the model are as follows:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid, although the surrounding area of the farm is open cropped land. The crop rotation is generally corn followed by soybean, but this is not strictly adhered to. The corn crop may have a canopy height of up to 3 m, while the soybean or wheat canopy height is approximately 1 m. The farm has additional roughness elements of buildings (to the E) of approximately 5 m (16 ft) height. Given prevailing winds from the NW, the buildings are downwind with at least a 1:3 fetch. For the prevailing southerly winds, the buildings are 11 m to the E of the flow. If the winds are from the NNE to SSE, the 1:3 fetch to the beamlines is inadequate and consequently emissions measurements will be invalidated (Fig. 2).
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period with the exception of when the winds are coming from the NNE to SSE (exclusion zone of Fig. 2). The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan.
3) The S-OPS concentration measurements are at upwind and downwind locations and are synoptic. This is essentially true when ½ hour averaging periods are used. Valid upwind and downwind paths will be when winds are from the N, NW and S; the prevailing winds during most of the year. It will not be true for winds from other directions.
4) Emission measurements will be invalidated when the friction velocity is less than 0.15 m/s, which corresponds approximately with winds of 1.1 m/s at 7-m height. The wind speeds at 7-m height at Des Moines, IA were 1.1 m/s or less 2.8% of the time between 1981 and 1990 (NCDC, 1998).

Surface manure sampling (SOP M1) will be conducted at the beginning or end of every measurement period when sufficient crusting exists in the basin. Surface samples will be collected at random locations in the basin. A minimum of three samples will be taken from separate locations in the basin to composite for each sample required. The composited piles will then be sampled using a corer (SOP M1). These samples will be analyzed for pH (SOP M2), moisture content (SOP M3), total nitrogen (SOP M4), ammonia (SOP M5), and total and volatile solids (SOP M3). Results will provide the basis for correlating these properties with emissions from the basin.

Communications

The instrumentation trailer (SOP U4) will be located between the center two barns (barns 2 and 3) at the W end of the barns, approximately 15 m from the basin (Fig. 3). Telemetry of TDLAS/scanners, 3D anemometers, and the meteorological/basin characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All measurements telemetered to the trailer will be sent to Purdue nightly via cellular DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the producer-supplied source. All wiring will be buried directly in the ground from the producer-supplied source, and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weather proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements at the time of initial setup and periodically during the year/measurement period as needed.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed.

Emissions Determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

References

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SOP E3. 2006. The Measurement of Solar Radiation with the Licor Model 200SL Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab.

SOP G5 2006. Standard Operating Procedure for Measurement of Hydrogen Sulfide (H2S) with the Thermo Electron Corporation Model 450C Pulsed- Flourescence 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 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.

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

SOP U4. 2006. Open Source Instrument Trailer. Standard Operating Procedure U4. Purdue Applied Meteorology Lab.

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

SOP W1. 2006. Humidity and Temperature Probe. Standard Operating Procedure W1. Purdue Applied Meteorology Lab.

SOP W2. 2006. Ultrasonic Anemometer for Wind Velocity. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.

SOP W3. 2006. Wetness Grid for Measuring Precipitation. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.

SOP W5. 2006. Barometric Pressure Sensor. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.

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

Figure 1. Overall view of farm and basin. Basin is fenced-in area to the left of the barns. Compass directions are indicated. Courtesy of Ron Myers, USEPA.

Table 1. Monthly climate description (Des Moines, IA).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days ≥0.01 precip[1]	8	7	10	10	11	11	9	9	9	7	6	7
Wind speed (mph)[2]	12	11	13	13	11	10	9	9	10	10	12	11
Wind direction[2]	NW	NW	NW	NW	S	S	S	S	S	S	NW	NW
Morning RH (%)[1]	75	78	78	78	78	79	81	84	84	78	78	79
Afternoon RH (%)[1]	68	67	62	56	55	56	56	58	59	54	63	70
Maximum temp (°F)[1]	27.5	32.5	42.5	59.7	70.9	79.8	84.9	83.2	74.6	64.9	46.4	32.8
Minimum temp (°F)[1]	11.3	15.8	25.2	39.2	50.9	61.1	65.3	63.4	54.0	43.6	29.2	17.2

[1] NCDC (1981)
[2] NCDC (1998)

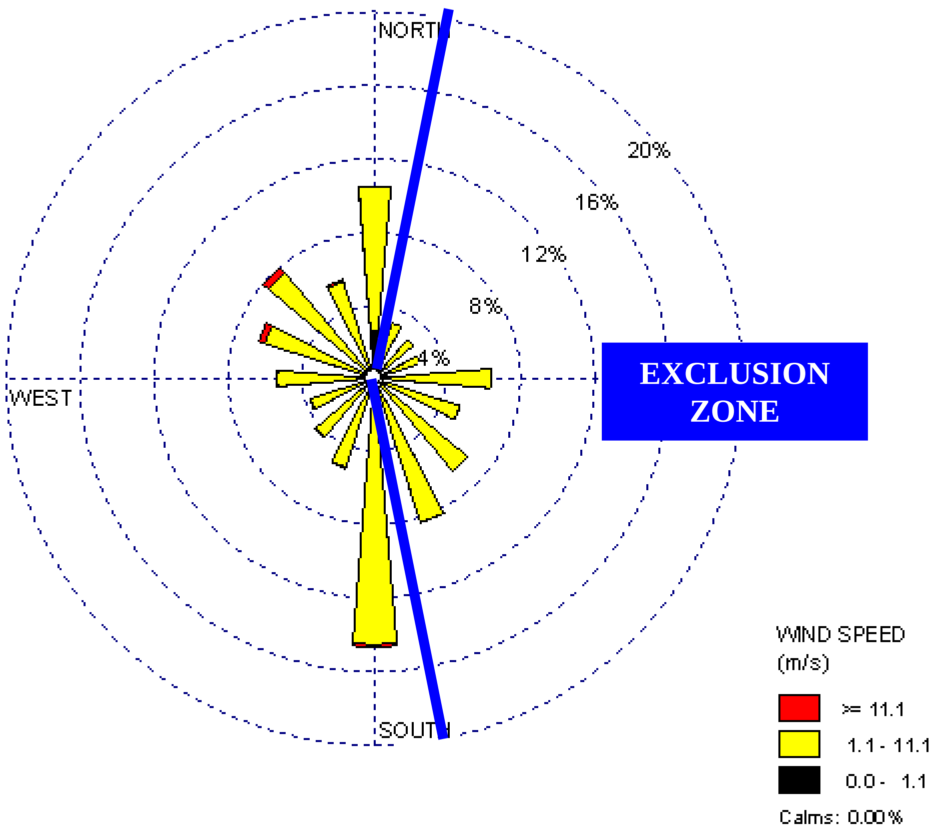

Figure 2. Des Moines, IA Windrose: 1981-1990. bLS based emissions measurements will be invalidated when the winds are in the wind direction exclusion zone indicated. Note that winds of <1.1 m/s are assigned to a nominal N direction, as they are below the threshold of the NWS anemometers.

Table 2. Characteristics of basin at the site.

Descriptive parameters	Unit 1
Livestock type	Swine Finisher
Year of facility construction	1998
Separation distance from barn fans, ft	45 (min)
Type of storage (basin, lagoon or tank)	Basin
Manure contributors to unit	
Animal 1 type (sows, cows, etc.)	Finisher hogs
Animal 1 average weight (lb)	150
Animal 1 inventory (# head)	3840
Manure collection (flush, scrape, PPR)	PP
Source flush or recharge water (if any)	None
Lagoon loading frequency	Once every 10 wks
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?	None
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.)	Crust
Are solids separated from influent?	No
Odor control	None
Sludge removal cycle, years	None
Last time sludge removed (e.g., 1999)	N/A
Agitation prior to pumpout?	Yes
Manure removal frequency, d	365
Pump out (contractor or producer)	Producer
Type of liner (clay, plastic, etc.)	Concrete
Volume, ft^3	203,537
Surface area, ft^2	25,442
Berm slope	Vertical
Maximum side length, ft	180 ft dia
Minimum side length, ft	
Actual freeboard, ft	1 ft
Inner berm height, ft	
Outer berm height, ft	
Liquid depth, ft	7 ft maximum
Sludge depth, ft	1 ft
Number of inlets	2
Shape	Round

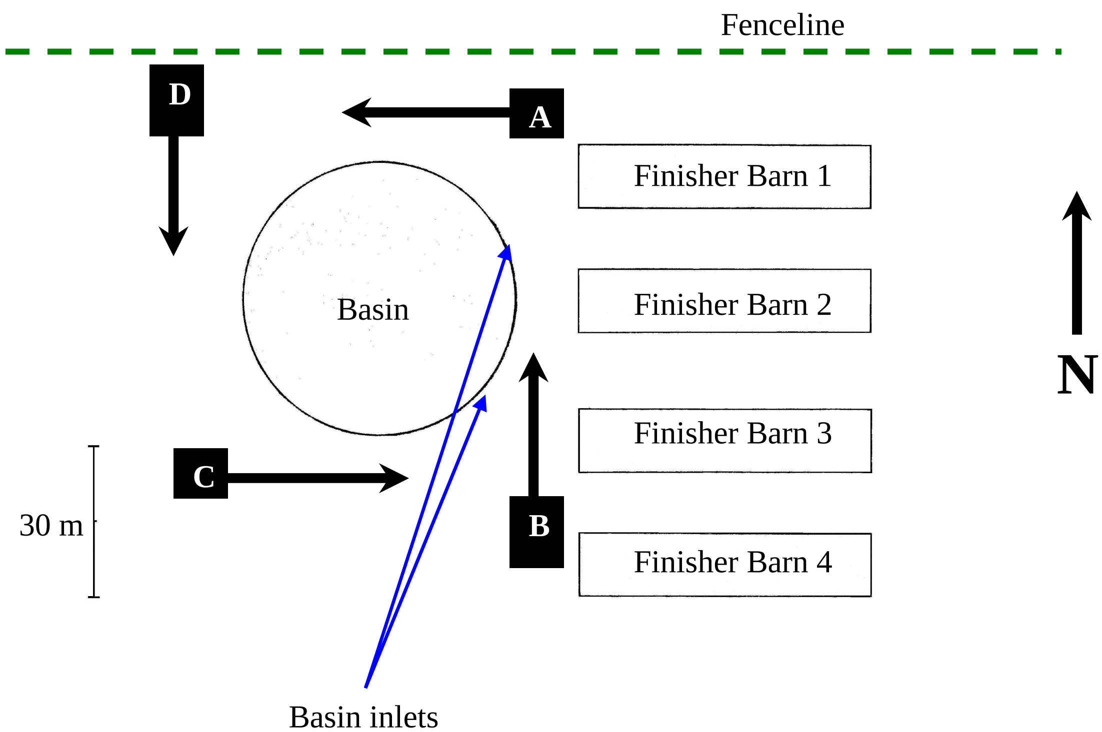

Figure 3 – General configuration of barns and basin. The direction of view of each photograph described in the measurement plan is indicated by letters (A: N view; B: E view; C: S view; D: W view).

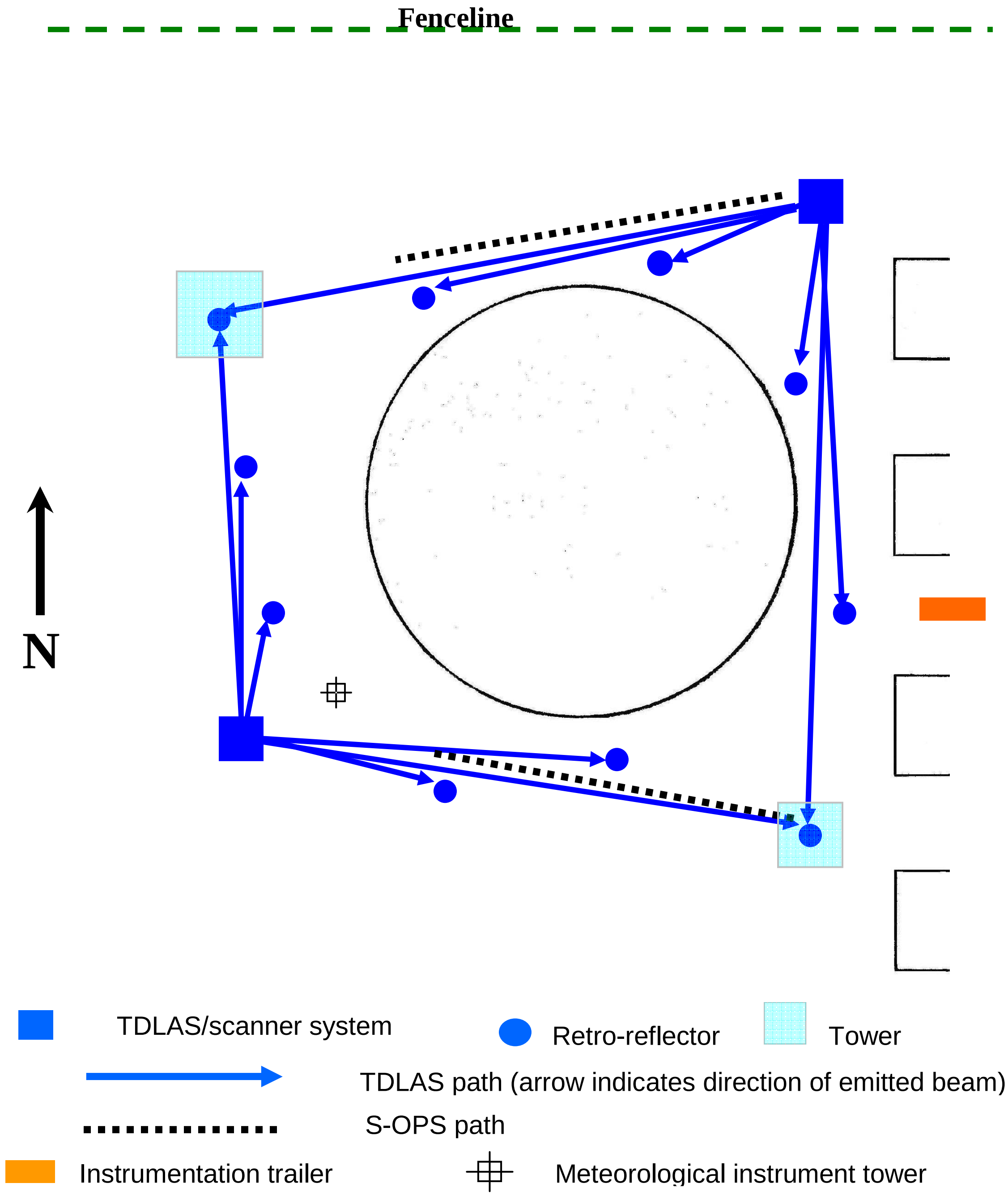

Figure 4. Measurement plan for the basin.

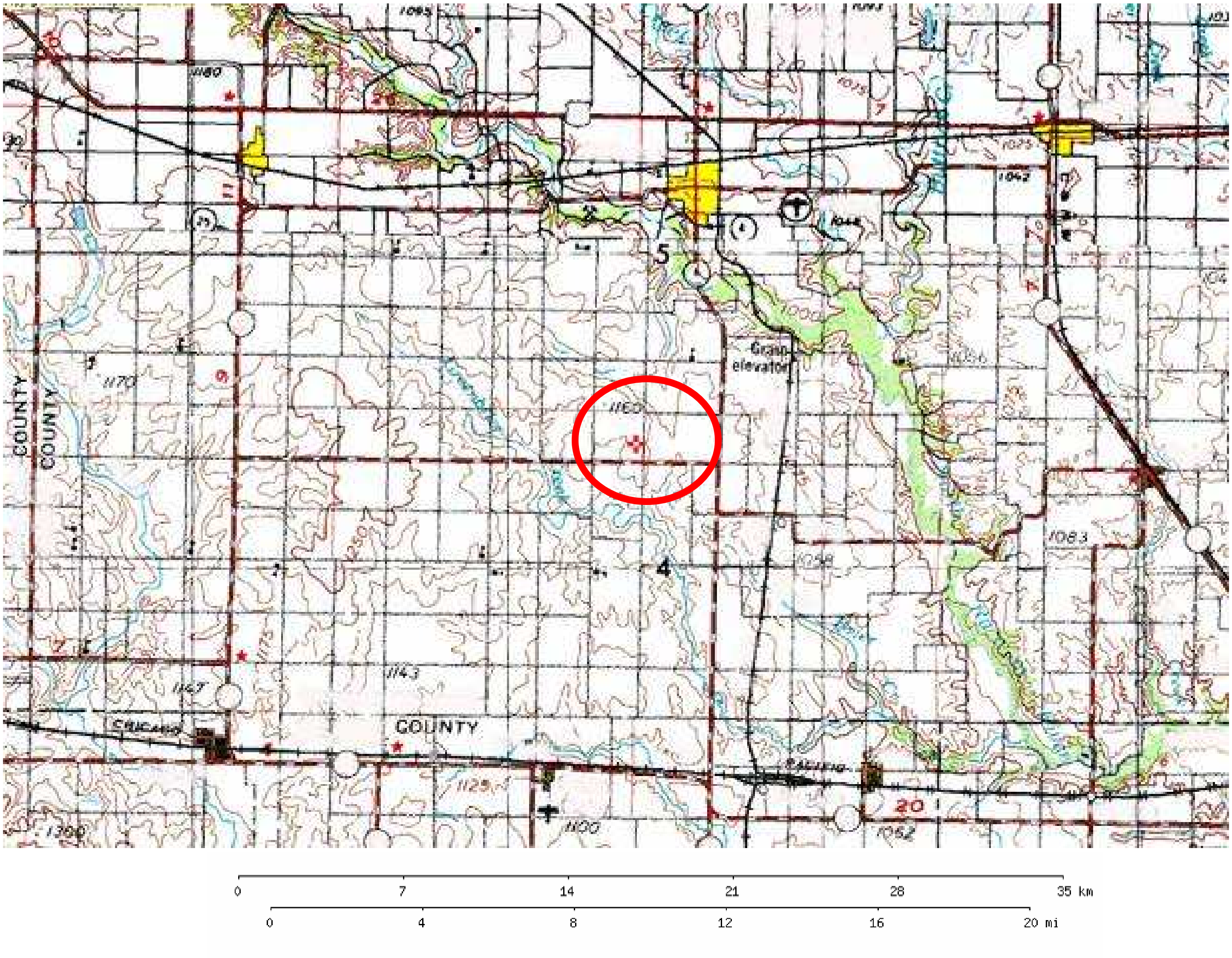

Figure 5. Terrain of surrounding area. Farm is indicated by the circle.

SMP IN4A
SITE MONITORING PLAN FOR SOW LAGOON IN INDIANA

SMP IN4A
SITE MONITORING PLAN FOR SOW LAGOON IN INDIANA

The Midwestern sow lagoon facility is located in Clinton County, Indiana. The elevation at the farm is 264 m (866 ft). The magnetic compass variation at this location is 04^{o}W. The farm consists of nine barns (Fig. 1) and a lagoon (Fig. 2), and has a capacity of 1400 sows. The facility has been added to for many years, starting operations in 1968, while the last building addition was done in 1992. Eight years ago (1998), the facility was changed from a finisher operation to farrow-to-wean operation.

Logistics

Measurements will be made continuously for one year by staff at the Purdue Applied Meteorology Laboratory in West Lafayette, IN. The farm is located 58 km (35 mi) S of West Lafayette, for a one-way driving time of approximately 45 min.

Climate (Table 1)

The climate for the area is represented by the Indianapolis, IN National Weather Service weather station approximately 56 km (35 mi) S of the farm. The area typically receives an average of 984 mm (38.7 inches) of precipitation (NCDC, 1981). The prevailing winds are from the SW (Fig. 3, NCDC, 1998). Maximum chances of days with precipitation are during the spring (NCDC, 1981). Mean monthly wind speeds range from 3 m/s (7 mph) to 5 m/s (12 mph) (NCDC, 1998). Average relative humidity (RH) ranges from 84% in the morning to 62% in the afternoon, while air temperatures range from 19^{o}C (62^{o}F) to 6^{o}C (42^{o}F) (NCDC, 1981).

Farm operations characteristics (Table 2)

Liquid waste from the deep pits of the barns is transferred once every two weeks to the lagoon by a single inlet on the E side of the lagoon (Fig. 4). A manure composting pile is present within 5 m (16 ft) of the base of the N berm. This will be moved for the study. The lagoon is S from the barns (Fig. 3). The lagoon berm is 2-3 m (7-10 ft) high, and the lagoon itself is 112 m (365 ft) by 115 m (378 ft).

Surrounding sources

There are no identifiable fixed ammonia or hydrogen sulfide emission sources within one mile of the farm (Fig. 2). Once per year, manure from the lagoon is spread on the surrounding fields to the S, E and W via piping laid on the ground. The fields are at least 10 m from the lagoon berm in all directions.

Monitoring Plan

The NH_3 emissions from the basin will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the basin during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, and the backward Lagrangian Stochastic model (SOP O1).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes around the lagoon. Fixed triangular towers will be located off the SW and NE corners of the lagoon berm (SOP U5) (Fig. 5). The scanning TDLAS instruments will be mounted at 1-m height above the berm at the NW and SE corners. The TDLAS/scanners will be mounted at 1-m height on anchored tripods (SOP U5). Retro-reflectors at the ⅓ and ⅔ distances down the berm sides will also be mounted at 1 m above berm height on anchored tripods (SOP U5) (Fig. 5). The TDLAS laser beam is eye-safe.

Two S-OPS air collection systems will be used to sample air from which measurements of VOC and H_2S will be made. The S-OPS will be near the berm height on two sides of the lagoon. Since the prevailing winds are from the SW throughout the year (Table 1), the S-OPS systems will be positioned to the N and S of the lagoon. It is expected that the southerly S-OPS system will usually be the upwind sensor system, while the northerly system will usually be the downwind system (Fig. 5).

Volatile organic compounds, including methane, methanol, ethanol, and total VOCs, will be measured using the INNOVA Model 1412 (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 2).

Hydrogen sulfide will be measured using pulsed-florescence (SOP G5) form air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 2).

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be located on the berm 15 m to the E of the lagoon's SW berm corner (Fig. 5). The meteorological measurement data will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2-m height and on the SW corner tower (Fig. 4) at 4-m and 16-m heights above berm level (Fig. 5) (SOP U5).

The barns 469 m (1540 ft) to the N of the lagoon have an approximate ridge height of 6 m (19 ft) agl, resulting in a fetch ratio to the N of better than 1:100 for all measurements. Crops approximately 10 m (currently) surrounding the lagoon can be less than 1 m (soybeans) to 3 m (corn) tall, on alternating years. The current year is corn; so, under typical rotation, 2007 will be in soybeans and 2008 in corn. Since measurement are at 2 m abl, the soybean crop would not affect the air flow at measurement height, and the corn would have at least a 5:1 fetch at the lowest (2 m) measurement height (assuming cropped land is kept 5 m from the tripods and towers). Consequently, all wind measurements should be relatively unaffected by upwind conditions.

Configuration specifics:
The TDLAS/scanners are located on the berm at the SE and NW berm corners; mounted at 1 m above the berm height on anchored tripods (Fig. 5). The TDLAS retro-reflector towers are located approximately 12 m N and 12 m E from the NE berm corner on a fixed 18-m (59-ft) triangular tower and 12 m S and 12 m W of the SV
triangular tower (Fig. 5).

A description of the position of each measurement path, with photographs showing the views corresponding to the locations and directions indicated in Fig. 4 follows:

N side of lagoon looking W. Lagoon is to the right.

N side of lagoon

- 50 m length S-OPS path due E-W 3 m N of lagoon berm mounted 1 m abl. and starting 37 m E of NW TDLAS/scanner.
- TDLAS retro-reflectors will be located 42.5 m and 87 m E along the berm from the NW corner. The retro-reflectors are mounted at 1 m above the berm using anchored tripods.
- Three TDLAS retro-reflectors are mounted on the NE corner tower 12 m E and 12 m N of the NE berm corner, each with a 144.5-m path length.

right.

E side of lagoon

- TDLAS retro-reflectors will be located on the berm, 41.5 m and 83 m N of the SE corner. The retro-reflectors are mounted at 1 m above the berm using anchored tripods.
- Three TDLAS retro-reflectors are mounted on the NE corner tower 12 m E and 12 m N of the NE berm corner, with a 146.5-m path length.

S side of lagoon looking E. Lagoon is on right.

S side of lagoon

- 50 m length S-OPS path due E-W 3 m S of lagoon berm at 1 m abl. starting 32 m W of SE TDLAS/scanner.
- TDLAS retro-reflectors will be located 42 m and 81.5 m W along the berm from the SE corner. The retro-reflectors are mounted at 1 m above the berm, using anchored tripods.

- Three TDLAS retro-reflectors are mounted on the SW corner tower 12 m W and 12 m S of the SW berm corner, with a 141-m path length.

W side of lagoon

- TDLAS retro-reflectors will be located on the berm 41.5 m and 83.5 m N of the SW corner. The retro-reflectors are mounted at 1 m above the berm using anchored tripods.
- Three TDLAS retro-reflectors are mounted on the NW corner tower 12 m W and 12 m N of the NW berm corner, with a 141-m path length.

W side of lagoon looking N. Lagoon is on right. Barns can be seen in the distance.

The NH_3 PIC measurements and VOC and H_2S S-OPS measurements are not expected to be strongly influenced by the flow conditions surrounding the relatively high-bermed lagoon. The high upwind outer berms of the lagoon contribute to regions of vertical flow convergence at the berm top, with a mean vertical flow between 10 and 20 degrees upward (PAML, 2006a). This upward flow on the upwind berm is not anticipated to cause problems in the emissions calculations, since the upwind conditions provide the background concentrations for the emissions calculations. The high downwind berm results in a recirculation at heights lower than the berm height; however, smoke tests conducted in September of 2006 (PAML, 2006a), demonstrated that the berm did not change the mean, nearly horizontal flow of air above the berm height.

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2), with data from the three sonic anemometers (SOP W2) and TDLAS measurements (SOP C2). Modeling and storage of results on-site will be accomplished by the individual instrument controlling computer (SOP O2, SOP D1). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are <1 m/s. Wind speeds (at 7-m height) at Indianapolis, IN were ≤1.1 m/s 4.4% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are >11 m/s. Wind speeds (at 7 m height) at Indianapolis, IN were ≥11.1 m/s 0.6% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS PIC measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane for all four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

VOC and hydrogen sulfide emissions from the lagoon are calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1) with the 2-m height sonic anemometer (SOP W2). Modeling and storage of results on-site will be accomplished by the bLS computer (SOP O1, SOP D1). Restrictions on the use of the model are:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid, although the surrounding area of the farm is open cropped land. The crop rotation is corn followed by soybean. The corn crop may have a canopy height of up to 3 m, while the soybean canopy height is approximately 1 m. Smoke and wind measurements indicate that the corn crop contributes to very complex downwind flow conditions (PAML, 2006a). Therefore, to minimize the impact of the crops on the flow around the lagoon, measurements will be made during 2007-2008 when the surrounding crops will be soybeans to the S, E, and N, and winter wheat to the W of the lagoon. The farm has additional roughness elements (buildings) to the N, with a height of approximately 6 m (19 ft). With the barns 1540 ft (469 m) to the N and the prevailing winds from the SW, there is minimal influence of the buildings to the flow at the PIC height of 1 m above berm height.
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period, since winds are consistent in direction and speed much of the year. The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006b). Smoke and wind measurements showed a persistent upward motion as the flow transitioned from the lagoon to the downwind berm, as well as when the flow encountered the upwind outer berm of the lagoon (PAML, 2006a). Berm wind measurements will be made in the center of the berm top to minimize upward motion from either the outer berm rise (for winds coming up the berm side) or the inner berm rise (for winds coming across the lagoon).
3) The S-OPS PIC sampling for measurements of upwind and downwind components are synoptic. This is approximately true when averaged over ½ hr periods. Given that the prevailing winds are from the SW for the entire year, the placement of S-OPS planes along the S and N sides of the lagoon should provide valid synoptic PICs for most measurement periods.
4) Emission measurements will be invalidated when the friction velocity is less than 0.15 m/s. This corresponds approximately with winds of 1.1 m/s. The wind speeds (at 7-m height) at Indianapolis, IN were ≤1.1 m/s 4.4% of the time between 1981 and 1990 (NCDC, 1998).

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the S and 3 m from the W shore at the SW corner of the lagoon (SOP U5). The lagoon characterization measurement data will be collected by the data logger (SOP W6). Lagoon sludge depth measurements (SOP L5) will be made at nine locations in the lagoon (approximate locations indicated in Fig. 3), at approximately 20-d intervals.

Communications

The instrumentation trailer (SOP U4) will be located 10 m E and 30 m S of the NE berm corner (Fig. 3). Telemetry of TDLAS/scanners, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All measurements telemetered to the trailer will be sent to Purdue nightly via wireless DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the separate transformer installed at the street for use by the project. All wiring will be buried directly in the ground and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weather- proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of initial setup and periodically during the year/measurement period as needed.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed.

Emissions determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006b) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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Figure 1. View of the buildings at the farm.

Figure 2. Satellite image of the farm and its surroundings. Lagoon is indicated by the circle.

Table 1. Monthly climate description for the site (Indianapolis, IN).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	12	10	13	12	12	10	9	9	8	8	10	11
Wind speed (mph)[2]	11	11	12	12	10	9	8	7	8	9	11	11
Wind direction[2]	WSW	WSW	SW	SW	WSW	WSW	SW	SW	SW	SW	SW	SW
Morning RH (%)[1]	81	80	80	78	82	83	87	91	91	87	85	83
Afternoon RH (%)[1]	70	67	63	56	56	57	60	62	59	57	66	73
Maximum temp (°F)[1]	36.0	39.3	49.0	62.8	72.9	82.3	85.4	84.0	77.7	67.0	50.5	38.7
Minimum temp (°F)[1]	19.7	22.1	30.3	41.8	51.5	61.1	64.6	62.4	54.9	44.3	32.8	23.1

[1] NCDC (1981)
[2] NCDC (1998)

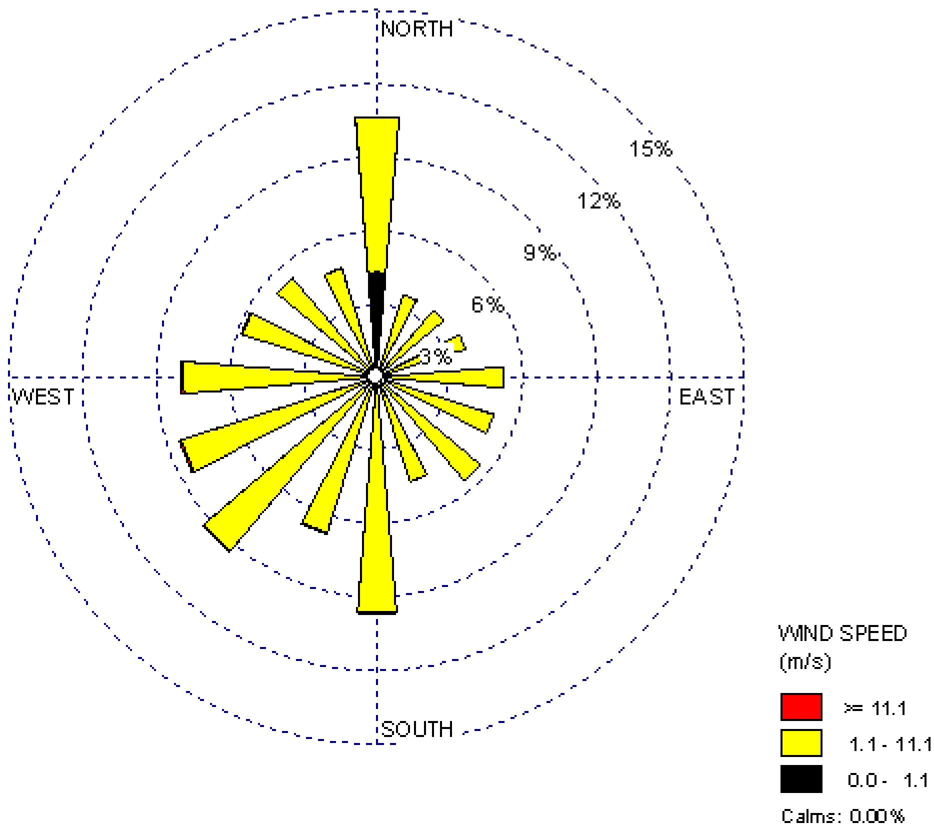

Figure 3. Indianapolis, IN Windrose: 1981-1990. Note that winds of <1.1 m/s are assigned to a nominal N, direction, as they are below the threshold of the NWS anemometers.

Table 2. Characteristics of the lagoon at the site.

Descriptive parameters.	Unit 1
Livestock type	Sows
Year of facility construction	1968-1992
Separation distance from barn fans, ft	1760
Type of storage (basin, lagoon or tank)	Lagoon
Stage of lagoon (1st, 2nd, 3rd)	1st
Manure contributors to unit	
Animal 1 type (sows, cows, etc.)	Sows
Animal 1 average weight (lb)	475
Animal 1 inventory (# head)	1400
Animal 2 type (sows, cows, etc.)	Baby pigs
Animal 2 average weight (lb)	8
Animal 2 inventory (# head)	
Manure collection (flush, scrape, PPR)	Deep pits
Source flush or recharge water (if any)	
Lagoon loading interval, h	Every 2 wks
Minimum space around unit, ft	
Volumetric loading rate, lb VS/d-1000ft^3	2.11 to 2.56
Surface loading rate, lb VS/d-acre	1001 to 1073
Obstructions within 3X height of unit?	No
If yes, what kind? (e.g. trees, barns)	
Height of worst obstruction, ft	n/a
Distance from worst obstruction, ft	n/a
Type of cover (crust, straw, none, etc.)	None
Are solids separated from influent?	No
Odor control	None
Sludge removal cycle, yr	Never
Last time sludge removed (e.g., 1999)	Never
Agitation prior to pumpout?	No
Manure removal frequency, d	365
Pump out (contractor or producer)	Producer
Type of liner	Clay
Volume, ft^3	1,200,000
Surface area, ft^2	121,000
Berm slope	3 :1
Maximum side length, ft	378
Minimum side length, ft	365
Actual freeboard, ft	4
Inner berm height, ft	4
Outer berm height, ft	12
Liquid depth, ft	12
Sludge depth, ft	Unknown
Number of inlets	1
Shape	Rectangular

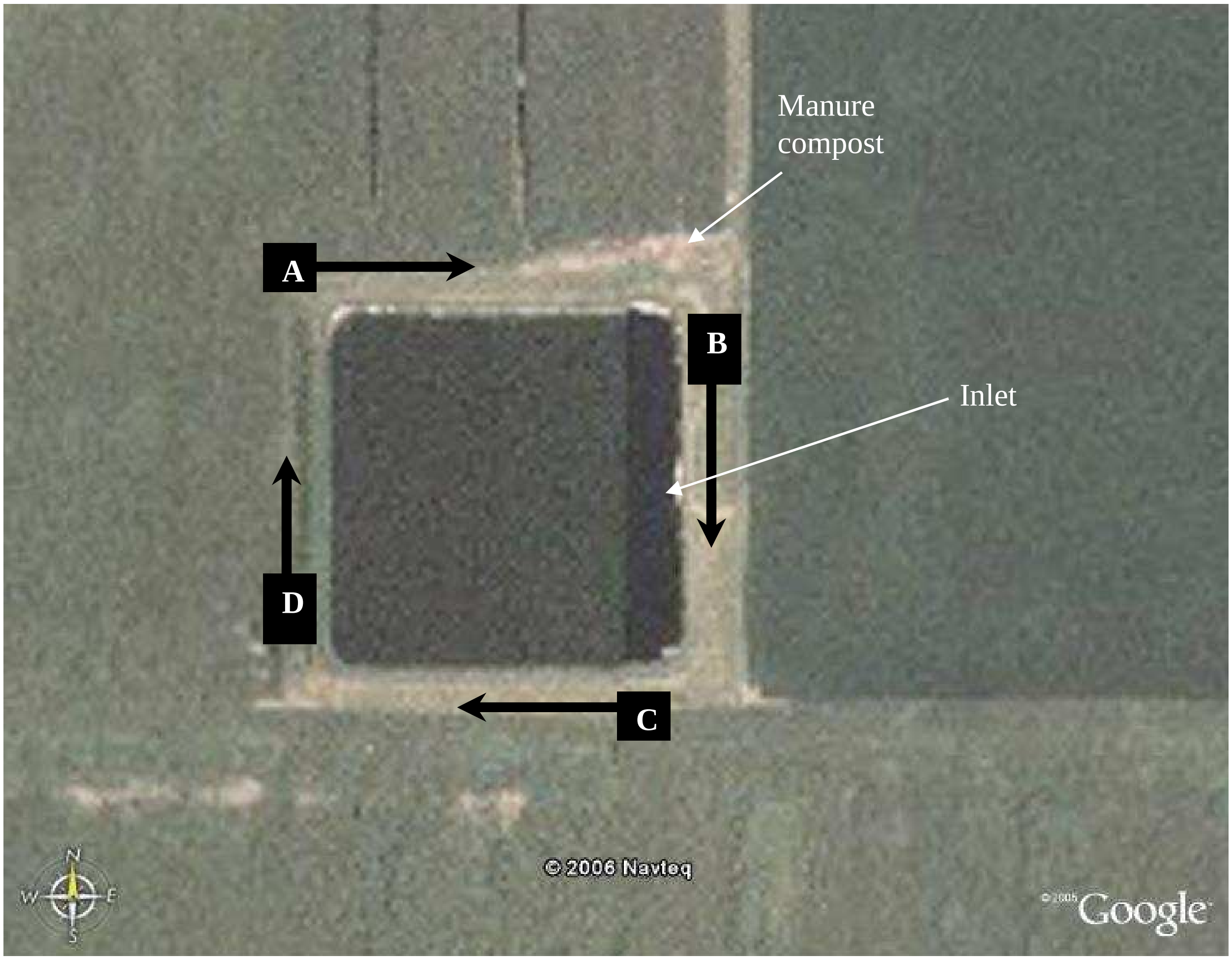

Figure 4. General configuration of the lagoon. The location and direction of view of each photograph described in the measurement plan is indicated by letters (A: N view; B: E view; C: S view; D: W view). Lagoon inlet is indicated, along with an existing manure compost pile that will be moved for the purpose of the study.

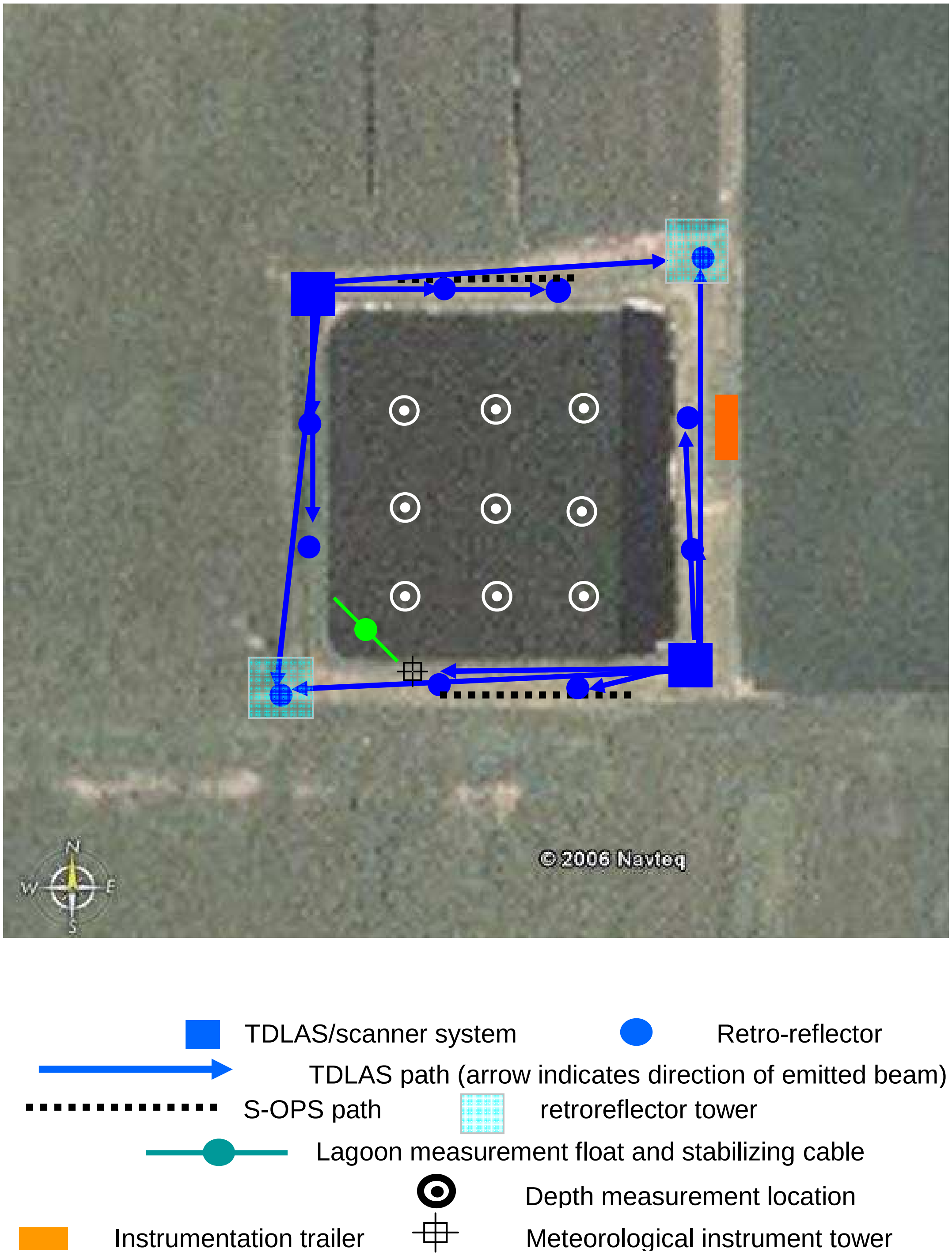

Figure 5. Measurement plan for the lagoon.

SMP IN5A
SITE MONITORING PLAN FOR DAIRY LAGOON IN INDIANA

SMP IN5A
SITE MONITORING PLAN FOR DAIRY LAGOON IN INDIANA

The facility that includes the Midwestern dairy lagoon is located in Cass County, IN. The elevation at the farm is 238 m (781 ft). The magnetic compass variation at this location is 02^{o}E. The dairy consists of three barns, a feed storage area, special needs barn, milking parlor, and an office and tool and repair shops (Fig. 1). The facility as a whole has a capacity of 2600 cows. Construction of the dairy was completed in 2002.

Logistics

Measurements will be made continuously for one year by the continuous lagoon measurement team from Purdue Applied Meteorology Laboratory (PAML) in West Lafayette, IN. The farm is 86 km (54 mi) N of West Lafayette, with a one-way driving time of approximately 1¾ hours.

Climate (Table 1)

The climate for the area is represented by the Fort Wayne, IN National Weather Service weather station, which is approximately 93 km (58 mi) NE of the farm. The area typically receives an average of 883 mm (34.75 inches) of precipitation annually (NCDC, 2001); this is fairly evenly distributed through the year (Table 1). The prevailing winds are from the W to S (Peru, IN; Table 1, Fig. 2). Mean monthly wind speeds range from 2 m/s (5 mph) to 5 m/s (12 mph) (Peru, IN; NCDC, 1998). Average relative humidity (RH) ranges from 37% in the morning to 37% in the afternoon, while air temperatures range from 23.3 ^{o}C (74.0 ^{o}F) to -5.1 ^{o}C (22.9 ^{o}F) (NCDC, 2001). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

Manure is vacuumed from the lactating cow barns and special needs barn every 12 hours, and placed in basins near the barns (Fig. 1). Manure is flushed from the holding area and milking parlor every ½ hour. A small fraction of waste is held in a slurry tank. Wastewater (flush) from the holding area and milking parlor goes to a rectangular settling basin S of the road, then into the waste lagoon S of the road. The clay-lined waste lagoon is 85 m (280 ft) wide and 116 m (380 ft) long, and is oriented N-S. The lagoon bank has a berm slope of 2.5:1. Liquid depth is approximately 5 m (16 ft). Sludge has never been removed from the lagoon.

Surrounding sources

There are no identifiable continuous NH_3 or H_2S emission sources within 1 mi of the measurement location (Fig. 5). Wastewater is spread on a field 250 ft to the S of the waste lagoon (through irrigation) (Fig 1).

Monitoring Plan

Emissions from the lagoon will be monitored continuously for one year using a Synthetic Open Path System (S-OPS) (SOP C4). The NH_3 concentrations will be determined using a photoacoustic spectrometer (PAS) (SOP G7) and scanning Tunable Diode Laser Absorption Spectrometer (TDLAS) open-path instruments (SOP C2), while the H_2S concentrations will be monitored using pulsed-florescence (PF) (SOP G5). NH_3 data, 3-dimensional (3D) sonic anemometer data (SOP W2), and meteorological measurements will be input into the radial plume mapping (RPM) emissions model (SOP O2) to determine NH_3 emissions. H_2S emissions will be generated through radial plume mapping (RPM) (SOP O2), using concentration data, 3-dimensional (3D) sonic anemometer data (SOP W2), meteorological measurements and ratiometric relationships of concentrations.

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3 so as to create vertical measurement planes on each side of the lagoon. Two 15-m (51-ft) towers (SOP U5) will be located at the NE and SW corners of the lagoon. The scanning TDLAS instruments will be mounted at 1 m height above the lagoon berm at the NW and SE corners. The NW corner TDLAS/scanner will be mounted on an anchored tripod at 1 m height (SOP U5). The retro-reflectors on the NE corner tower will be at 1 m, 8 m, and 15 m heights. Retro-reflectors at the 1/3 and 2/3 distance down the lagoon sides will be mounted on anchored tripods (SOP U5) on the respective berm (Fig. 4). The retro-reflectors on the SW corner tower will also be at 1 m, 8 m and 15 m height. The TDLAS laser beam is eye-safe, and presents no hazard to farm workers.

Two S-OPS will be used to collect air along linear paths at 1 m above berm level (abl) along the lagoon berm on two sides of the lagoon for the measurement of VOCs (SOP G7) and H_2S (SOP G5). Each 50-m S-OPS consists of ten orifices spaced at a 5 m interval along the line. S-OPS lines will sample parallel to the N and S sides of the lagoon. The S-OPS along the S side of the lagoon will primarily act as the upwind station, while the S-OPS on the N side of the lagoon will primarily act as the downwind measurement path (Fig. 4).

Meteorological measurements, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3) will be located 10 m W and 30 m S from the NW berm corner (Fig. 4). The data from these meteorological measurements will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2 m height, and on the SW corner tower (Fig. 4) at 4 m and 16 m heights above ground level (Fig. 4) (SOP U5).

The barns 245 m (803 ft) to the N have ridge heights of approximately 8.5 m (28 ft) agl. and therefore a fetch ratio of 27:1 for the lowest TDLAS paths. A single line of trees (approximately 10 m or 30 ft) are 145 m (475 ft) to the W and 77 m to the S, resulting in upwind fetches of 16:1 and 8.5:1 for the TDLAS paths. Fetch to the E is better than 1:100, with the upwind conditions consisting primarily of irrigated crops (Figs. 1 & 5). A description of the position of each measurement path, including a photograph view taken in the directions and locations indicated by the black arrows and letter code in Fig. 3 follows:

N side of lagoon

- 50-m long S-OPS path parallel to and 5 m N of berm beginning 5 m N of NW berm corner extending 50 m E parallel to the berm.
- Retro-reflectors at 33 m, 66 m, and 3 at approx. 99 m on corner tower. The 33-m and 66-m retro-reflectors are mounted on the berm at 1 m height above berm on anchored tripods.
- TDLAS paths approximately parallel to and 5 m N of berm.

Location of N side S-OPS and TDLAS beam path, looking E TDLAS/scanner.

E side of lagoon

- TDLAS paths approximately parallel to the E berm of the lagoon, with retro-reflectors at 42 m, 84 m, and 3 at approx.124 m on the corner towers. The 42-m and 84-m retro-reflectors are mounted on anchored tripods along the berm at 1 m height above berm.
- TDLAS paths 1 - 5 m from berm.

Location of E side TDLAS beam path, looking S towards the location of the 15-m TDLAS retro-reflector tower. Lagoon berm is on right.

S side of lagoon

- 50-m long S-OPS path 1 m above, parallel to, and 5 m S of lagoon berm starting 5 m S of SW corner of berm (in the drainage swale) and running E parallel to the berm.
- Retro-reflectors at 31 m, 63 m, and 3 at approx. 95 m on the corner tower. The 31-m and 63-m retro-reflectors are mounted on the berm at 1 m height above berm on anchored tripods.

Location of S side TDLAS beam path, looking W towards the location of the 15-m TDLAS retro-reflector tower. Lagoon berm is on right.

W side of lagoon

- Retro-reflectors at 42 m, 84 m, and 3 at approx. 125 m on the corner tower.
- The 42 m and 84 m retro-reflectors are mounted on the berm at 1 m height above berm on anchored tripods. TDLAS paths 1 - 5 m from berm.

Location of W side TDLAS beam path, looking N towards the TDLAS/scanner system. Lagoon berm is on right

In addition:

- TDLAS scanner located 1 m E and 5 m S of SE berm corner on an anchored tripod at 1 m height abl.
- TDLAS scanner located 5 m W and 5 m N of NW corner of lagoon mounted at 1 m height abl on an anchored tripod.
- TDLAS tower located 5 m E and 5 m N of NE corner of berm.
- TDLAS tower located 5 m W and 1 m S of SW corner of berm.

Ammonia emissions from the lagoon will be calculated using the RPM model (SOP O2) with data from the three sonic anemometers (SOP W2) and TDLAS measurements (SOP C2). Restrictions on the use of the model are as follows:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are < 1 m/s. Wind speeds (7 m height) at Peru, IN were ≤ 1.1 m/s 3.2% of the time between 1981 and 1990 (NCDC, 2007).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are > 11 m/s. Wind speeds (7 m height) at Peru, IN were ≥ 11.1 m/s or more 2.6% of the time between 1995 and 2006 (NCDC, 2007).

Volatile organic compounds (VOC), including methane, methanol, ethanol, and total VOCs, will be measured using the INNOVA Model 1412 Multi-gas photoacoustic analyzer (SOP G7) from the air sampled using the S-OPS (SOP C4) upwind and downwind of the lagoon (Fig. 4). Measurement data will be collected on the LAN server in the trailer (SOP D1, SOP U4).

The single line of trees to the W and S have upwind fetches of 16:1 and 8.5:1, respectively, which may result in a increased turbulence on the S berm, and the sonic anemometer from which the turbulence statistics for the bLS are derived has a fetch of only 10:1 with the S trees. Thus, the bLS emissions model cannot be used. VOC and H_2S emissions from the lagoon will be calculated using the ratiometric method. The ratio of VOC measured by the S-OPS/PAS or H_2S measured by the S-OPS/PF to the to ammonia measured by TDLAS and the emission of ammonia by the lagoon measured by the RPM method will be used to estimate the VOC and H_2S emission according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006). Restrictions on the use of the model are:

1) The S-OPS path and corresponding TDLAS path are equivalent, such that the NH_3 PIC values can be assumed to represent that along the S-OPS path.

2) The S-OPS air samples from upwind and downwind locations are synoptic. This can be assumed since concentrations will be averaged over ½-hr intervals. The synoptic measurements will provide the ability to determine the ammonia, VOC, and hydrogen sulfide concentration change for the air crossing over the lagoon.

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float that is positioned 3 m N and 3 m W from the SE corner of the lagoon (SOP U5). The lagoon characterization measurement data will be collected on the data logger (SOP W6). Lagoon sludge depth (SOP L5) measurements will be taken at eight locations in the lagoon (Fig. 4) at the beginning or end of each measurement period. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted, or if winds prohibit being able to keep the boat stationary for the measurements.

Animal inventory will also be obtained from the producer, and will be verified every six months by the study personnel (SOP S7).

Communications

The instrumentation trailer (SOP U4) will be located 10 m N of the SE corner of the lagoon (Fig. 4). Telemetry of TDLAS, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All data telemetered to the trailer will be sent to Purdue nightly via wireless DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the producer-supplied source at the S side of the lagoon. All wiring will be buried directly in the ground from the producer-supplied (transformer-reduced 480 VAC 3 phase) source and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weather-proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be minimal due to location on the farm. Furthermore training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of the initial setup, and as needed during the year/measurement period.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be chewed or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals, and will be inspected and repaired or replaced if necessary after each measurement period. .

Power cables are not anticipated to be damaged by animals. All cables and tubing will be inspected at the beginning and end of the measurement periods, and repairs made as needed.

Emissions determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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

Figure 1. Aerial view of the Indiana dairy lagoon site. Image shows the relationship of the lagoon (lower center) to the freestall barns and the milking parlor (upper center). The areas marked P are the scrapping pits from the barns.

Table 1. Monthly climate description for the site (from Fort Wayne/Peru, IN).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	12	10	13	13	12	10	10	9	9	9	11	13
Wind speed (mph)[2]	12	10	10	10	8	7	6	5	6	8	9	10
Wind direction[2]	W	W	W	W	N	S	W	S	S	S	W	W
Morning RH (%)[1]	81	81	80	79	79	81	85	89	89	85	83	83
Afternoon RH (%)[1]	72	69	63	56	55	55	56	59	57	58	68	75
Maximum temp (^oF)[1]	30.4	34.0	46.3	59.8	71.2	80.9	84.6	82.2	75.6	63.1	49.1	35.5
Minimum temp (^oF)[1]	15.3	17.8	28.8	38.5	49.1	59.3	63.2	60.9	54.2	42.5	33.5	21.6

[1] NCDC (2001); Fort Wayne, IN
[2] NCDC (1998); Grissom Air Force Base, Peru, IN

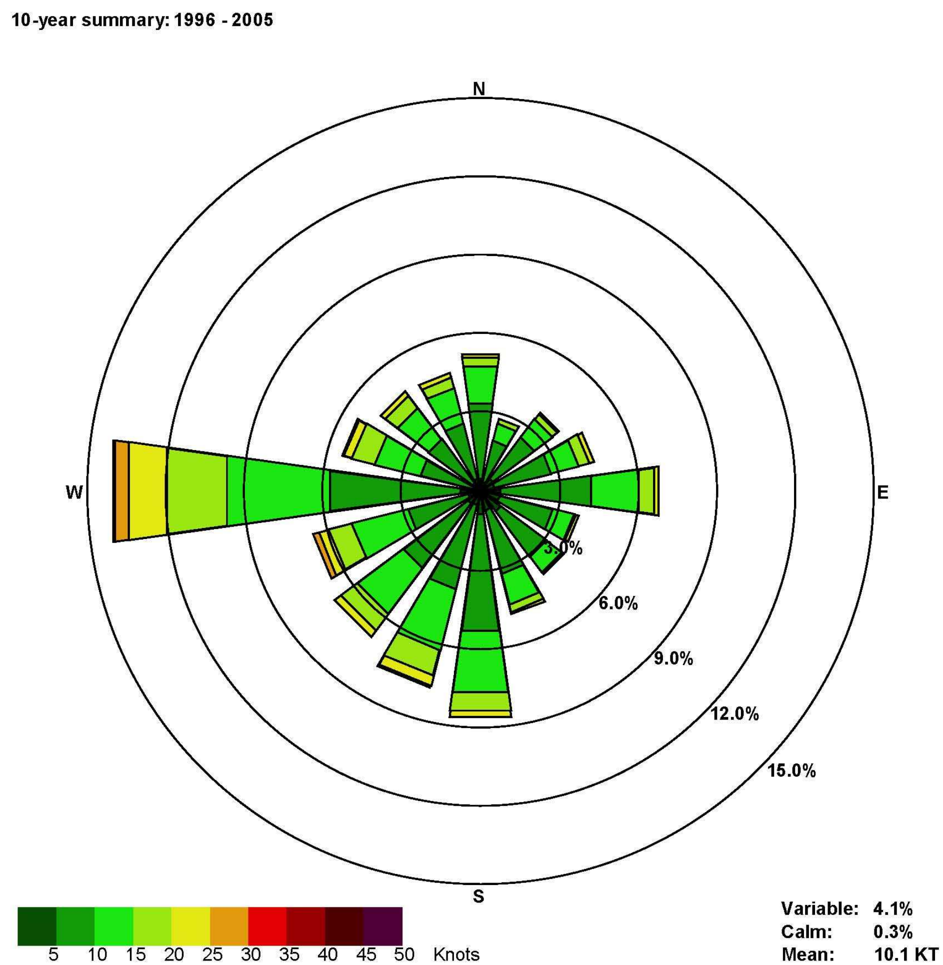

Figure 2. Grissom Air Force base, Peru, IN Windrose: 1996-2005.

Table 2. Characteristics of the manure storage units at the Indiana dairy lagoon site.

Descriptive parameters.	**Unit 1**	**Pits**
Livestock type	Dairy cattle	Dairy cattle
Type of storage	Dirt lagoon	Concrete lagoon
Number of units		
Year of facility construction	2003	2003
Separation distance from barn fans, ft	1000	750
Stage of lagoon (1st, 2nd, 3rd)	1st	2nd
Manure contributors to unit		
Animal 1 type	Cows	Cows
Animal 1 average weight (lb)	1500	1500
Animal 1 inventory (# head)	2600	2600
Manure collection	Flush, Vacuum	Flush, Vacuum
Source flush or recharge water (if any)	Holding pen & milking parlor	Holding pen & milking parlor
Lagoon loading interval, h	2/hr	2/hr
Minimum space around unit, ft		
Volumetric loading rate, lb vs/d-ft^3		
Surface loading rate, lb vs/d-ft^2		
Obstructions within 3X height of unit?	Yes	No
If yes, what kind?	Trees	
Height of worst obstruction, ft	35	
Distance from worst obstruction, ft	200	
Type of cover	None	Crust
Are solids separated from influent?	Yes	
Odor control	None	None
Sludge removal cycle, years	None	10x/yr
Last time sludge removed	Never	11/2007
Agitation prior to pumpout?	Yes	No
Manure removal frequency, days	Irrigation during growing season	Every 40d
Pump out (contractor or producer)	Producer	Both
Type of liner	Clay	Concrete
Volume, ft^3	1,702,400	15,888
Surface area, ft^2	280 x 380	24 x 180
Berm slope	2.5 :1	None
Maximum side length, ft	380	180
Minimum side length, ft	280	24
Actual freeboard, ft	5	3
Inner berm height, ft	10	7
Outer berm height, ft	5	7
Liquid depth, ft	16	4
Sludge depth, ft	0	4
Number of inlets	1	1
Shape	Rectangular	

Figure 3. Closeup of lagoon, showing the locations and directions of the four photos illustrating the measurement paths.

(A – N path view; B – E path view; C – S path view; D – W path view)

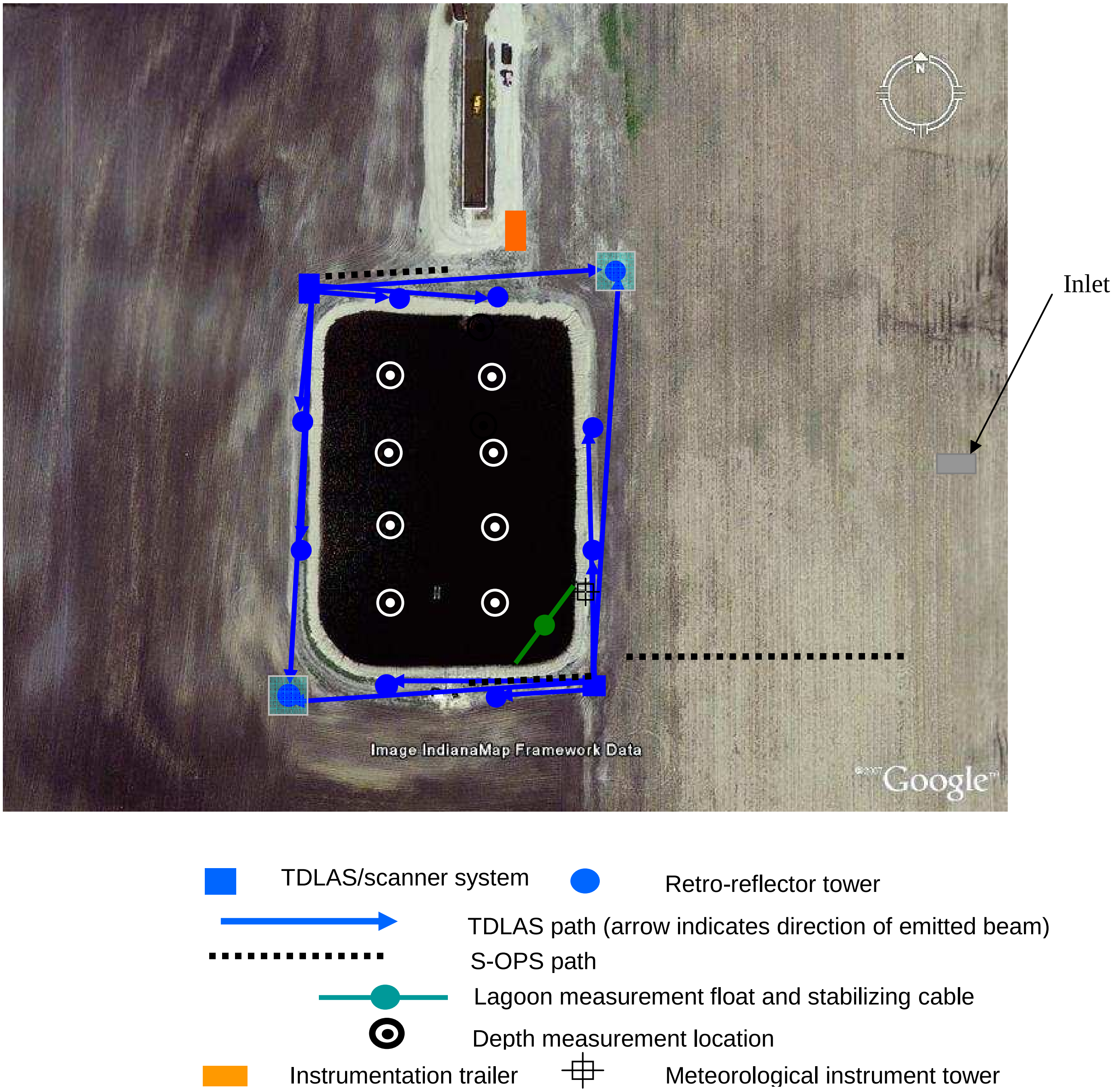

Figure 4. Dimensional plan of the lagoon.

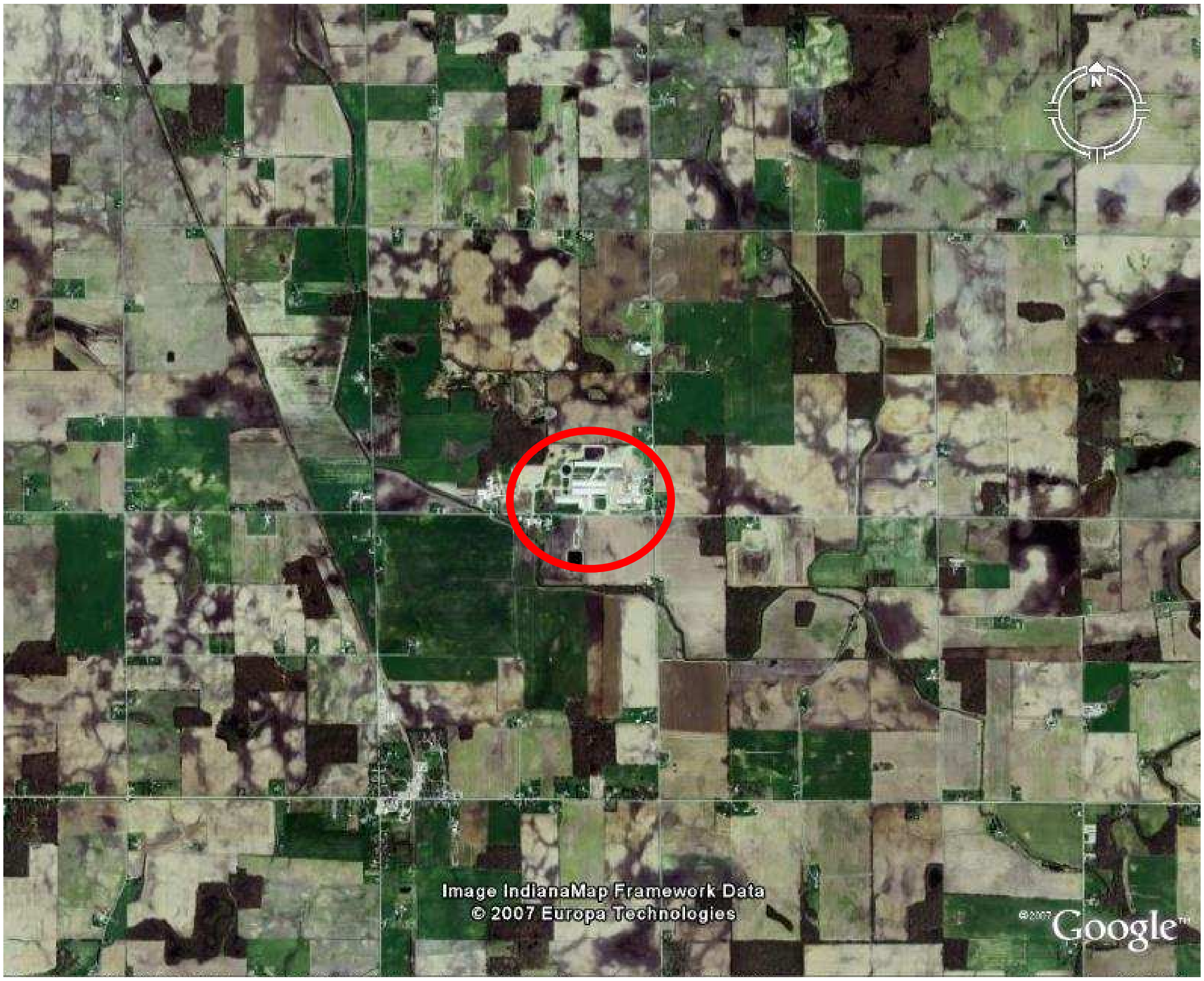

Figure 5. Satellite image of the farm's surroundings.
The farm that will be monitored is indicated by a red circle.

SMP NC3A
SITE MONITORING PLAN FOR FINISHER SWINE LAGOON IN NORTH CAROLINA

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SITE MONITORING PLAN FOR FINISHER SWINE LAGOON IN NORTH CAROLINA

The Southeastern finisher lagoon facility is located in Bladen County, North Carolina. The elevation at the farm is 36 m (119 ft). The magnetic compass variation at this location is 07^{o}W. The farm consists of five barns (Fig. 1) and an office, in addition to the lagoon itself. The facility has a capacity of 8000 finishing pigs in five units. Construction of the farm was completed in 1996.

Logistics

Measurements will be made by one of the rotating measurement teams from Purdue Applied Meteorology Laboratory (PAML) in West Lafayette, IN. The nearest airport is located at Raleigh/Durham, NC. The farm is located 132 km (79 mi))S of the Raleigh/Durham airport, for a one-way driving time of approximately 2 h.

Climate (Table 1)

The climate for the area is represented by the Fayetteville and Raleigh, NC National Weather Service weather stations. The wind climatology is from the Fayetteville station, approximately 32 km (20 mi) NW of the farm. The precipitation, humidity, and temperature climatology is from the Raleigh station, approximately 127 km (79 mi) NW of the farm. The area typically receives an average of 1080 mm (42.5 in) of precipitation (NCDC, 1981). The variation in winds over the year is illustrated in Fig. 2. The prevailing winds are from the SW to WSW during winter, spring, and summer, and N in fall (Table 1). Maximum chances of days with precipitation are during the summer (NCDC, 1981). Mean monthly wind speeds range from 2 m/s (5 mph) to 3 m/s (7 mph) (NCDC, 1998). Relative humidity (RH) ranges from 85% in the morning to 55% in the afternoon, while air temperatures range from 21^{o}C (70^{o}F) to 7^{o}C (48^{o}F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

Manure from the barns is transferred daily to the lagoon by pull plug and lagoon water recharge. Waste water combines into one inlet (Fig. 1). The rectangular waste lagoon is located to the N and separated by a drainage swale from the barns. The clay-lined lagoon is 113 m (370 ft) wide and 173 m (568 ft) long, and is oriented E-W. Liquid depth is variable, and is removed as weather permits. Sludge from the lagoon has not been removed since construction (15-year sludge removal cycle).

Surrounding sources

There are no identifiable NH_3 or H_2S emission sources within one mile of the farm site. The area immediately surrounding the farm is approximately ¾ woodlands and ¼ agricultural fields (Fig. 3).

Biosecurity Requirements

The producer requires that all visitors to the farm meet the following requirements:

- A minimum of 48 hours of downtime from any other swine contact
- No contact with swine in a foreign country in the last 7-10 d.
- No visit to any location with any live birds, or contact with other poultry or domestic birds (including parakeets, parrots, etc) within 48 hours prior to the farm visit.

Monitoring Plan

The NH_3 emissions from the basin will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the basin during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) using a ratiometric emissions calculation method (PAML 2006a). VOC emissions will be monitored using S-OPS sample collection (SOP C4) and INNOVA Photoacoustic spectroscopy (SOP G7) using a ratiometric emissions calculation method (PAML 2006a).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes on each side of the lagoon. Two 15-m (51-ft) towers will be located at the NW and SE corners of the lagoon. The scanning TDLAS instruments will be mounted at 1 m height above the lagoon berm on the berm at the NE and SW corners on anchored tripods (SOP U5). Retro-reflectors at the approximate ⅓ and ⅔ distances down the lagoon sides will also be mounted on the berm at 1 m height on anchored tripods on the respective berm (Fig. 3) (SOP U5). The TDLAS laser beam is eye-safe.

Two S-OPS air collection systems will be used to sample the air along a linear path from which measurements of VOC and H_2S near lagoon berm height on two sides of the lagoon. S-OPS will be mounted at 1 m height parallel to the N and S sides of the lagoon. The S-OPS along the S side of the lagoon will primarily act as the upwind station, while the S-OPS on the N side of the lagoon will primarily act as the downwind measurement path (Fig. 4).

Volatile organic compounds, including methane, methanol, ethanol, and total VOCs, will be measured using the INNOVA Model 1412 (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 4).

Hydrogen sulfide will be measured using pulsed-florescence (SOP G5) from air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 4).

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be located on the berm 30 m W of the NE berm corner (Fig. 4). The meteorological measurement data will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2-m height and the SE corner tower (Fig. 3) at 4-m and 16-m heights above berm level (Fig. 4) (SOP U5).

The barns 20 m (67 ft) to the S of the lagoon berm have an approximate ridge height of 6 m (19 ft) agl (above ground level), resulting in a fetch ratio to the W of 3:10 to the lagoon. Fetch to the E for the wind measurements is 3.5:1 for the 16-m measurement height, 1.3:1 for the 4-m measurement height, and 2.8:1 for the 2-m measurement, with the obstruction to the E of a 23-m (75 ft) deciduous forest canopy. The W obstruction for the 2-m wind measurement is a similar forest at 140 m (460 ft) distance, with a fetch of 6:1. Obstructions to the SW for the other wind measurements are the 5.5-m (18-ft) high farm barns at 50 m (165 ft) distance. The 16-m measurement height should be unaffected by the barns, while the fetch is 33:1 for the 4-m measurement height, indicating a small influence on the westerly flow by the buildings.

The barn exhausts to the S of the lagoon will likely contribute to the upwind NH_3 PIC values under SW winds. The S TDLAS measurement plane and the S berm S-OPS PIC values will be the upwind measurements for the SW flow NH_3 emissions measurements.

Configuration specifics:
A TDLAS/ scanner is located at the NE and SW corners of the lagoon berm, each mounted at 1 m agl on an anchored tripod (Fig. 4). Fixed triangular retro-reflector towers are located 25 m N of the NW berm corner and 15 m S and 18 m E of the SE berm corner (Fig. 4).

A description of the position of equipment on each measurement path follows:

N side of lagoon

- 50 m S-OPS path 1m abl.
- S-OPS path begins at the NE berm corner and extends W 50 m.
- TDLAS retro-reflectors will be located at 60.5 m and 112 m down the berm from the scanner at the NE corner for the berm. The 60.5-m and 112-m retro-reflectors are mounted on anchored tripods on the berm at 1 m height above berm.
- Three retro-reflectors are mounted on a tower off the NW berm corner at 207.5 m from the scanner at the NE corner.

N berm looking W towards NW retro-reflector tower location.

E side of lagoon

- TDLAS retro-reflectors will be located at 40.5 m and 77.5 m along the berm from the NE corner scanner, and 3 at approximately 130 m path length to the

E berm looking S towards SE retro-reflector tower location.

SE corner tower. The 40.5-m and 77.5-m retro-reflectors are mounted on the berm at 1-m height on anchored tripods.

S side of lagoon

- 50 m S-OPS path 1m abl.
- S-OPS path begins at the SW berm corner and extends E 50 m.
- TDLAS retro-reflectors will be located at 57.5 m and 110 m E along the berm from the SW corner scanner, and 3 retro-reflectors with a 183 m path length to the SE corner tower.
- The 57.5-m and 110-m retro-reflectors are mounted on the berm at 1 m abl, using an anchored tripod.

S berm looking W towards TDLAS/ scanner location.

W side of lagoon

- TDLAS retro-reflectors will be located at 53 m and 89.5 m N along the W berm from the scanner, and 3 retro-reflectors at a 135.5 m path to the fixed tower from the TDLAS/scanner.
- The 53-m and 89.5-m retro-reflectors are mounted on the berm at 1 m above berm.

W berm looking S towards SE retro-reflector tower location.

Ammonia emissions from the lagoon are calculated using the Radial Plume Mapping (RPM) model (SOP O2), with data from the sonic anemometer (SOP W2) and TDLAS measurements (SOP C2). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are <1 m/s. Wind speeds at Raleigh, NC (at 7-m height) were ≤1.1 m/s 6.9% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are >11 m/s. Wind speeds at 7-m height at Raleigh, NC were ≥11.1 m/s 0.1% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS path-integrated concentration (PIC) measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane for all four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

VOC and H_2S emissions from the lagoon will be calculated using the ratiometric method. The ratio of VOC measured by the S-OPS/PAS or H_2S measured by the S-OPS/PF to the to ammonia measured by TDLAS and the emission of ammonia by the lagoon measured by the RPM method will be used to estimate the VOC and H_2S emission according to the National Air Emissions

Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006). Restrictions on the use of the model are:

1) The S-OPS path and corresponding TDLAS path are equivalent such that the NH_3 PIC values can be assumed to represent that along the S-OPS path.
2) The S-OPS air samples from upwind and downwind locations are synoptic. This can be assumed since concentrations sampled from the S-OPS sampled air will be averaged over ½ hr intervals. The synoptic measurements will provide the ability to determine the ammonia and hydrogen sulfide concentration change for the air crossing over the lagoon.

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the N and 3 m from the E shore of the NE corner of the lagoon (SOP U5). The lagoon characterization measurement data will be collected by the data logger (SOP W6). Lagoon sludge depth measurements (SOP L5) will be made at nine locations in the lagoon (locations shown in Fig. 4) at the beginning or end of each measurement period. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted or if winds prohibit being able to keep the boat stationary for the measurements.

Communications

The instrumentation trailer (SOP U4) will be located approximately10 m W and 10 m S of the SE corner of the lagoon (Fig. 4). Telemetry of TDLAS/scanners, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All measurements telemetered to the trailer will be sent to Purdue nightly via cellular DSL (SOP D1).

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Emissions Determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. The H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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Figure 1. Aerial view of lagoon, showing relationship to the barns. Red lines indicate soils delineations, and not a physical property boundary.

Inlet

Table 1. Monthly climate description (Fayetteville/Raleigh, NC).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	10	10	11	9	10	9	11	10	8	7	8	9
Wind speed (mph)[2]	5	6	6	6	5	5	3	3	3	3	3	5
Wind direction[2]	WSW	WSW	W	SW	SW	WSW	SW	SW	NE	N	N	WSW
Morning RH (%)[1]	79	76	81	81	87	88	91	93	93	90	85	81
Afternoon RH (%)[1]	56	50	50	45	55	58	59	60	60	54	52	55
Maximum temp (°F)[1]	51.0	53.2	61.0	72.2	79.7	85.6	87.7	86.8	81.5	72.4	62.1	51.9
Minimum temp (°F)[1]	30.0	31.1	37.4	46.7	55.4	63.1	67.2	66.2	59.7	48.0	37.8	30.5

[1] NCDC (1981)
[2] NCDC (1998)

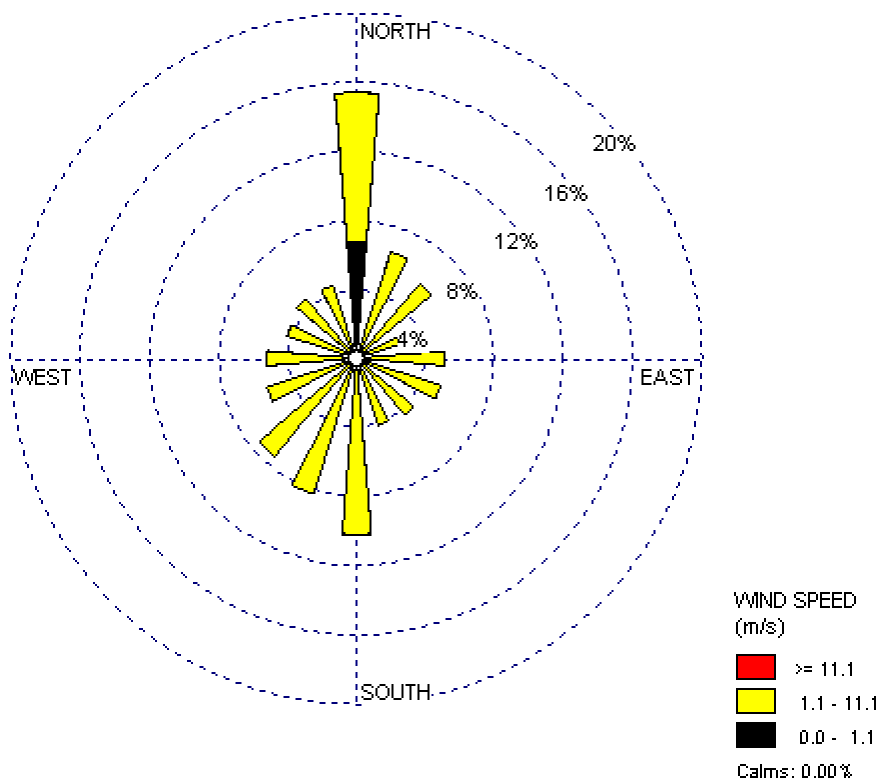
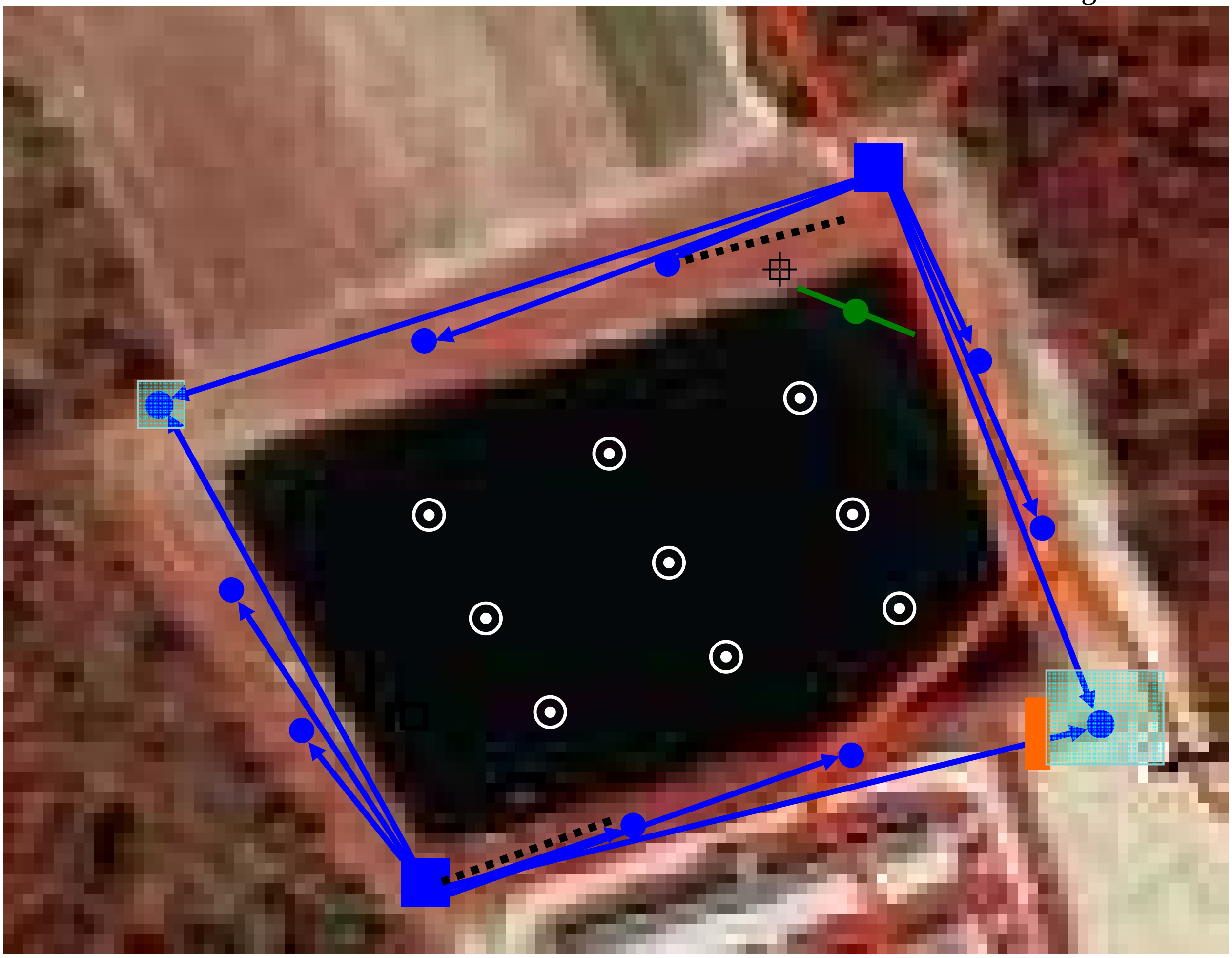


Figure 2. Raleigh Windrose, 1981-1990. Note that winds of <1.1 m/s are assigned to a nominal N, direction, as they are below the threshold of the NWS anemometers.

Table 2. Characteristics of lagoon at the NC finisher site.

Descriptive parameters.	Unit 1
Livestock type	Finishing
Year of facility construction	1996
Separation distance from barn fans, ft	60
Type of storage	Lagoon
Stage of lagoon (1st, 2nd, 3rd)	1st
Manure contributors to unit	
Animal 1 type (sows, cows, etc.)	Finishing swine
Animal 1 average weight (lb)	135
Animal 1 inventory (# head)	8000
Manure collection (flush, scrape, PPR)	Pit recharge
Source flush or recharge water	Lagoon
Lagoon loading interval, h	24
Minimum space around unit, ft	?
Volumetric loading rate, lb/d-1000ft^3	5.7
Surface loading rate, lb VS/d-acre	2006
Obstructions within 3X height of unit?	Yes
If yes, what kind?	Trees
Height of worst obstruction, ft	75
Distance from worst obstruction, ft	150
Type of cover (crust, straw, none, etc.)	None
Are solids separated from influent?	No
Odor control	
Sludge removal cycle, yr	15
Last time sludge removed (e.g., 1999)	Never
Agitation prior to pumpout?	No
Manure removal frequency, d	As weather permits
Pump out (contractor or producer)	Producer
Type of liner	Clay
Volume, ft^3	1,623,326
Surface area, ft^2	204,386
Berm slope	3:1
Maximum side length, ft	567.5
Minimum side length, ft	370
Actual freeboard, ft	-
Inner berm height, ft	-
Outer berm height, ft	-
Liquid depth, ft	-
Sludge depth, ft	1.9
Number of inlets	1
Shape	Rectangular

Figure 3. Satellite image of surroundings. Red lines indicate soils delineations, and not a physical property boundary.



TDLAS/scanner system — Retro-reflector — Tower

TDLAS path (arrow indicates direction of emitted beam)

S-OPS path

Lagoon measurement float and stabilizing cable

Depth measurement location

Instrumentation trailer — Meteorological instrument tower

Figure 4. Dimensional plan of the lagoon.

SMP NC4A
SITE MONITORING PLAN FOR SOW FARM LAGOON IN NORTH CAROLINA

SMP NC4A
SITE MONITORING PLAN FOR SOW FARM LAGOON IN NORTH CAROLINA

The Southeastern sow facility is located in Duplin County, North Carolina. The elevation at the farm is 59 m (170 ft). The magnetic compass variation at this location is 08^{o}W. The farm consists of three barns – one each of gestation, breeding, and farrowing – and an office (Fig. 1). The facility has a capacity of 2000 sows in three units. Construction of the farm was completed in 1994.

Logistics

Measurements will be made by one of the rotating measurement teams from Purdue Applied Meteorology Laboratory (PAML) in West Lafayette, IN. The nearest airport is located at Raleigh/Durham, NC. The farm is located 108 km (65 mi) SE of the Raleigh/Durham airport, with a one-way driving time of approximately 1 h.

Climate (Table 1)

The climate for the area is represented by the Goldsboro and Raleigh, NC National Weather Service weather stations. The wind climatology is from the Goldsboro station, which is approximately 32 km (20 mi) N of the farm. The precipitation, humidity, and temperature climatology is from the Raleigh station, approximately 104 km (65 mi) N of the farm. The area typically receives an average of 1080 mm (42.5 in) of precipitation (NCDC, 1981). The variation in winds over the year is illustrated in Fig. 2. The prevailing winds are from the S during spring and summer, and N during the fall and winter (Table 1). Maximum chances of days with precipitation are during the summer (NCDC, 1981). Mean monthly wind speeds range from 2 m/s (5 mph) to 3 m/s (7 mph) (NCDC, 1998). Relative humidity (RH) ranges from 85% in the morning to 55% in the afternoon, while air temperatures range from 21^{o}C (70^{o}F) to 7^{o}C (48^{o}F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

Manure from the barns is transferred once a week from the gestation, farrowing, and breeding barns to the lagoon by pull plug and lagoon water recharge. Waste water from all three buildings combines into one inlet (SW corner of lagoon- Fig. 1). The waste lagoon is located to the N of the barns. The clay-lined trapezoidal-shaped lagoon is 123 m (410 ft) wide and 187 m (624 ft) long, and is oriented E-W. The lagoon bank is clay, with a berm slope of 3:1. Liquid depth is approximately 2.5 m (8 ft), while the sludge depth is approximately 0.7 m (2 ft). Liquid is removed as weather permits. Sludge from the lagoon has not been removed since construction (15-yr sludge removal cycle).

Surrounding sources

There are no identifiable NH_3 or H_2S emission sources within one mile of the farm site (Fig. 3).

Biosecurity Requirements

The producer requires that all visitors to the farm meet the following requirements:

- A minimum of 48 hours of downtime from any other swine contact
- No contact with swine in a foreign country in the last 7-10 days
- No visit to any location with any live birds, or contact with other poultry or domestic birds (including parakeets, parrots, etc) within 48 hours prior to the farm visit.

Monitoring Plan

The NH_3 emissions from the basin will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the basin during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, and the backward Lagrangian Stochastic model (SOP O1). VOC emissions will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and air sampled using the S-OPS (SOP C4) and analyzed by the INNOVA (SOP G7). Measurement data will be collected on the LAN server in the trailer (SOP D1, SOP U4).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes on each side of the lagoon. Two fixed 15-m (51-ft) towers (SOP U5) will be located at the NW and SE corners of the lagoon (Fig. 4). The scanning TDLAS instruments will be mounted at 1 m height above the lagoon berm on the berm at the NE and SW corners. The TDLAS/scanners will be mounted at 1 m height on anchored tripods (SOP U5). Retro-reflectors at the approximate ⅓ and ⅔ distance down the lagoon sides will also be mounted on the berm at 1 m height on anchored tripods (SOP U5) on the respective berm (Fig. 3). The TDLAS laser beam is eye-safe.

Two S-OPS systems (SOP C4) will collect the gas along linear paths at 1 m abl on opposite sides of the lagoon for the measurement of the synthetic PIC of H_2S and various VOC. Each 50-m S-OPS consists of ten orifices spaced 5 m apart. Since the prevailing winds are N or S, the S-OPS will usually be positioned to the N and S of the lagoon (Fig. 4). Changes in anticipated wind direction will result in the use of the alternate E and W paths (Fig. 4).

Volatile organic compounds, including methane, methanol, ethanol and total VOCs, will be tentatively measured using an INNOVA 1412 multi-gas photoacoustic analyzer (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the basin (Fig. 4).

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be located on the berm 30 m S of the NE berm corner (Fig. 4). The meteorological measurement data will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2 m height and on the SE corner tower (Fig. 4) at 4 m and 16 m heights above berm level (Fig. 4) (SOP U5).

The barns 20 m (67 ft) to the S of the lagoon berm have an approximate ridge height of 6 m (19 ft) agl, resulting in a fetch ratio to the S of 10:3 to the surface of the lagoon. Fetch for winds from the E (cropland) for the wind measurements is 1:100 for the all measurement heights. Fetch to the W for the wind measurements is limited by a 23-m (75-ft) deciduous tree line. The fetch to the W for the 2-m wind measurement is 1:14. Fetch to the W for the 4-m wind measurement (influenced by the 5.5-m (18-ft) high breeding building) is 1:15. Fetch to the W for the 16-m height wind measurement (influenced by the 23-m (75-ft) high tree line at a 287-m (950-ft) distance) is 1:41. Consequently, all wind measurements should be relatively unaffected by upwind conditions. The fan exhaust from the northernmost barn is to both the E and W. The fan exhaust from the middle barn is to the W.

Configuration specifics:
The TDLAS/ scanners are located on the NE and SW corners of the lagoon berm, mounted at 1 m above berm height on anchored tripods (Fig. 4). TDLAS retro-reflectors are mounted on two 15-m (51-ft) fixed triangular towers located 16 m N of the NW berm corner and 10 m S and 17 m E of the SE berm corner (Fig. 4).

A description of the position of each measurement path, with photographs showing the views corresponding to the locations and directions indicated in Fig. 1 follows:

N side of lagoon

- 50 m length S-OPS path 1 m abl.
- S-OPS beginning at NE berm corner extending W.
- TDLAS retro-reflectors will be located 59 m and 116 m W of the TDLAS/ scanner on the NE berm corner.
- Three retro-reflectors are mounted on the tower at the NW corner with a 184-m path length. The 59-m and 116-m retro-reflectors are mounted on the berm at 1 m height using anchored tripods.

N of N berm looking SW. Lagoon is between berm and barns.

E side of lagoon

- TDLAS retro-reflectors will be located 44 m and 83 m S of the TDLAS/ scanner at the NE berm corner. The 44-m and 83-m retro-reflectors are mounted on the

berm at 1 m height using anchored tripods.
- Three retro-reflectors are mounted on the SE corner tower 135 m S of the TDLAS/ scanner on the NE berm corner.

Location of E side TDLAS beam path, looking S towards the location of the 15-m TDLAS retro-reflector tower. Lagoon berm is on right.

S side of lagoon
- 50-m long S-OPS path 1 m abl
- S-OPS beginning 62 m E of the SW berm corner extending E.
- TDLAS retro-reflectors will be located at 62 m and 126 m E from the TDLAS/scanner at the SW berm corner. The 62-m and 126-m retro-reflectors are mounted on the berm at 1 m height on anchored tripods.
- Three retro-reflectors are mounted on the tower in the SE corner of the lagoon with a path length of 210 m E of the scanner.

S berm looking from the NE berm corner.

W side of lagoon
- TDLAS retro-reflectors will be located 46 m and 90 m N from the TDLAS/scanner located at the SW berm corner. The 46-m and 90-m retro-reflectors are mounted on the berm at 1 m height using an anchored tripod.
- Three retro-reflectors are mounted on the NW corner tower, approximately 150 m N of the scanner.

Location of W side TDLAS beam path, looking N towards the TDLAS tower location. Lagoon berm is on right.

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2), with data from the three sonic anemometers (SOP W2) and TDLAS measurements (SOP C2). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are <1 m/s. Wind speeds at Raleigh, NC (at 7-m height) were ≤1.1 m/s 6.9% of the time between 1981 and 1990 (NCDC, 1998).

2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are >11 m/s. Wind speeds at 7-m height at Raleigh, NC were ≥11.1 m/s 0.1% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS path-integrated concentration (PIC) measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane for all four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

VOC and hydrogen sulfide emissions from the lagoon will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and gaseous measurements of air collected through the S-OPS (SOP C4). Restrictions on the use of the model are as follows:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid; although the surrounding area of the farm is open cropped land, the farm has additional roughness elements (a building to the S, and a tree line to the W of the lagoon). The aerodynamic roughness of the 19-ft high barns contributes to non-homogeneous surface roughness. The barns and other buildings are 20 m (67 ft) to the S of the lagoon berm (Fig. 4), and the prevailing winds are W, SW, or N (Table 1). This will reduce the impact of the buildings on airflow around the lagoons.
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period, since winds are consistent in direction and speed much of the year. The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006). The breeding barn exhaust is 20 m (65 ft) from the S berm TDLAS measurement plane, and 27 m (90 ft) from the S S-OPS sampling path that is 10 m S of the berm, and therefore is not expected to strongly influence emissions into the lagoon.
3) The concentration (PIC) measurements of upwind and downwind air sampled by the S-OPS must be synoptic. This can be assumed since concentrations sampled from the S-OPS sampled air will be averaged over ½ hr intervals. There will be loss of emission measurements when the winds do not provide an upwind and downwind pair of PIC measurements.
4) Emission measurements will be invalidated when the friction velocity is <0.15 m/s. This corresponds approximately with wind speeds of 1.1 m/s. For wind measurements made at Raleigh (at the 7-m height), this occurred only 6.9% of the time between 1981 and 1990 (NCDC, 1998).

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the N and 3 m from the E shore of the NE corner of the lagoon (SOP U5). The lagoon characterization measurement data will be collected by the data logger (SOP W6). Lagoon sludge depth measurements (SOP L5) will be made at nine locations in the lagoon (approximate locations indicated in Fig. 4) at the beginning or end of each measurement period. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted or when winds are too high to keep the boat stationary during measurements.

Communications

The instrumentation trailer (SOP U4) will be located 20 m S of the SE corner of the lagoon (Fig. 3). Telemetry of TDLAS/scanners, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All measurements telemetered to the trailer will be sent to Purdue nightly via cellular DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the producer-supplied source. All wiring will be buried directly in the ground from the producer-supplied source and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weather proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of initial setup and periodically during the year/measurement period as needed.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed

Emissions Determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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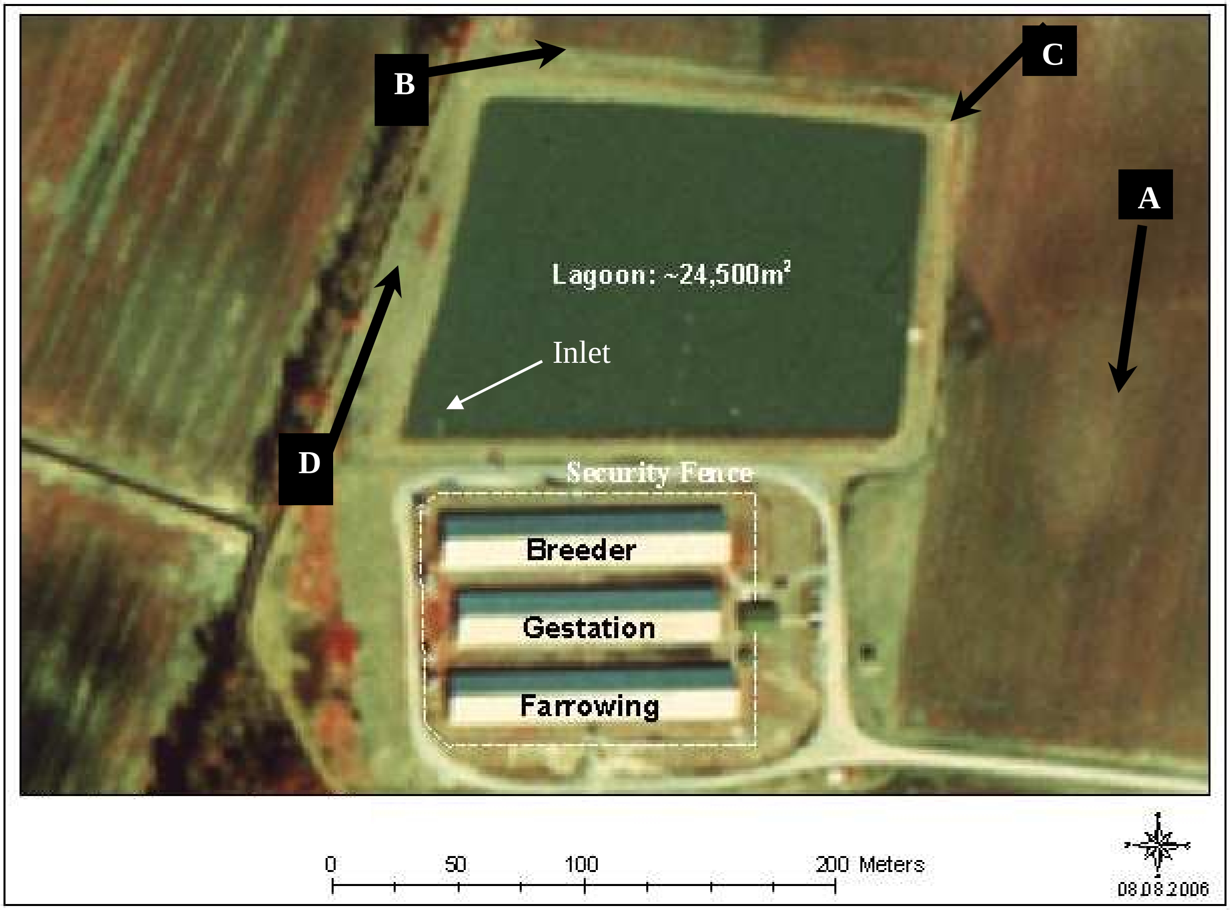

Figure 1. General layout of the farm and configuration of the lagoon. The location and direction of view of each photograph described in the measurement plan is indicated by letters (A: N view; B: E view; C: S view; D: W view).

Table 1. Monthly climate description for the NC sow site (Goldsboro/Raleigh, NC).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	10	10	11	9	10	9	11	10	8	7	8	9
Wind speed (mph)[2]	6	7	7	7	6	5	5	5	5	5	5	6
Wind direction[2]	N	N	N	SW	S	S	S	S	NNE	N	N	W
Morning RH (%)[1]	79	76	81	81	87	88	91	93	93	90	85	81
Afternoon RH (%)[1]	56	50	50	45	55	58	59	60	60	54	52	55
Maximum temp (°F)[1]	51.0	53.2	61.0	72.2	79.7	85.6	87.7	86.8	81.5	72.4	62.1	51.9
Minimum temp (°F)[1]	30.0	31.1	37.4	46.7	55.4	63.1	67.2	66.2	59.7	48.0	37.8	30.5

[1] NCDC (1981)
[2] NCDC (1998)

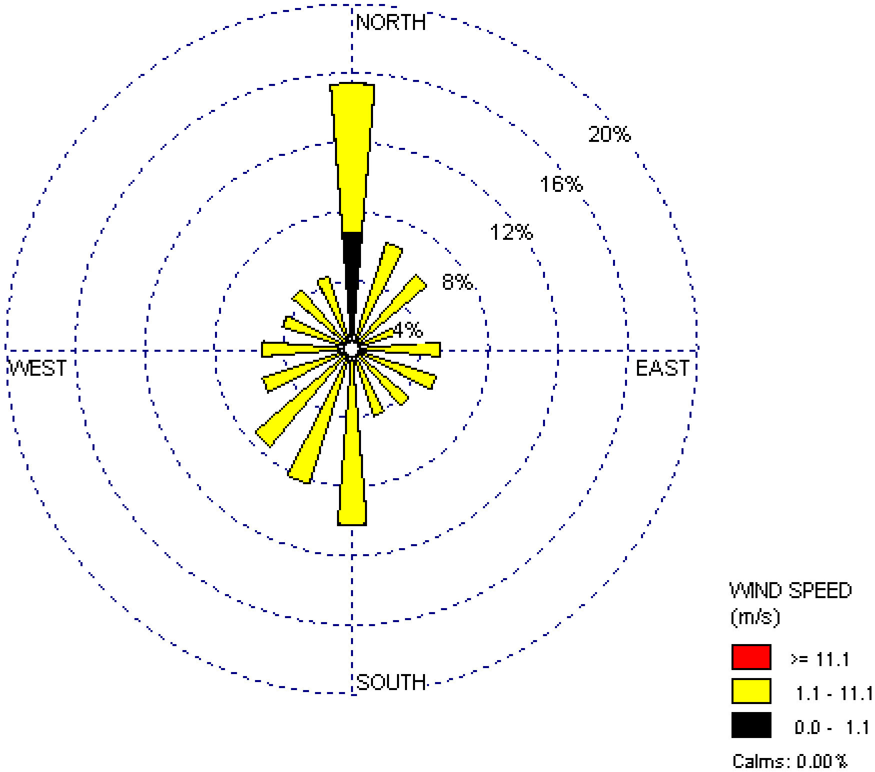

Figure 2. Raleigh Windrose, 1981-1990. Note that winds of <1.1 m/s are assigned to a nominal N, direction, as they are below the threshold of the NWS anemometers.

Table 2. Characteristics of the lagoon at the NC sow farm.

Descriptive parameters.	Unit 1
Livestock type	Sow (farrow-wean)
Year of facility construction	1994
Separation distance from barn fans, ft	100
Type of storage (basin, lagoon or tank)	Lagoon
Stage of lagoon (1st, 2nd, 3rd)	1st
Manure contributors to unit	
Animal 1 type (sows, cows, etc.)	Sows (farrow-wean)
Animal 1 average weight (lb)	433
Animal 1 inventory (# head)	2000
Manure collection (flush, scrape, PPR)	Pit recharge
Source flush or recharge water (if any)	Lagoon
Lagoon loading interval, hr	1X per week
Minimum space around unit, ft	?
Volumetric loading rate, lb VS/d-1000ft^3	1.82
Surface loading rate, lb VS/acre-d	692
Obstructions within 3X height of unit?	Yes
If yes, what kind? (e.g. trees, barns)	Trees
Height of worst obstruction, ft	75
Distance from worst obstruction, ft	150
Type of cover (crust, straw, none, etc.)	None
Are solids separated from influent?	No
Odor control: (digester, additives)	None
Sludge removal cycle, yr	15
Last time sludge removed (e.g., 1999)	Never
Agitation prior to pumpout?	No
Manure removal frequency, d	As weather permits
Pump out (contractor or producer)	Producer
Type of liner (clay, plastic, etc.)	Clay
Volume, ft^3	2007450
Surface area, ft^2	249672
Berm slope (e.g. 3:1, 3.5:1, etc.)	3:1
Maximum side length, ft	624
Minimum side length, ft	410
Actual freeboard, ft	-
Inner berm height, ft	-
Outer berm height, ft	-
Liquid depth, ft	10 total
Sludge depth, ft	2.33
Number of inlets (show on drawings)	?
Shape (rectangular, oval, etc.)	Rectangular

Figure 3. Satellite image of the farm's surroundings.

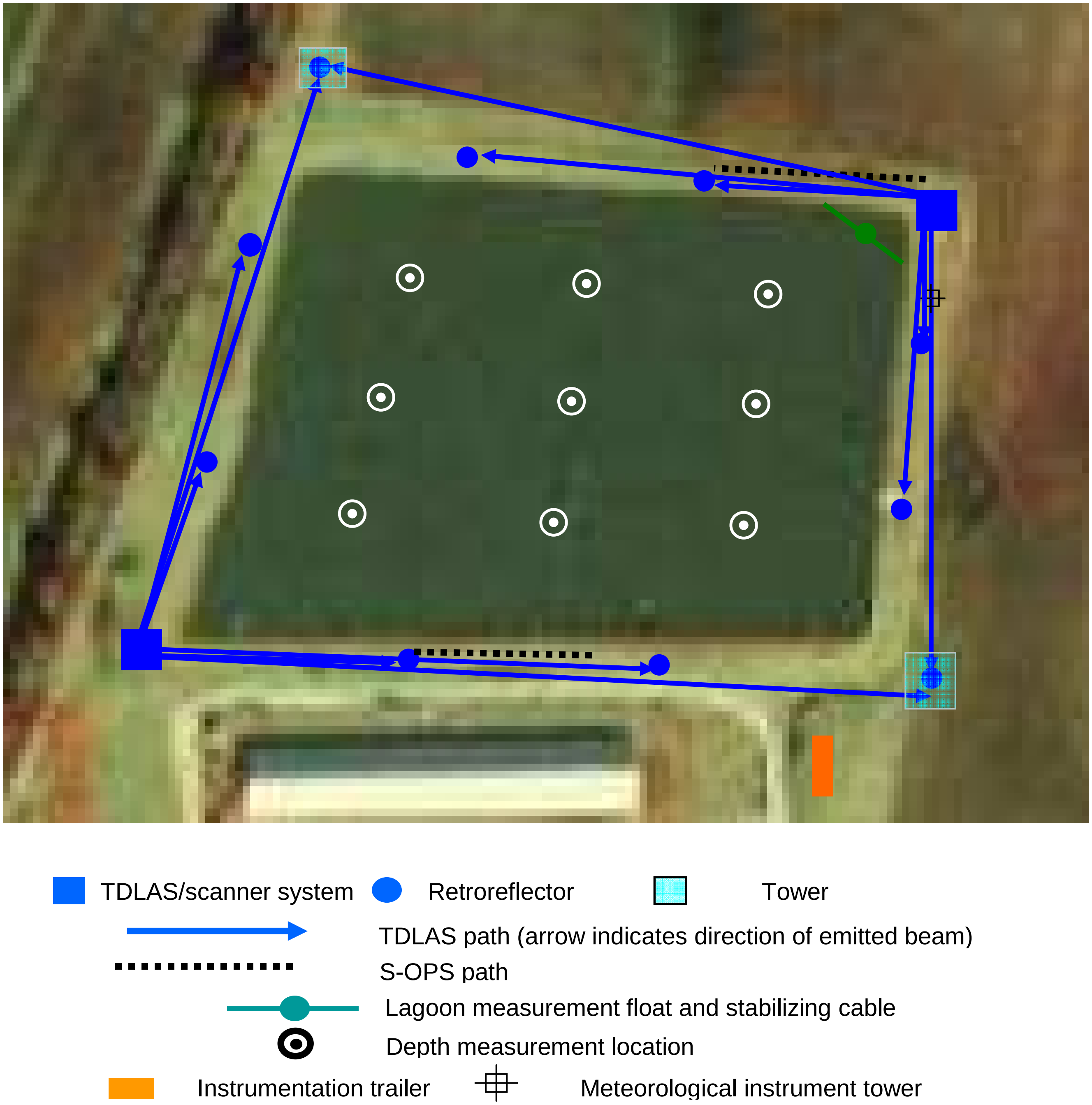

Figure 4. Measurement plan for the lagoon. The exact location of S-OPS depends on wind direction; both seasonally-dependent locations are indicated.

SMP OK3A
SITE MONITORING PLAN FOR WEST FINISHER LAGOON SITE

SMP OK3A
SITE MONITORING PLAN FOR WEST FINISHER LAGOON SITE

The Western finisher facility is located near Guymon, Oklahoma. The elevation at the farm is 927 m (3051 ft), the magnetic compass variation at this location is 09^{o}E. The farm consists of three barns (Fig. 1). The facility has a maximum capacity of 3,024 finishing pigs. Construction was completed in 1997.

Logistics

Measurements will be made by one of the rotating measurement teams from Purdue Applied Meteorology Laboratory in West Lafayette, IN. Airports are located in both Amarillo, TX and Liberal, KS. The farm is located 200 km (120 mi) N of Amarillo, TX and 67 km (40 mi.) SE of Liberal, KS. Driving times from the two airports are approximately 2 h and 1 h, respectively.

Climate (Table 1)

The climate for the area is represented by the Amarillo, TX, National Weather Service weather station, which is approximately 188 km (117 mi) S of the farm. The area typically receives an average of 515 mm (20.28 inches) of precipitation (NCDC, 1981). The prevailing winds are from the S to SW during summer, fall and winter and N in spring (NCDC, 1998). Maximum chances of days with precipitation are during the summer (NCDC, 1981). Mean monthly wind speeds range from 6 m/s (13 mph) to 7 m/s (16 mph) (NCDC, 1998). Average relative humidity (RH) ranges from 72% in the morning to 45% in the afternoon, while average air temperatures range from 22^{o}C (71^{o}F) to 7^{o}C (44^{o}F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

Manure from the barns is transferred three times a week to the lagoon by a pull plug system with lagoon water recharge. Waste water from all three units combines into one inlet. The waste lagoon is rectangular and is located to the W of the barns (separated by a drainage swale). The clay-lined lagoon is 59 m (195 ft) wide and 210 m (689 ft) long, and is oriented N-S. The lagoon bank is clay, with a berm slope of 3.8:1. Liquid depth is approximately 6 m (20 ft) with an inner berm-to-water distance of 0.6 m to 1.2 m (2 to 4 ft). Liquid is removed approximately every six months. Sludge from the lagoon has not been removed since construction (20-yr sludge removal cycle).

Surrounding sources

The nearest sources of identifiable NH_3 or H_2S emission are four different farrow-to-finish swine farms; 1 mi to the E, ½ mi to the N, S, SE and SW. A cattle stockyard is 1 ½ mi S of the site. There are more than 20 farms within a 5-mi radius of the site.

Monitoring Plan

The NH_3 emissions from the basin will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the basin during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, and the backward Lagrangian Stochastic model (SOP O1). VOC emissions will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and air sampled using the S-OPS (SOP C4) and analyzed by the INNOVA (SOP G7). Measurement data will be collected on the LAN server in the trailer (SOP D1, SOP U4).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes on each side of the lagoon. Two 17-m (56-ft) towers will be located at the NE and SW corners of the lagoon, while maintaining an approximately 4-m right-of-way from the county roads. The scanning TDLAS instruments will be mounted at 1-m height above the lagoon berm at the NW and SE corners. Since the berm is less than 1 m high all around the lagoon, the TDLAS/scanners will be mounted at 1-m height on anchored tripods. Retro-reflectors at the 1/3 and 2/3 distance down the lagoon sides will also be mounted at 1-m height on anchored tripods on the respective berm (Fig. 2). The TDLAS laser beam is eye-safe, and presents no hazard to farm workers.

Two S-OPS systems (SOP C4) will be used to collect the gas for the measurement of the synthetic PIC of H_2S and various VOC near lagoon berm height on two sides of the lagoon. Since the prevailing winds are N, SSW, S, and SW, a S-OPS will be positioned to the N of the N berm of the lagoon and another S of the S berm. The S-OPS along the S side of the lagoon will primarily act as the upwind station, while the S-OPS on the N side of the lagoon will primarily act as the downwind measurement path (Fig. 1). Each 50 m S-OPS will sample air at 1-m height and have 10 orifices spaced at 5 m intervals.

Volatile organic compounds, including methane, methanol, ethanol, and total VOCs, will be measured, using the INNOVA Model 1412 (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the basin (Fig. 2).

Meteorological measurements (barometric pressure (SOP W5), air temperature and relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3)) will be located 10 m S of the NW berm corner (Fig. 2). The 3D sonic anemometers will be located on the meteorological tower at 2-m height and on the SW corner tower (Fig. 2) at 4-m and 16-m heights above berm level (Fig. 2). All fans exhaust on the E side of the barns and therefore will not influence the lagoon PIC measurements, except under easterly winds (which are not the prevailing wind at any time of the year).

Setup and configuration of the trailer and site power, towers, and instrumentation are discussed in SOPs U4, U5, and W6, respectively.

The barns 10 m (33 ft) to the E of the lagoon berm have an approximate ridge height of 19 ft agl, resulting in a fetch ratio of 6:10 to the east side of the lagoon. A region of wind conditions from E to SE will be excluded from emissions calculation due to this poor fetch (Fig. 1). The impact of this exclusion region is expected to be small, since the prevailing winds do not come from the direction of the buildings at any time of the year. Fetch in all other directions is better than 1:100, with the upwind conditions being primarily center-pivot irrigation of crops (Fig. 1). A description of the position of each measurement path, including a photograph view corresponding to the paths indicated by black arrows and letters in Fig. 1 follows:

N side of lagoon

- 50 m length S-OPS path parallel to and 5 m N of berm. County road is 5 m N and parallel to path.
- S-OPS begins at the NW corner of the lagoon and extends E with orifices mounted at 1 m abl.
- TDLAS paths of 21 m, 42 m, and 3 at 63 m length, approx. parallel to the berm. The 21-m and 42-m retro-reflectors are mounted on the berm at 1 m abl.
- TDLAS and scanner located 1 m N and 1 m W of NW corner of berm. The TDLAS and scanner are mounted at 1 m abl on an anchored tripod.
- TDLAS tower located 5 m N and 10 m E of NE berm corner. Distance to road is approximately 5 m to N.

Location of N side S-OPS path, looking W towards the location of the 15-m TDLAS retro-reflector tower.

E side of lagoon (Photo B)

- TDLAS paths of 69, 138, and approx.215.5 m length, approx. parallel to the E berm of the lagoon. The 69-m and 138-m retro-reflectors are mounted on the berm, at 1 m abl.
- TDLAS paths 1 to 3 m from berm.
- TDLAS scanner located 1 m S and 55 m E from SE berm corner.
- TDLAS tower located 5 m N and 10 m E of NE berm corner.

Location of E side TDLAS beam path, looking N towards the location of the 15-m TDLAS retro-reflector tower. Lagoon is on left.

S side of lagoon

- 50 m S-OPS path at 1 m abl starting at the SE corner of the lagoon extending W.

- TDLAS paths of 20 m, 40 m, and 3 at 68 m length. The 20-m and 40-m retro-reflectors are mounted on the berm, at 1 m abl.
- TDLAS tower located 8 m S and 8 m W of SW berm corner.

Location of SW side S-OPS and TDLAS beam path, looking E towards the TDLAS/scanner. Lagoon berm is on left.

W side of lagoon

- TDLAS paths of 70, 144, and approx. 220 m length, parallel to the W berm of the lagoon. The 70-m and 144-m retro-reflectors are mounted on the berm, at 1 m abl.
- TDLAS paths approx. on the berm and 7 m from a farm access road.
- TDLAS scanner located 1 m W and 1 m N of NW berm corner.
- TDLAS tower located 8 m S and 8 m W of SW berm corner

Location of W side TDLAS beam path, looking S towards the TDLAS tower location. Lagoon berm is on left.

VOC and hydrogen sulfide emissions from the lagoon are calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1). Restrictions on the use of the model are:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid; although the surrounding area of the farm is open cropped land, the farm has additional roughness elements. The aerodynamic roughness of the barns (19 ft high) contributes to non-homogeneous surface roughness. However, the barns and other buildings are 33 ft (10 m) to the E of the lagoon berm (Fig. 2), and the prevailing winds are S, SW, or N (Table 1). This will reduce the impact of the buildings on airflow around the lagoons. However, as discussed above, the proximity of the buildings does result in an exclusion region for winds from the E to SE (Fig. 1).
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period, since winds are consistent in direction and speed much of the year. Inhomogeneous flow is expected for winds coming from the direction of the exclusion region (Fig. 1), because of the presence of the barns. The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006). The fan exhaust from the three barns is directed to the E, and therefore is not expected to influence the determination of lagoon emissions.
3) The S-OPS PIC measurements for upwind and downwind components must be synoptic. There will be loss of emission measurements when the winds do not provide an upwind and downwind pair of PIC measurements. An averaging time of ½ hr for the S-OPS gas measurements will assure near-synoptic measurement pairs.

4) Emission measurements will be invalidated when the friction velocity is less than 0.15 m/s. This corresponds approximately with winds of 1.1 m/s; at the 7-m height for wind measurements made at Amarillo, this occurred only 1.5% of the time between 1981 and 1990 (NCDC, 1998).

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2). Restrictions on the use of this model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are less than 1 m/s. For Amarillo, this occurred 1.5% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m abl) are greater than 11 m/s. The wind speeds recorded (at a 7-m height) at Amarillo, TX were 11.1 m/s or more 3.3% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS PIC measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane for all four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the N and 3 m from the W shore of the NW corner of the lagoon. Lagoon sludge depth sampling (SOP L5) will be made at eight (8) locations in the lagoon at the beginning or end of each measurement period; the approximate locations of these sampling points are indicated in Fig. 2. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted or winds are too high to keep the boat stationary during measurements.

Communications

Telemetry of TDLAS/scanners, 3D anemometers, and meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP D1). All measurements telemetered to the trailer will be sent to Purdue nightly via DSL cellular service.

Electrical Supply

All electrical supply needs will be fed from the producer-supplied source (SOP S7) from the southern barn or the meter on the power pole south of the barns and directly buried underground to the trailer, which will be located approximately 10 m S of the SE corner of the southernmost barn. The line routed around the lagoon will be buried directly in the ground from the producer-supplied source and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weatherproof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of initial setup and periodically during the year/measurement period as needed.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed

Emissions Determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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Table 1. Monthly climate description (from Amarillo, Texas).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	4	4	4	5	8	8	8	8	6	5	3	4
Wind speed (mph)[2]	13.1	14.2	15.6	15.5	14.7	14.4	12.5	12.2	12.9	13.0	13.1	13.0
Wind direction[2]	SW	SW	SW	N	N	N	SSW	SSW	SSW	S	S	S
Morning RH (%)[1]	70	71	66	67	73	76	73	76	79	70	73	68
Afternoon RH (%)[1]	51	49	41	38	42	44	42	45	49	41	48	47
Maximum temp (F)[1]	49.4	53.0	60.0	70.9	79.2	88.0	91.4	90.4	82.9	72.9	60.0	51.5
Minimum temp (F)[1]	22.5	26.4	31.2	42.1	51.9	61.2	65.9	64.7	56.7	46.1	32.5	25.5

[1] NCDC (1981)
[2] NCDC (1998)

Table 2. Characteristics of the lagoon at the Oklahoma finisher site.

Descriptive parameters.	Unit 1
Livestock type	Finishing
Type of storage (basin, lagoon or tank)	Lagoon
Number of units	1
Year of facility construction	1997
Separation distance from barn fans, ft	50
Stage of lagoon (1st, 2nd, 3rd)	Single
Manure contributors to unit	Finishing pigs
Animal 1 type (sows, cows, etc.)	Finishing pigs
Animal 1 average weight (lb)	170
Animal 1 inventory (# head)	Approx 3,000/site, 1,000/barn
Manure collection (flush, scrape, PPR)	PPR
Source flush or recharge water (if any)	Fresh recharge
Lagoon loading interval, h	3x/week
Minimum space around unit, ft	50
Volumetric loading rate, lb VS/d-ft^3	
Surface loading rate, lb VS/d-ft^2	
Obstructions within 3X height of unit?	Yes
If yes, what kind?	Barn
Height of worst obstruction, ft	19
Distance from worst obstruction, ft	30
Type of cover (crust, straw, none, etc.)	None
Are solids separated from influent?	No
Odor control	Micro-Aid
Sludge removal cycle, years	20 (Est.)
Last time sludge removed (e.g., 1999)	Not yet
Agitation prior to pumpout?	No
Manure removal frequency, days	Every 6 mos.
Pump out (contractor or producer)	Producer
Type of liner	Clay
Volume, ft^3	1,011,463
Surface area, ft^2	120,600
Berm slope	3.8 :1
Maximum side length, ft	683’
Minimum side length, ft	193’
Actual freeboard, ft	2’
Inner berm height, ft	4’
Outer berm height, ft	5’
Liquid depth, ft	20
Sludge depth, ft	2 (Est.)
Number of inlets	1
Shape	Rectangle

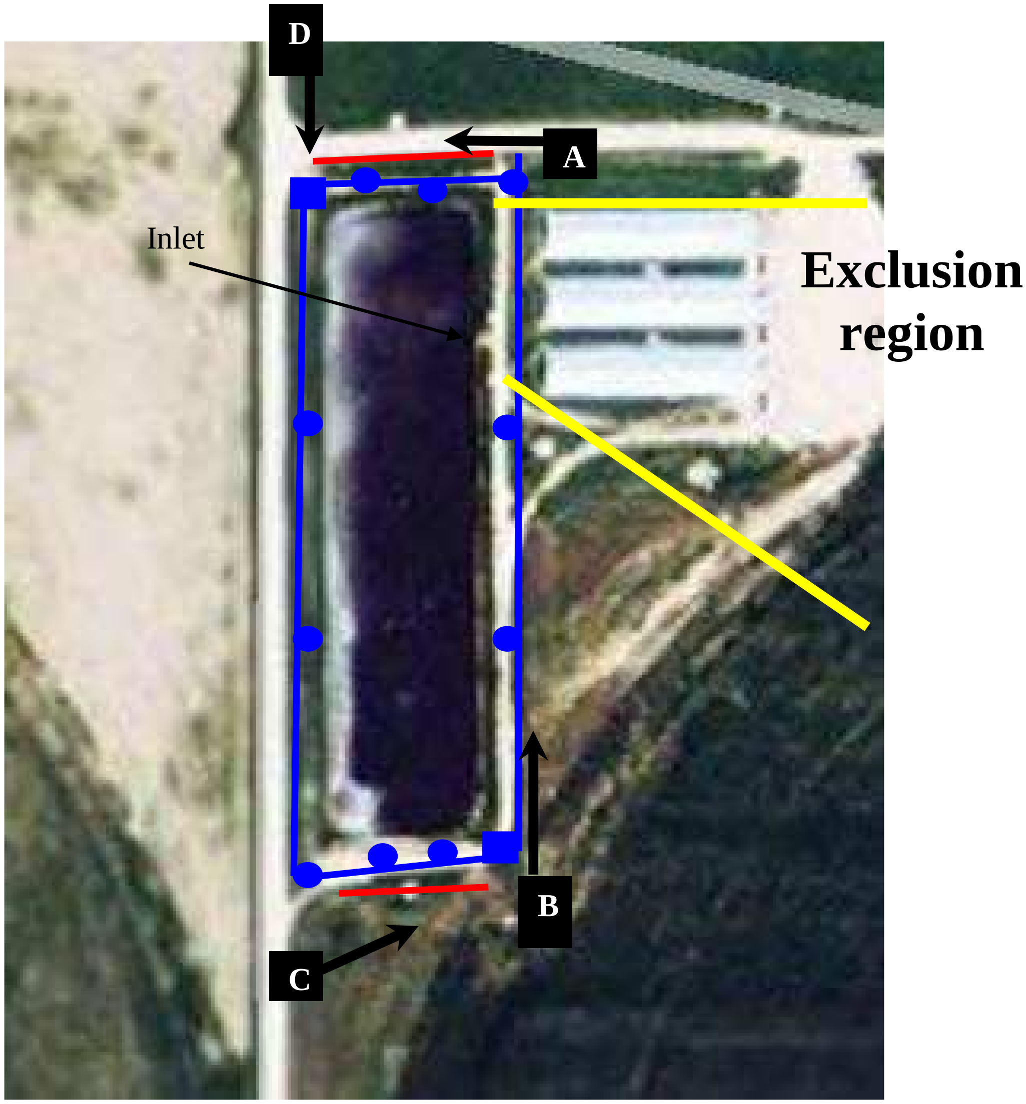

Figure 1. Plan layout of lagoon.

The S-OPS paths (red lines), TDLAS/ scanner (blue squares) instruments and retro-reflector locations (blue circles) are indicated with the scan beam lines/ planes indicated by letter. Blue lines indicate the planes of the TDLAS scanner and retro-reflector pairs. A wind direction exclusion region for emissions calculations (due to flow disruption caused by the barns) is indicated in yellow. Black boxes A,B,C, and D, and black arrows correspond to the locations and lines of sight for the N, E, SE, and W lagoon side photos above.

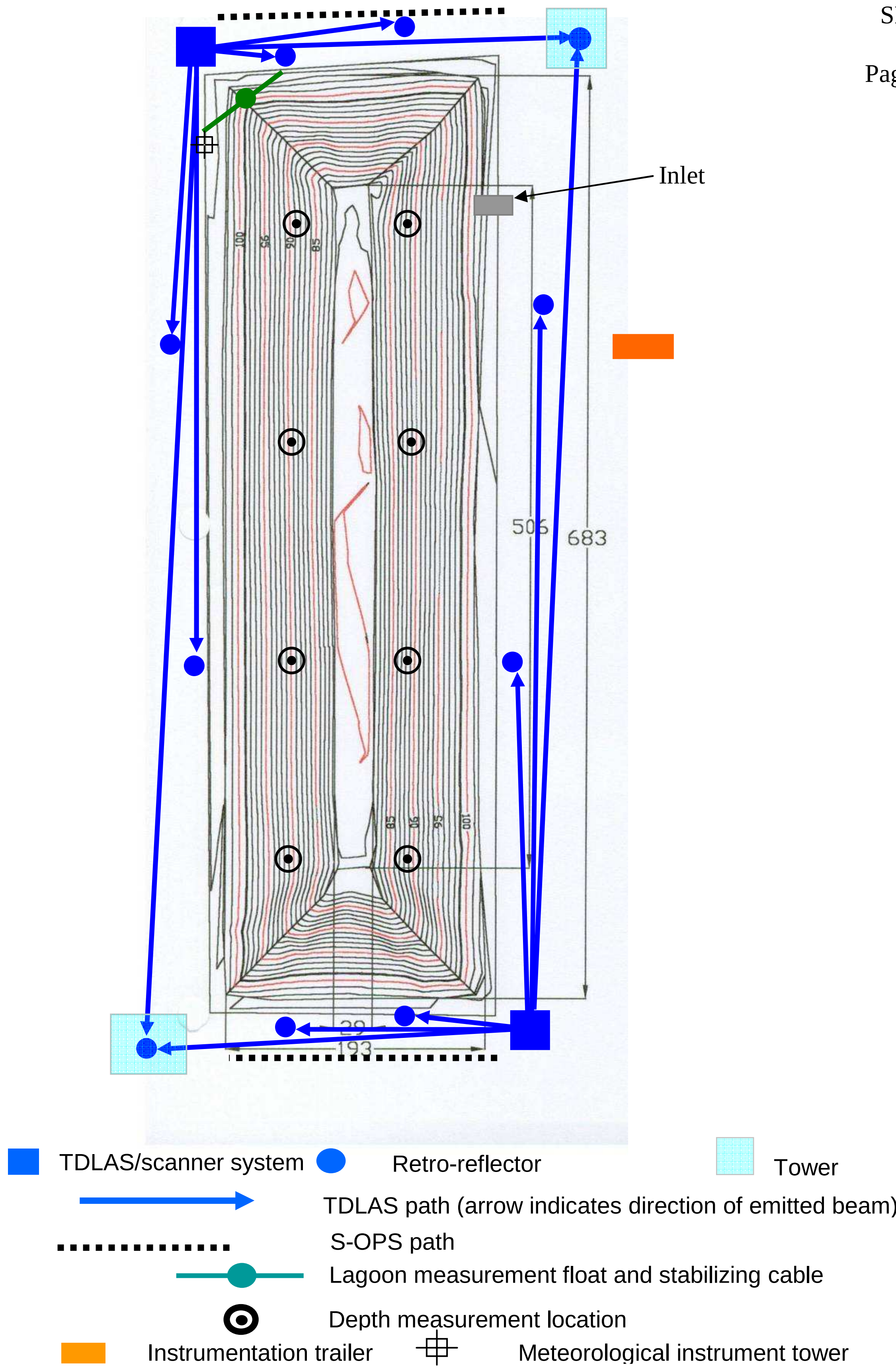

Figure 2. Dimensional plan of the lagoon.

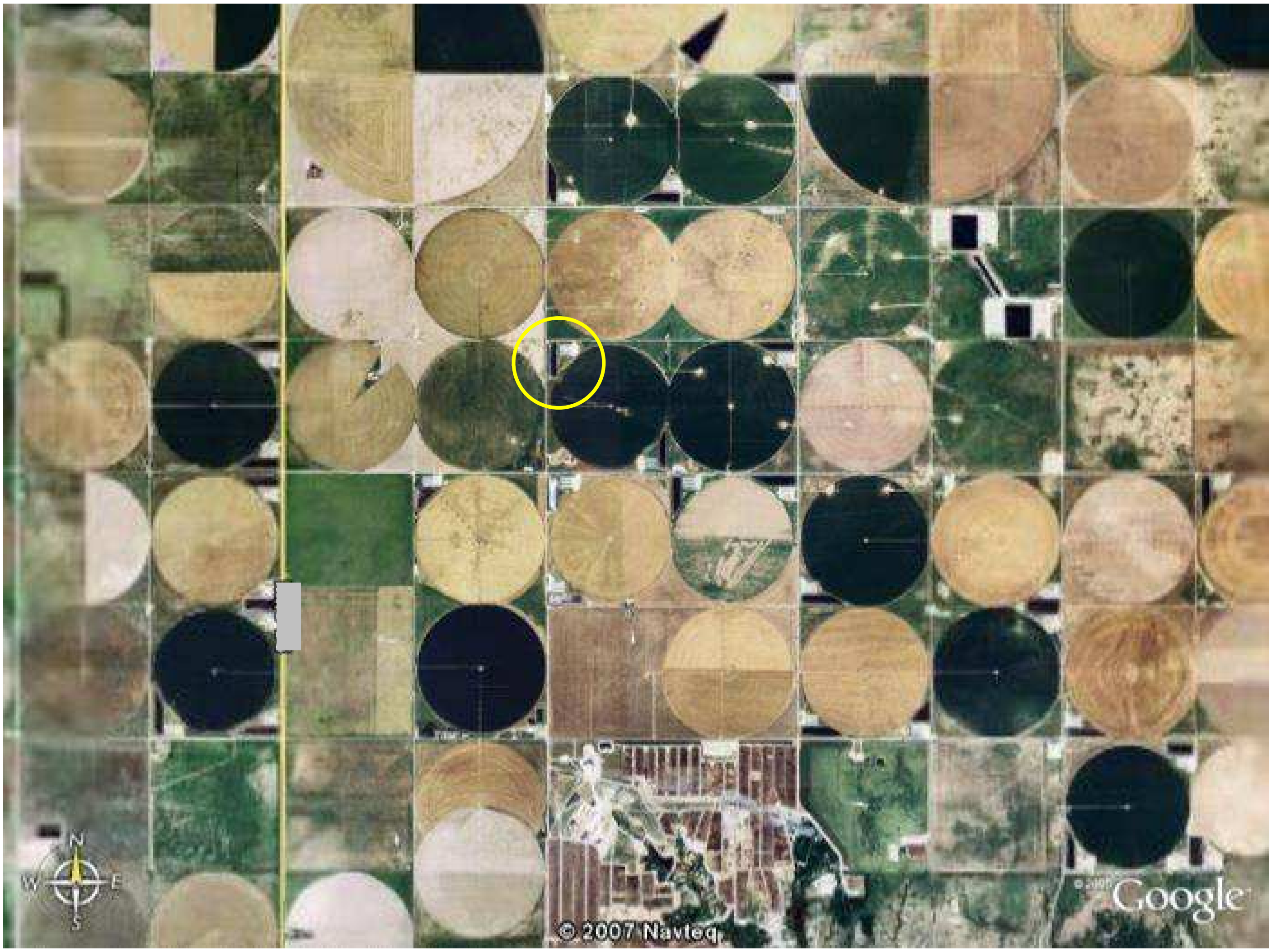

Figure 3. Satellite image of the farm's surroundings.
Farm location indicated by yellow circle

SMP OK4A
SITE MONITORING PLAN FOR WEST SOW SITE
(LAGOON COMPONENT)

SMP OK4A
SITE MONITORING PLAN FOR WEST SOW SITE
(LAGOON COMPONENT)

The Western sow facility is located near Hooker, Oklahoma. The elevation at the farm is 905 m (2968 ft), with a magnetic compass variation at this location is 09^{o}E. The sow farm consists of three barns and one office (Fig. 1). The facility has a capacity of 1225 breeding and gestation sows in each of two breeding and gestation units, and 384 farrowing sows in one farrowing unit. Construction of the sow farm was completed in 1994.

Logistics

Measurements will be made by one of the rotating measurement teams from Purdue Applied Meteorology laboratory in West Lafayette, IN. Airports are located in both Amarillo, TX and Liberal, KS. The farm is located 210 km (125 mi) N of Amarillo, TX and 33 km (20 mi.) SE of Liberal, KS. Driving times from the two airports are approximately 2 hr, and 40 min, respectively.

Climate (Table 1)

The climate for the area is represented by the Amarillo, TX, National Weather Service weather station, which is approximately 188 km (117 mi) S of the farm. The area typically receives an average of 515 mm (20.28 inches) of precipitation (NCDC, 1981). The prevailing winds are from the S to SW during summer, fall and winter and N in spring (NCDC, 1998). Maximum chances of days with precipitation are during the summer (NCDC, 1981). Mean monthly wind speeds range from 5.6 m/s (12.5 mph) to 7 m/s (15.6 mph) (NCDC, 1998). Relative humidity (RH) ranges from 72% in the morning to 45% in the afternoon, while air temperatures range from 22^{o}C (71^{o}F) to 7^{o}C (44^{o}F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

Manure from the barns is transferred weekly from the two gestation units and every 2.5 weeks from the farrowing unit to the lagoon by pull plug and lagoon water recharge. Waste water from the two gestation units combines into one inlet (the southerly inlet in Fig. 2), while wastewater from the farrowing unit enters the lagoon from the northerly inlet (Fig. 2). The rectangular waste lagoon is located to the E and separated by a drainage swale from the barns. The clay-lined lagoon is 119 m (390 ft) wide and 193 m (634 ft) long, and is oriented N-S. The lagoon bank is rocky with a berm slope of 4:1. Liquid depth is approximately 5.5 m (18 ft), with an inner berm-to-water distance of 1.2 to 3 m (4 to 10 ft). Sludge from the lagoon has not been removed since construction (20-yr sludge removal cycle).

Lagoon liquid analysis is contracted by the producer every year for all nitrogen components. Lagoon liquid is applied through center-pivot irrigation when liquid levels reach maximum lagoon capacity (minimum freeboard). Additional liquid analyses for all nitrogen compounds occur at the time of field applications (0-2 times annually based on rainfall).

Surrounding sources

There is one identifiable NH_3 or H_2S emission source (a farrow-to-finish swine farm), which is 2 km (1.2 mi) N of the measurement location, one identifiable NH_3 or H_2S emission source (another farrow-to-finish swine farm) 3 km (2 mi) E of the measurement location, and two identifiable NH_3 or H_2S emission sources (one farrow-to-finish and one sow swine farm) 4 km (2.5 mi) SW of the measurement location (Fig. 3).

Monitoring Plan

The NH_3 emissions from the basin will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the basin during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, and the backward Lagrangian Stochastic model (SOP O1).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of $NH_{3,}$ so as to create vertical measurement planes on each side of the lagoon. Two 15-m (51-ft) towers will be located at the NW and SE corners of the lagoon, while maintaining an approximately 4-m right-of-way from the county roads. The scanning TDLAS instruments will be mounted at 1-m height above the lagoon berm at the NE and SW corners. The NE corner TDLAS/ scanner will be mounted on an anchored tripod at 2-m height as a result of the 1 m N berm height. The retro-reflectors on the NW corner tower will be at 2-m, 7-m, and 15-m heights. Retro-reflectors at the approximate 1/3 and 2/3 distance down the lagoon sides will be mounted on anchored tripods on the respective berms (Fig. 2). The retro-reflectors on the SW corner tower will be at 2-m, 7-m and 15-m heights. The laser beam is eye-safe, so these heights will not create a hazard.

Two S-OPS air collection systems will be used to sample the air from which measurements of VOC and H_2S near lagoon berm height on two sides of the lagoon. S-OPS will be mounted at 1 m height parallel to the N and S sides of the lagoon. The S-OPS along the S side of the lagoon will primarily act as the upwind station, while the S-OPS on the N side of the lagoon will primarily act as the downwind measurement path (Fig. 2).

Volatile organic compounds, including methane, methanol, ethanol, and total VOCs, will be measured using the INNOVA Model 1412 (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 2).

Hydrogen sulfide will be measured using pulsed-florescence (SOP G5) form air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 2).

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature and relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3) will be located 5 m W from the NE berm corner, on the berm (Fig. 2). The 3D sonic anemometers will be located on the meteorological tower (SOP U5) at 2-m height and the NE corner tower (Fig. 2) at 4-m and 16-m heights above berm level (Fig. 2).

110 VAC power for equipment is provided by the farm (SOP S7) from a central power distribution point, which will be installed at the trailer location, approximately 25 m (83 ft) from the NW corner of the lagoon berm. Setup and configuration of the trailer and site power, towers, and instrumentation are discussed in SOPs U4, U5, and W6, respectively.

The barns 53 m (173 ft) to the W of and 1.2 m (4 ft) above the lagoon berm have a ridge height of 5.8 m (19 ft) agl. Therefore, the nearest building obstruction is 7 m (23 ft) above the berm, resulting in a fetch ratio to the W of 8:100. Fetch in all other directions is better than 1:100 (Fig. 1). A description of the position of each measurement path, including a photograph view corresponding to the paths indicated by black arrows and letters in Fig. 1 follows:

N side of lagoon

- 50 m length S-OPS path at 1 m abl.
- S-OPS begins at NE berm corner extending W along the berm.
- TDLAS paths of 44 m, 80 m, and 3 at 125 m length, approx. parallel to and 10 m N of berm. The 44-m and 88-m retro-reflectors are mounted on the berm at 1 m height above berm.
- TDLAS and scanner located 10 m N and 10 m W of NW corner of berm. The TDLAS and scanner are mounted at 1 m height on a anchored tripod.
- TDLAS 15 m tower located 10 m N of NE berm corner. Distance to road is 15 m to E

Location of N side TDLAS beam path, looking E towards the location of the TDLAS/scanner. Lagoon berm is on right.

E side of lagoon

- TDLAS paths of 66, 132, and 209 m length, approx. parallel to the E berm of the lagoon. The 66- and 132-m retro-reflectors are mounted on the berm at 1 m height above berm.
- TDLAS paths 5 m from berm and 10 m from county road.
- TDLAS scanner located due E of NE berm corner.
- TDLAS tower located 5 m E and 5 m N of NW berm corner.

Location of E side TDLAS beam path, looking S towards the location of the 15-m TDLAS retro-reflector tower. Lagoon berm is on right.

S side of lagoon

- 50 m length S-OPS path 1 m abl.

- S-OPS begins at SW berm corner and extends to the E along the berm.
- TDLAS paths at 54 m, 82 m, and 3 at approx. 131 m lengths. The 54-m and 82-m retro-reflectors are mounted on the berm at 1 m height above berm.

Location of S side UV-DOAS and TDLAS beam paths, looking W towards the location of the TDLAS/scanner and the UV-DOAS receiver. Lagoon berm is on right side of photo.

W side of lagoon

- TDLAS paths of 66, 132, and approx 210 m lengths parallel to the W berm of the lagoon. The 66-m and 132-m retro-reflectors are mounted on the berm at 1 m height above berm.
- TDLAS paths 5 m from berm and 10 m from county road.
- TDLAS scanner located due W of SW corner of lagoon.
- TDLAS tower located 5 m W and 5 m N of the NW berm corner.

Location of W side TDLAS beam path, looking S towards the TDLAS/scanner system. Lagoon berm is on left.

VOC and hydrogen sulfide emissions from the lagoon will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1). Restrictions on the use of the model are as follows:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid; although the surrounding area of the farm is open cropped land, the farm has additional roughness elements. The aerodynamic roughness of the barns is 5.8 m (19 ft) high, and other miscellaneous buildings contribute to non-homogeneous surface roughness. However, the barns and other buildings are more than 50 m (164 ft) to the W of the lagoon (Fig. 2) and the prevailing winds are S, SW, or N (Table 1). This will reduce the impact of the buildings on airflow around the lagoons.
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period, since winds are consistent in direction and speed much of the year. The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006).
3) The S-OPS PIC sampling for measurements of upwind and downwind components must be synoptic. This is approximately true when averaged over ½ hr periods. There will be

loss of emission measurements when the winds do not provide an upwind and downwind pair of PIC measurements.

4) Emission measurements will be invalidated when the friction velocity is less than 0.15 m/s. This corresponds approximately with winds of 1.1 m/s at the 7 m height for wind measurements made at Amarillo. This occurred only 1.5% of the time between 1981 and 1990 (NCDC, 1998).

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are less than 1 m/s. The wind speeds recorded at a 7-m height at Amarillo, TX were 1.1 m/s or less 1.5% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m above ground level) are greater than 11 m/s. The wind speeds recorded at a 7-m height at Amarillo, TX were 11.1 m/s or more 3.3% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS PIC measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane for all four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the N and 3 m from the E shore of the NE corner of the lagoon. Lagoon sludge depth sampling (SOP L5) will be made at nine (9) locations in the lagoon at the beginning of each measurement period; the approximate locations of these sampling points are indicated in Fig. 2. Lagoon sludge depth measurements (SOP L5) will be made at nine locations in the lagoon (approximate locations indicated in Fig. 4) at the beginning or end of each measurement period. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted or if winds prohibit being able to keep the boat stationary for the measurements.

Communications

Telemetry of TDLAS/scanners, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP D1). All measurements telemetered to the trailer will be sent to Purdue nightly via cellular DSL. Trailer power will be wired from the barns (Fig. 1).

Electrical Supply

All electrical supply needs will be fed from the producer-supplied source. All wiring will be buried directly in the ground from the producer-supplied source and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weather proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of initial setup and periodically during the year/measurement period as needed.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed

Emissions Determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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Table 1. Monthly climate description (from Amarillo, Texas).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	4	4	4	5	8	8	8	8	6	5	3	4
Wind speed (mph)[2]	13.1	14.2	15.6	15.5	14.7	14.4	12.5	12.2	12.9	13.0	13.1	13.0
Wind direction[2]	SW	SW	SW	N	N	N	SSW	SSW	SSW	S	S	S
Morning RH (%)[1]	70	71	66	67	73	76	73	76	79	70	73	68
Afternoon RH (%)[1]	51	49	41	38	42	44	42	45	49	41	48	47
Maximum temp (^{o}F)[1]	49.4	53.0	60.0	70.9	79.2	88.0	91.4	90.4	82.9	72.9	60.0	51.5
Minimum temp (^{o}F)[1]	22.5	26.4	31.2	42.1	51.9	61.2	65.9	64.7	56.7	46.1	32.5	25.5

[1] NCDC (1981)
[2] NCDC (1998)

Table 2. Characteristics of the lagoon at the Oklahoma sow facility.

Descriptive parameters.	**Unit 1**
Livestock type	Swine
Type of storage	Lagoon
Number of units	1
Year of facility construction	1994
Separation distance from barn fans, ft	173
Stage of lagoon (1^{st}, 2^{nd}, 3^{rd})	1^{st}
Manure contributors to unit	
Animal 1 type (sows, cows, etc.)	Sows
Animal 1 average weight (lb)	230-750
Animal 1 inventory (# head)	2784
Manure collection	PPR
Source flush or recharge water (if any)	Lagoon (Recharge)
Lagoon loading interval, h	24
Minimum space around unit, ft	173 ft
Volumetric loading rate, lb VS/d-ft^3	0.0048
Surface loading rate, lb VS/d-ft^2	0.0597
Obstructions within 3X height of unit?	None
If yes, what kind?	--
Height of worst obstruction, ft	--
Distance from worst obstruction, ft	--
Type of cover	None
Are solids separated from influent?	No
Odor control	None
Sludge removal cycle, years	20
Last time sludge removed	Never
Agitation prior to pumpout?	None
Manure removal frequency, days	180-365
Pump out (contractor or producer)	Producer
Type of liner	Clay
Volume, cubic ft	234,133
Surface area, square feet	242,056
Berm slope	4 :1
Maximum side length, ft^3	632
Minimum side length, ft^2	383
Actual freeboard, ft	1.5
Inner berm height, ft	4-10
Outer berm height, ft	0-2
Liquid depth, ft	18
Sludge depth, ft	Unknown
Number of inlets	2
Shape	Rectangular

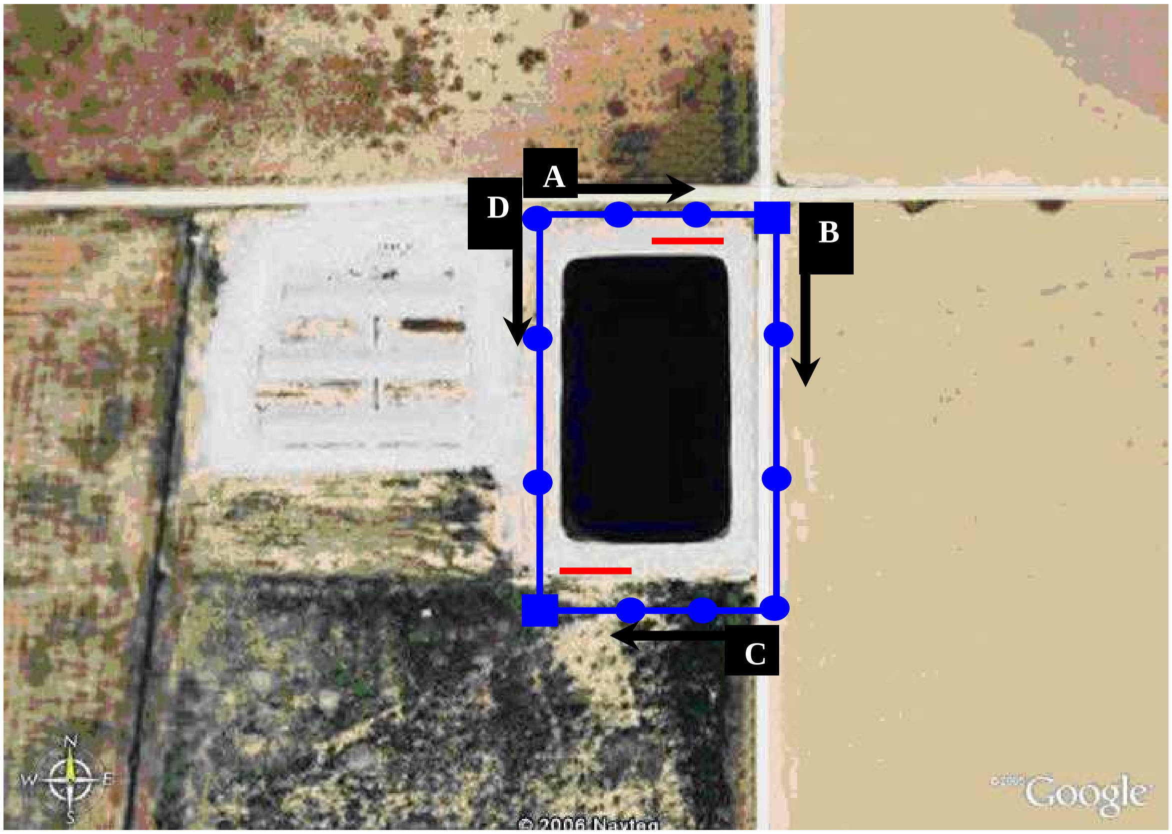


Figure 1. Plan layout of lagoon.

The S-OPS (red lines), TDLAS/ scanner (blue squares) instruments and retro-reflector locations (blue circles) are indicated, with the scan beam lines/planes indicated by letter. Blue lines indicate the planes of the TDLAS scanner and retro-reflector pairs. Black boxes A,B,C, and D, and black arrows correspond to the locations and lines of sight for the N, E, S, and W lagoon side photos above.

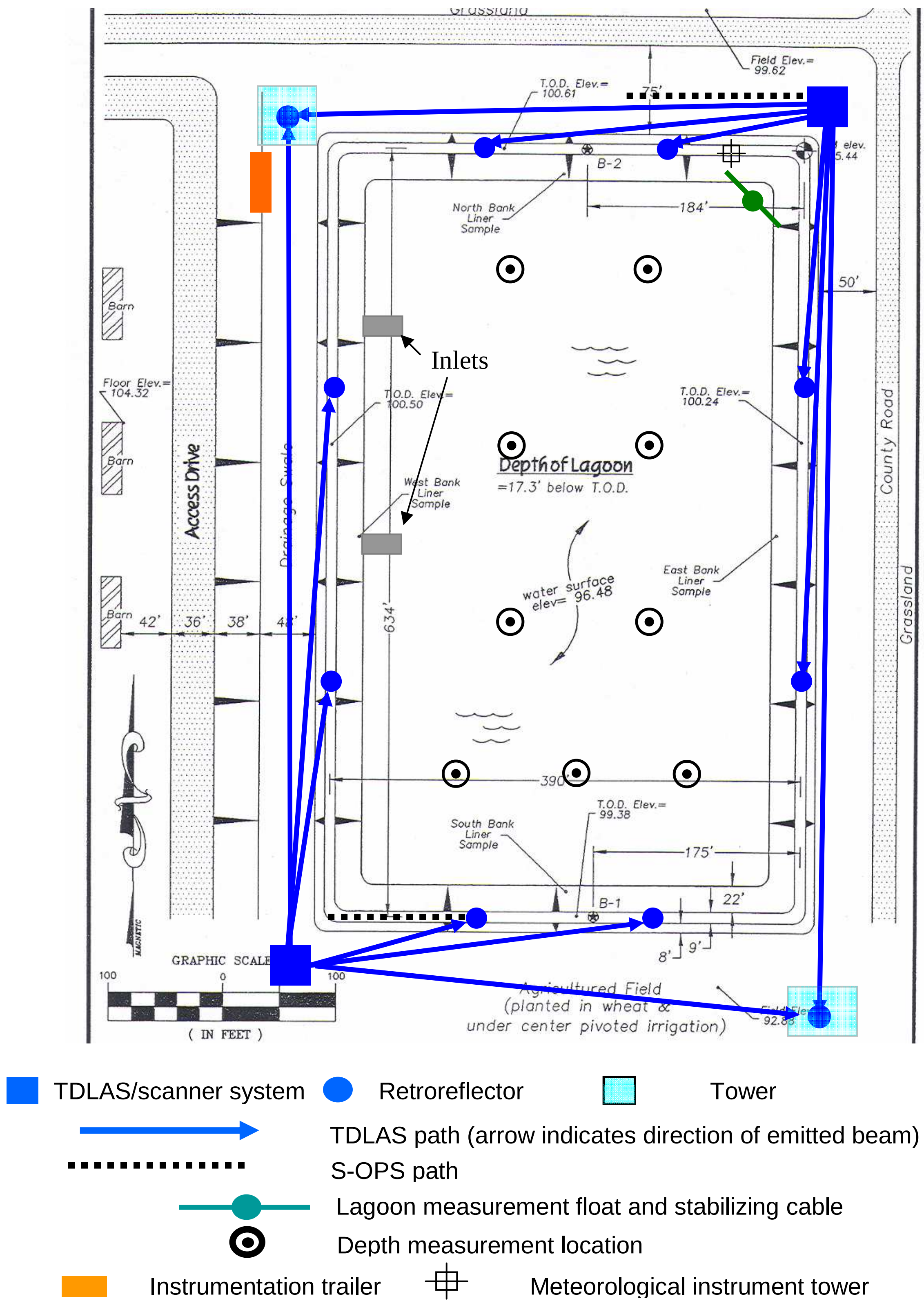


Figure 2. Dimensional plan of the lagoon, including locations of structures and roads. Berm along S side is 6 ft from ground. Berm along N side is 1 ft above ground. Drainage swale W of lagoon varies from 1 ft to 6 ft deep from N to S.

Figure 3. Satellite image of surroundings.

SMP WA5A
SITE MONITORING PLAN FOR DAIRY SITE IN WASHINGTON STATE
(LAGOON COMPONENT)

SMP WA5A
SITE MONITORING PLAN FOR DAIRY SITE IN WASHINGTON STATE (LAGOON COMPONENT)

The Western freestall dairy facility is located in Yakima County, Washington. The elevation at the farm is approximately 244 m (800 ft). The magnetic compass variation at this location is 17^{o}E. The farm consists of six barns, a milking parlor, and an office (Fig. 1). The facility has a capacity of 4400 milking cows and 1200 dry cows in three units. Construction of the dairy was completed in 2002.

Logistics

Measurements will be made by one of the rotating measurement teams from the Purdue Applied Meteorology Laboratory (PAML) in West Lafayette, IN. Airports are located in Yakima, WA and Pasco, WA. The farm is located 68 km (42 mi) SE of Yakima, WA, with a one-way driving time of less than one hour.

Climate (Table 1)

The climate for the area is represented by the Yakima, WA, National Weather Service weather station, which is approximately 59.45 km (37 mi) NW of the farm. The area typically receives an average of 203.15 mm (8.00 in) of precipitation (NCDC, 1981). The prevailing wind information, taken from the 'Mabton' weather station of the Washington State University *AgWeatherNet* network, indicates a generally SW wind all year, but with distinct diurnal slope wind influences. A monthly breakdown of the winds is indicated in Fig. 2. Maximum chances of days with precipitation are during the summer (NCDC, 1981). Mean monthly wind speeds range from 1 m/s (2 mph) to 3 m/s (6 mph) (*AgWeatherNet*, 2006). The average relative humidity (RH) ranges from 53% in the morning to 44% in the afternoon, while air temperatures range from 19^{o}C (63^{o}F) to 5.5^{o}C (36^{o}F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

The farm has freestall style barns, with automated flushing four times daily. Manure is transferred to the upper lagoon/settling basins (to be measured in this study) from a sand separation pit. Liquids are skim separated and returned as flush to the barns. Settled solids are removed yearly. Remaining solids are strained through Agpro screens and centrifugal/screw presses, and liquid transferred to large serpentine concrete basins for secondary settling. Solids are then dried for bedding. Removed water is stored in a large clarified water storage basin for dilution of barn flush water. Sludge is applied on land, utilizing underground pressurized pipes and a no-till soil injector. Wastewater enters the initial lagoon/basin from the N, near the NW corner of the lagoon (Figs. 3 & 4).

The two upper earthen-lined lagoon/settling basins are located to the S of the barns, and are used in alternate years. Consequently, the positioning of sensors for 2007/8 (Spring 2007 through

Winter 2008) differs from that of 2008/9. One of the lagoons is rectangular (East lagoon), with dimensions of 183 m (600 ft) by 72 m (235 ft.). The West lagoon is five-sided with dimensions of approximately 183 m (600 ft). long and 83 m (271 ft) wide with the SW corner of the lagoon cut off (Fig. 3). The berm on the W side drops from 2 m (6 ft) high to 4 m (12 ft) high from S to N, flat along the S side, and dropping 50 ft or more to the north toward the serpentine basins. The berm on the E side drops about 1 to 2 m (3 to 6 ft), then rises approximately 2 m (6 ft) to fields to the E.

Surrounding sources

On-farm sources of potential NH_3 or H_2S emissions include the land application areas approximately 50 m (164 ft) to the W, settling basins 20 m (65 ft) to the S, and an open lot for heifers 60 m (198 ft) to the N. The nearest identifiable off-farm sources of NH_3 or H_2S emissions are a small open lot dairy located to the N on the valley floor, a seasonally-used sheep lambing camp ¼ mile to the W, and a calf operation ⅓ mile to the W.

Monitoring Plan

The NH_3 emissions from the two upper lagoons/settling basins will be monitored for 8 to 20 d each quarter of the year for two years, using scanning TDLAS open-path instruments (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements and the radial plume mapping (RPM) (SOP O2). H_2S emissions from the same lagoons/settling basins over the same periods of time will be monitored using pulsed-florescence (PF) (SOP G5) sampled through a Synthetic Open Path System (S-OPS) (SOP C4) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements and backward Lagrangian Stochastic (bLS) emissions models (SOP O1). VOC emissions including methane, methanol, ethanol, and total non-methane VOC will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and air sampled using the S-OPS (SOP C4) and analyzed by the INNOVA (SOP G7). Measurement data will be collected on the LAN server in the trailer (SOP D1, SOP U4).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes on each side of the lagoon. Fixed sheet metal towers will be used to withstand the reported 90-mph winds associated with Chinooks. Two towers (SOP U5) will be located at the NW and NE corners of the lagoons. One 15-m (51-ft) tower will be placed at the center point of the two lagoons, approximately 15 m S of the south berms. The scanning TDLAS instruments will be mounted at 1-m height above the lagoon berm at the NW and SE corners of the E lagoon for 2007 and at the NE and SW corners of the W lagoon for 2008. The TDLAS/scanners will be mounted at 1-m height above berm on an anchored tripod (SOP U5). Retro-reflectors at approximately ⅓ and ⅔ of the distance down the lagoon sides will also be mounted at 1-m heights above berm level (abl) on anchored tripods (SOP U5) on the berms (Fig. 4A/B).

Two S-OPS systems (SOP C4) will collect the gas along linear paths on opposite sides of the lagoon for the measurement of the synthetic PIC of H_2S and various VOC. Since the prevailing winds are SW, S-OPS paths will be positioned to the N ends of the E and W lagoons. The S-OPS along the SW side of the lagoon will primarily act as the upwind station. The S-OPS on the northern end of the E side of the E lagoon will primarily act as the downwind measurement path in 2007 (Fig 3), while the S-OPS on the N side of the W lagoon will act as the prevailing downwind measurement path in 2008 (Fig. 3).

Meteorological measurements, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be located 19 m S and 5 m East of the NE berm corner of the West lagoon (Fig 4A/B) for both years. The meteorological measurements will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2-m height above berm level. Two 3D sonic anemometers will be located at 4-m and 16-m heights above ground level (agl) (SOP U5) on the centrally located S fixed sheet metal tower for both years.

Fetch to the W is better than 1:100 before terrain rises. Fetch to the E, towards the center-pivot irrigation system, is interrupted by a 3- to 6-m (10- to 20-ft) deep and 30- to 45-m (100- to 150-ft) wide gulley (Fig. 1) to be filled in in the near future. A description of the position of each measurement path by photo and by year of operation (Figs. 3 & 4A/B) follows:

<u>2007/8: East Lagoon Measurements</u>

W side of East lagoon

- Retro-reflectors at 67 m and 132 m, and 3 on SW fixed tower at approx. 259 m from NW corner TDLAS scanner. The 67-m and 132-m retro-reflectors are mounted on anchored tripods on the berm at 1 m abl.
- Met tower will be placed on the East lagoon side of the dividing berm between the lagoons, 23 m S of the N berm.

W side of East lagoon (right) and E side of West lagoon (left) looking N.

N side of lagoon

- S-OPS path parallel to the berm and 50 m long beginning 10 m N of the NW berm corner
- Retro-reflectors at 29 m and 52 m along berm from NW corner TDLAS/scanner and 3 at approx. 83 m on fixed tower at NE berm corner.
- TDLAS paths approximately parallel to the N berm of the lagoon. The 29-m and 52-m retro-reflectors are mounted on the berm on anchored tripods at 1 m abl height.

N side of East lagoon from NE corner looking W. Lagoons on left.

E side of lagoon

- Retro-reflectors at 70 m and 135 m from SE corner TDLAS/scanner and 3 on NE corner fixed tower at approximately 206 m from the scanner. The 70 m and 135 m retro-reflectors are mounted on the berm (West side of road) at 1 m abl.
- Instrument trailer is located at SE bermcorner and just E of the road.

NE corner of East lagoon, looking S along E edge.

S side of lagoon

- 50-m long S-OPS path south of road beginning 10 m S of berm SE corner.
- Retro-reflectors at 32 and 57 m W along berm from TDLAS/scanner at SE corner, and 3 on a SW corner fixed tower at approximately 100 m. The 32 m and 57 m retro-reflectors are mounted on anchored tripods on the berm at 1 m abl.

S side of East lagoon in distance. Lagoon is to left.

In addition:

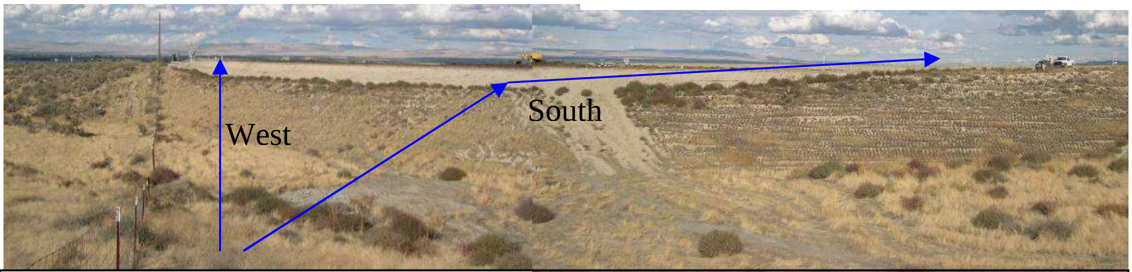
- SW fixed tower located 67 m S and 4 m W of SW berm corner of East lagoon.
- SE TDLAS/scanner located 4 m E and 14 m S of SE berm corner (S and E of road) mounted at 2 m agl on an anchored tripod.
- NE fixed tower located 4 m E and 4 m N of NE berm corner (N and E of road).
- NW TDLAS/scanner located 4 m W and 4 m N of NW berm corner mounted at 2 m agl on an anchored tripod.

<u>2008/9: West Lagoon Measurements</u>

S side of lagoon

- 50-m long S-OPS path parallel to and 5 m from S berm.
- S-OPS path 1 m S of southerly SW side corner of berm extending E to SE berm corner.
- Instrument trailer will be located near the SE corner, just E of the center road between the two lagoons.
- Retro-reflectors at 60.5 m, 84 m and 3 on the SE corner tower 111 m from SW corner TDLAS/scanner. The 60.5 m, 84 m retro-reflectors are on berm mounted on an

SW side of West lagoon to right. Location of SW TDLAS/scanner indicated by blue arrow anchored tripod at 1 m abl.



SW side of West lagoon looking N from TDLAS/scanner position. Lagoon is center and right in image. Paths for west side of lagoon and south side of lagoon indicated by labeled

W side of lagoon

- Retro-reflectors 93.5 m and 160 m, and 3 on the NW corner fixed tower at approx. 237 m from SW corner TDLAS/scanner. The 93.5-m and 160-m retro-reflectors are mounted on the berm on anchored tripods at 1 m abl.

N side of lagoon

- Retro-reflectors at 27 m and 60 m along berm from the NE berm corner TDLAS/scanner and 3 at approx. 95 m from the fixed tower at the NW corner.
- The 27-m and 60-m retro-reflectors are mounted on the berm at a height of 1 m abl.
- 50-m S-OPS path located on the northernmost edge of the berm 10 m E of the NW corner of the East lagoon.

N side of lagoons (West lagoon nearest to right). NW corner of West lagoon, looking E along N edge.

E side of West lagoon (center road)

- TDLAS/scanner located on the outside of the road at the NE berm corner.
- Retro-reflectors at 65 m and 130 m down the side of the lagoon, and 3 on a fixed tower approximately 300 m from the scanner. The 65-m and 130-m retro-reflectors are mounted at 1 m abl on anchored tripods.
- Met tower will be placed on the East lagoon side of the dividing berm, approximately 23 m S of the N berm.

E side of West lagoon looking N along center road towards TDLAS/scanner location..

In addition:

- NE TDLAS scanner 4 m N and 4 m E of NE berm corner of West lagoon mounted on anchored tripod at 1 m abl (N of berm road at center lane in between lagoons).

- SE fixed tower located 67 m S and even with SE berm corner of West lagoon (same location as for East lagoon measurements).
- SW TDLAS/scanner 4 m W of SW berm corner (W of berm road).
- NW fixed tower located 4 m W and 4 m N of NW berm corner.

VOC and hydrogen sulfide emissions from the lagoon will be calculated either using the backward Lagrangian Stochastic (bLS) model (SOP O1) with the 2-m height sonic anemometer (SOP W2) and measurements from the S-OPS/PAS (SOP C4, G7) and S-OPS/PF (SOP C4, G5) or by ratio of VOC and hydrogen sulfide to NH_3 and the emissions of NH_3 determined from the RPM emissions model method.. Restrictions on the use of the bLS model are:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid, since the dairy is located on a shelf about 23 m (75 ft) above the main Yakima Valley floor, with sloping ground to the S. The area surrounding the farm slopes gently 2 to 3 degrees upward to the S (Figs. 5 & 6). Fetch to the W is better than 1:100 before terrain rises. Winds are fairly steady down the valley from the W (Fig. 2). Fetch to the E, towards the center-pivot irrigation system, is interrupted by a 3- to 6-m (10- to 20-ft) deep and 30- to 45-m (100- to 150-ft) wide gulley (Fig. 3) to be filled in in the near future. The barns, another source of roughness, are 172 m (563 ft) to the N of the N lagoon berm (Fig. 1), and should not significantly influence wind flow, since winds are from the N less than 5% of the time (Fig. 2).
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period, since winds are consistent in direction and speed much of the year. However, weak valley/slope winds driven by temperature gradients in the Yakima Valley will likely cause changes in turbulence (through changes in stability) through the course of the day. The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006).
3) The S-OPS measurements for upwind and downwind components must be synoptic. This will be approximately true over an averaging period of ½ hour.
4) Emission measurements will be invalidated when the friction velocity is <0.15 m/s. This corresponds approximately with winds of 1.1 m/s. At the 7-m height, this occurred only 0.8% of the time at Yakima, WA from 1981-1990 (NCDC, 1998).

Ammonia emissions from the lagoon will be calculated using the radial plume mapping (RPM) model (SOP O2) with the three sonic anemometer (SOP W2) and TDLAS measurements (SOP C2). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are <1 m/s. The wind speeds at 7-m height at Yakima, WA were ≤1.1 m/s 10.2% of the time between 1981 and 1990. (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are >11 m/s. Wind speeds at 7-m height at Yakima, WA were ≥11.1 m/s 0.8% of the time between 1981 and 1990 (NCDC, 1998).

3) The TDLAS PIC measurements for upwind and downwind components must be synoptic. This is maintained in the measurement plan.

Communications

The instrumentation trailer (SOP U4) will be located just E of the road on the SE corner of the East lagoon for 2007/8 and just off the S side of the road on the SE corner of the West lagoon for 2008/9 (Fig. 4A/B). Telemetry of TDLAS, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All measurements telemetered to the trailer will be sent to Purdue nightly via cellular DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the producer supplied source. Piping (2″ schedule 40 PVC conduit) will be run underground from an existing 600-amp 480-V 3-phase service located at the SW corner of the lagoon to the trailer location. A total of 3 #6 THHN copper conductors (2 ungrounded, 1 grounded) will be run through the conduit. A 25-kva 480-V primary 120-V secondary transformer will be provided at the trailer location to supply the required 120-V 50-amp circuit.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of initial setup and as needed during the study period.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed.

Emissions Determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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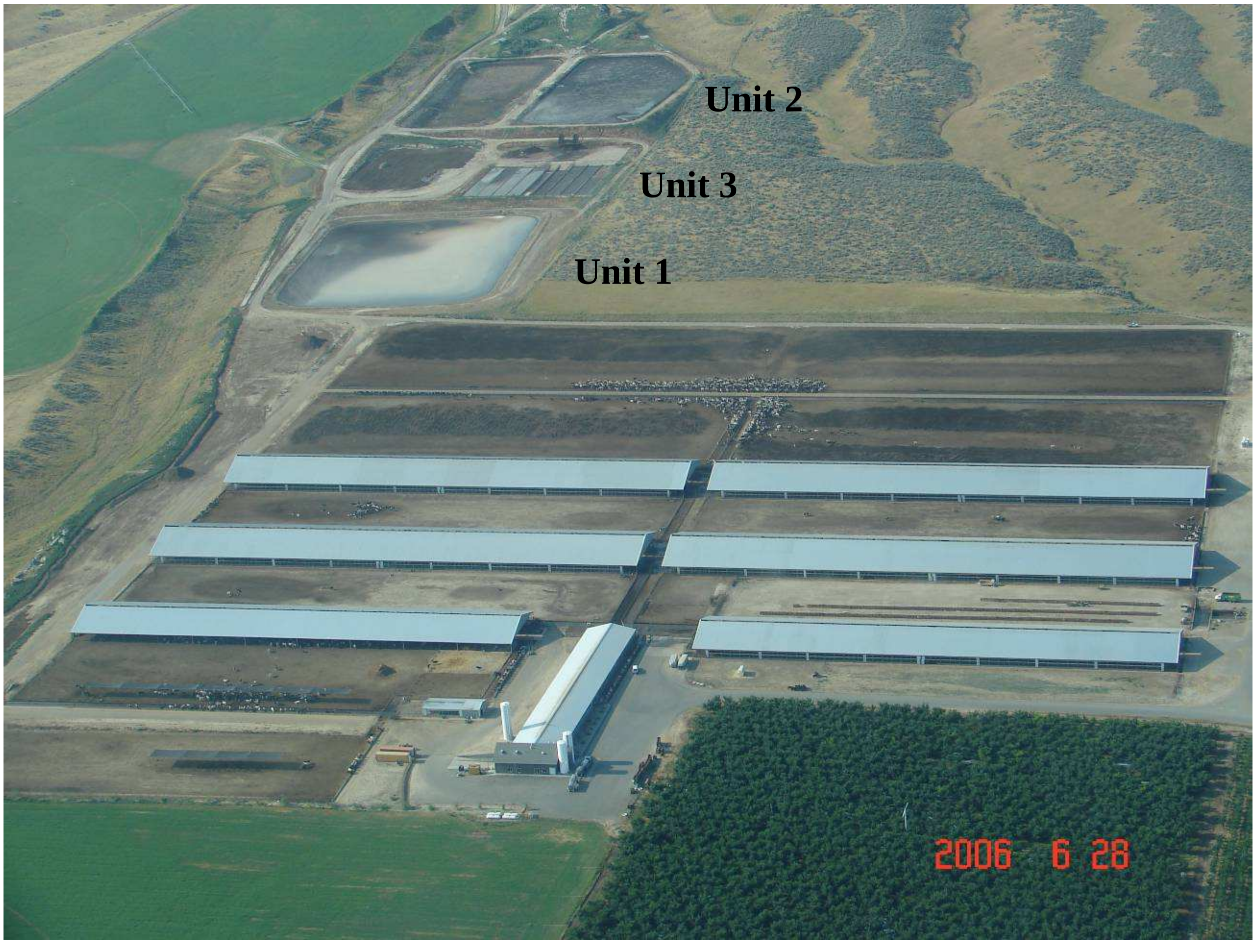

Figure 1. Overall layout of farm, as viewed from the NNW.
Photograph courtesy of Stewart Turner, CPAg.

Table 1. Monthly climate description for the site (from Yakima, WA and Mabton, WA).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	10	7	6	4	5	5	2	3	3	5	8	10
Morning RH (%)[1]	77	70	52	40	37	38	35	39	44	55	72	80
Afternoon RH (%)[1]	70	58	41	32	30	30	25	28	32	43	63	74
Maximum temp (°F)[1]	36.4	46.1	54.8	64.1	73.1	79.7	88.1	85.9	78.3	64.1	51.1	41.0
Minimum temp (°F)[1]	18.6	25.2	28.8	34.8	42.6	49.3	53.3	51.2	44.3	35.4	28.3	23.5
Wind speed (mph)[2]	6.0	5.2	5.7	5.5	4.5	4.9	4.8	4.3	4.1	3.7	3.2	2.3

[1] Yakima, WA: NCDC (1981)
[2] Mabton, WA: U. of Wash. Automated Weather Network *AgWeatherNet*, Sept 2005-Aug 2006.

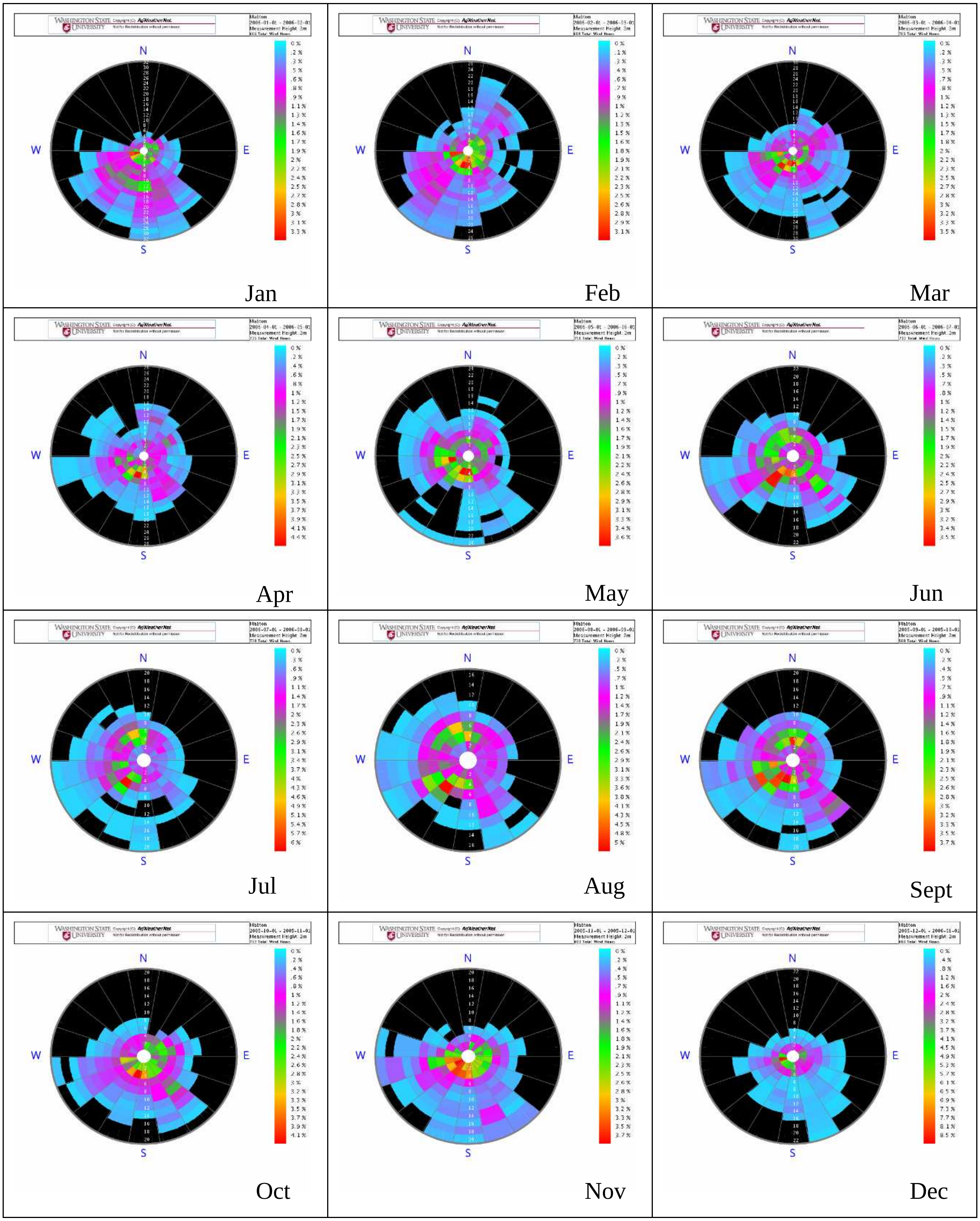

Figure 2. Wind Rose Maps from Washington State University (Sept 2005- August 2006).

Table 2. Characteristics of the lagoons and basins at the site.

Descriptive parameters	Unit 1	Unit 2	Unit 3
Livestock type	Dairy cows	Dairy cows	Dairy cows
Type of storage	Main storage basin	Drying ponds	Serpentine basins
Number of units	1	2	2
Year of facility construction	2002	2002	2002
Volume (each) (Mgal)	25	15	1
Volume, ft^3	3,342,500	2,005,500	133,700
Stage of lagoon (1^{st}, 2^{nd}, 3^{rd})	1^{st}	-	-
Distance from barn fans, ft	About 600	About 1600	About 1200
Manure contributors to unit			
Animal 1 type	Milking cows	Milking cows	Milking cows
Animal 1 average weight (lb)	1400	1400	1400
Animal 1 inventory (# head)	4400	4400	4400
Animal 2 type	Dry cows	Dry cows	Dry cows
Animal 2 average weight (lb)	1400	1400	1400
Animal 2 inventory (# head)	1200	1200	1200
Manure collection	Flush/alley scraping	Flush/alley scraping	Flush/alley scraping
Source flush or recharge water	Well	Well	Well
Lagoon loading interval, hours	Continuous	Continuous	Continuous
Minimum space around unit, ft	65	50	40
Volumetric loading rate, lb vs/d-ft^3	-	-	-
Surface loading rate, lb vs/d-ft^2	-	-	-
Obstructions within 3X height?	No	No	No
Type of cover	-	-	-
Are solids separated from influent?	Yes	Yes	Yes
Odor control	None	None	None
Sludge removal cycle, years	-	2 for each pond (alternating use 1 yr)	-
Last time sludge removed	-	2006 (E), 2005 (W)	-
Agitation prior to pumpout?	Yes	-	-
Manure removal frequency, days	Varies	Varies	Varies
Pump out (contractor or producer)	Producer	Producer	Producer
Type of liner	PVC	Clay	Concrete
Berm slope	3 :1 – 4 :1	3 :1 – 4 :1	3 :1 – 4 :1
Maximum side length, ft	563	600 (E), ≈ 600 (W)	180
Minimum side length, ft	368	235 (E), 271 (W)	70
Surface area, ft^2	207,184	141,000 (E) 163,200 (W)	12,600
Actual freeboard, ft	2	-	-
Inner berm height, ft	-	Varies	-
Outer berm height, ft	11.5 (max)	12 (max)	
Liquid depth, ft	17 (max)	16-18	
Sludge depth, ft	Varies	Varies	Varies
Number of inlets	1	1	1
Shape (rectangular, oval, etc.)	Rectangular	Rectangular and Trapezoidal	Rectangular

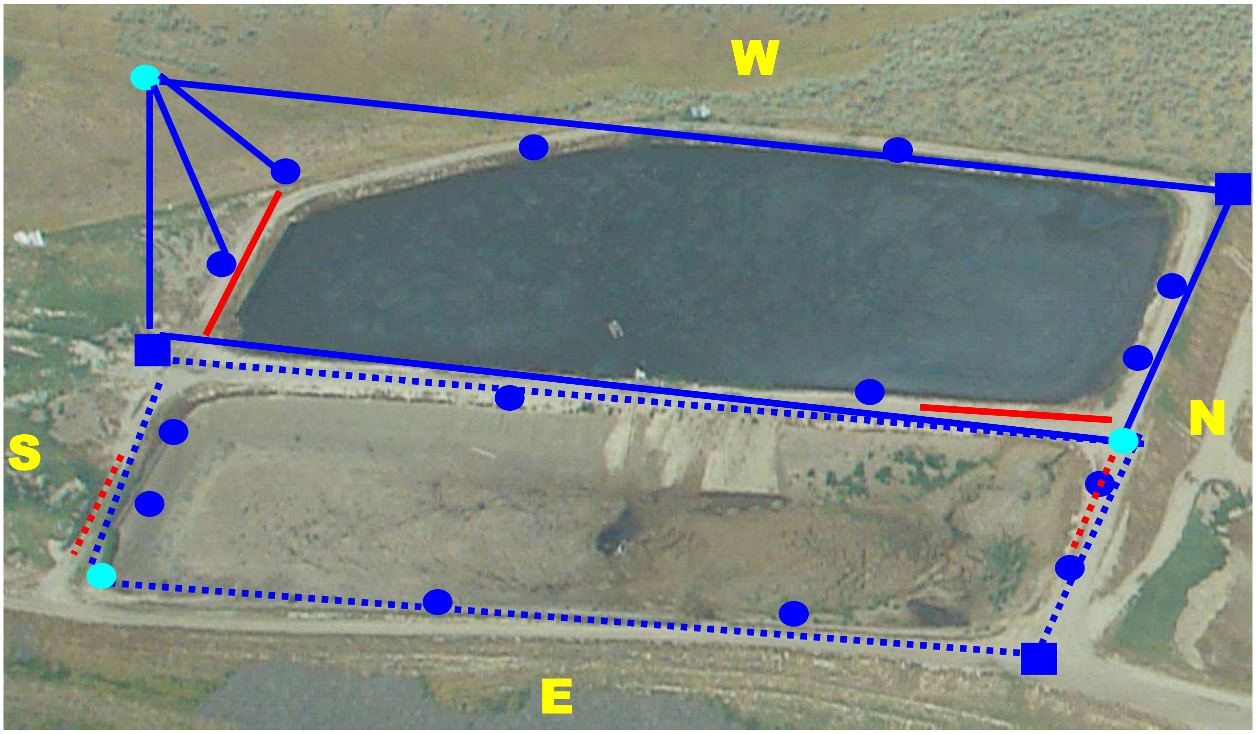

Figure 3. Plan layout of lagoon.

The S-OPS (red), TDLAS/ scanner (light blue circles) instruments and retro-reflector locations (blue circles) are indicated, retro-reflector towers (blue squares) and the scan beam lines/ planes (blue lines) are indicated by letter. Dashed lines correspond to 2007/8 measurement; solid lines to 2008/9. Photograph courtesy of Stewart Turner, CPAg.

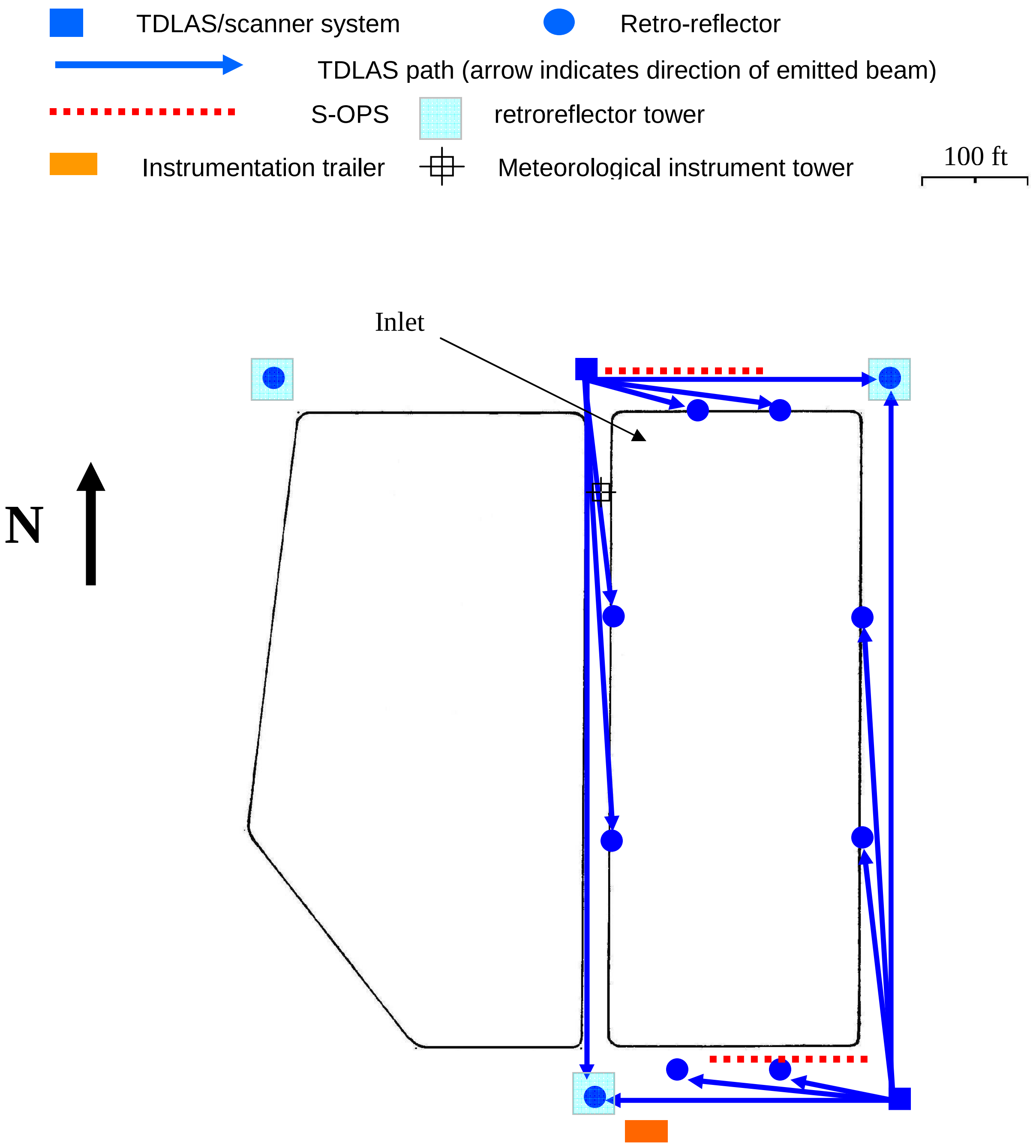

Figure 4A. Dimensional plan of the lagoon (2007/8).

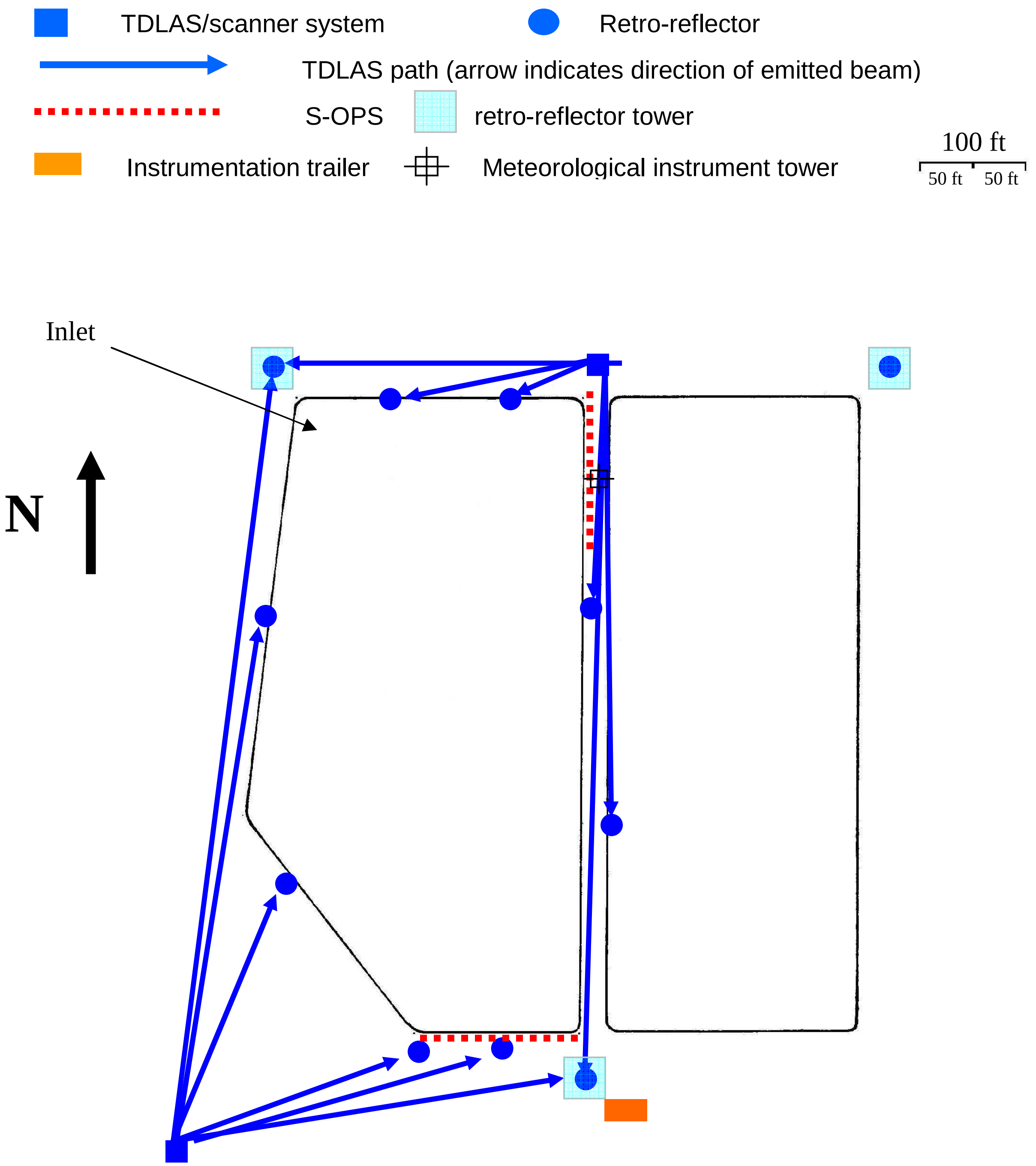

Figure 4B. Dimensional plan of the lagoon (2008/9).

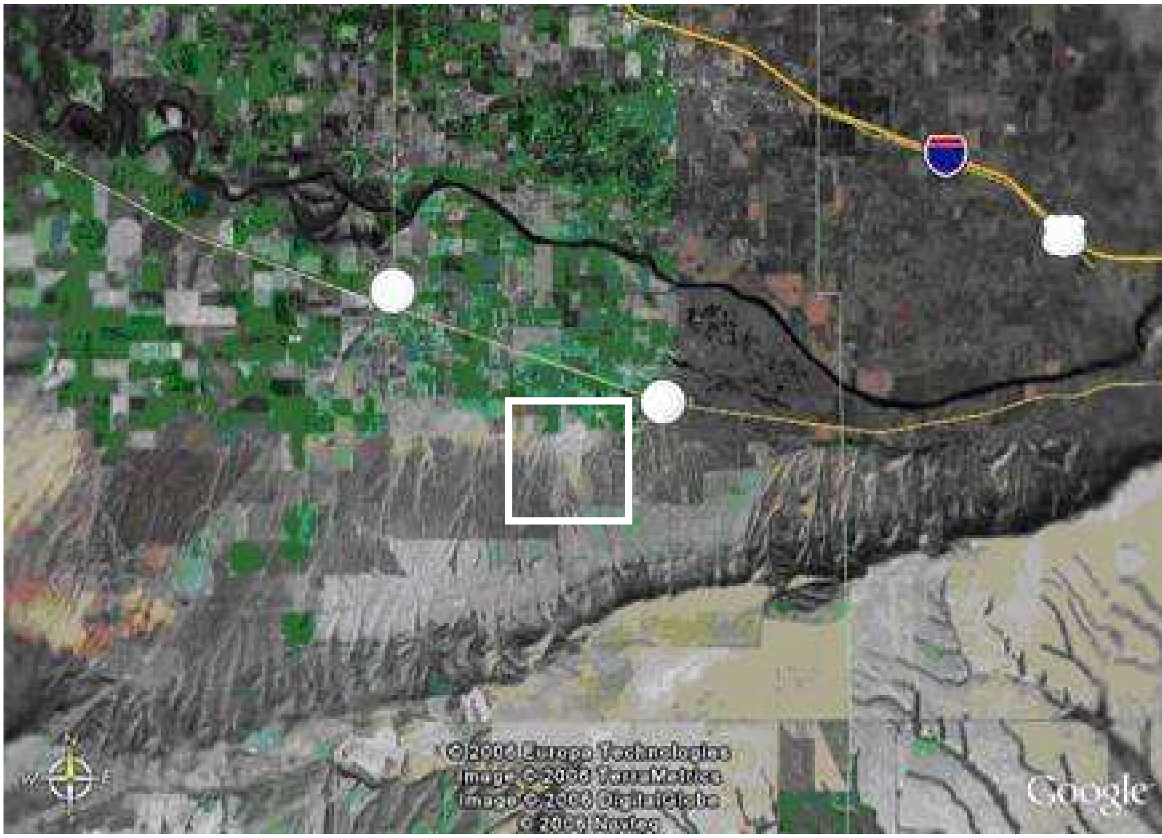

Figure 5. Satellite image of the farm's surroundings.
Location of farm, which was still under construction at the time of the imagery, is indicated by the square.

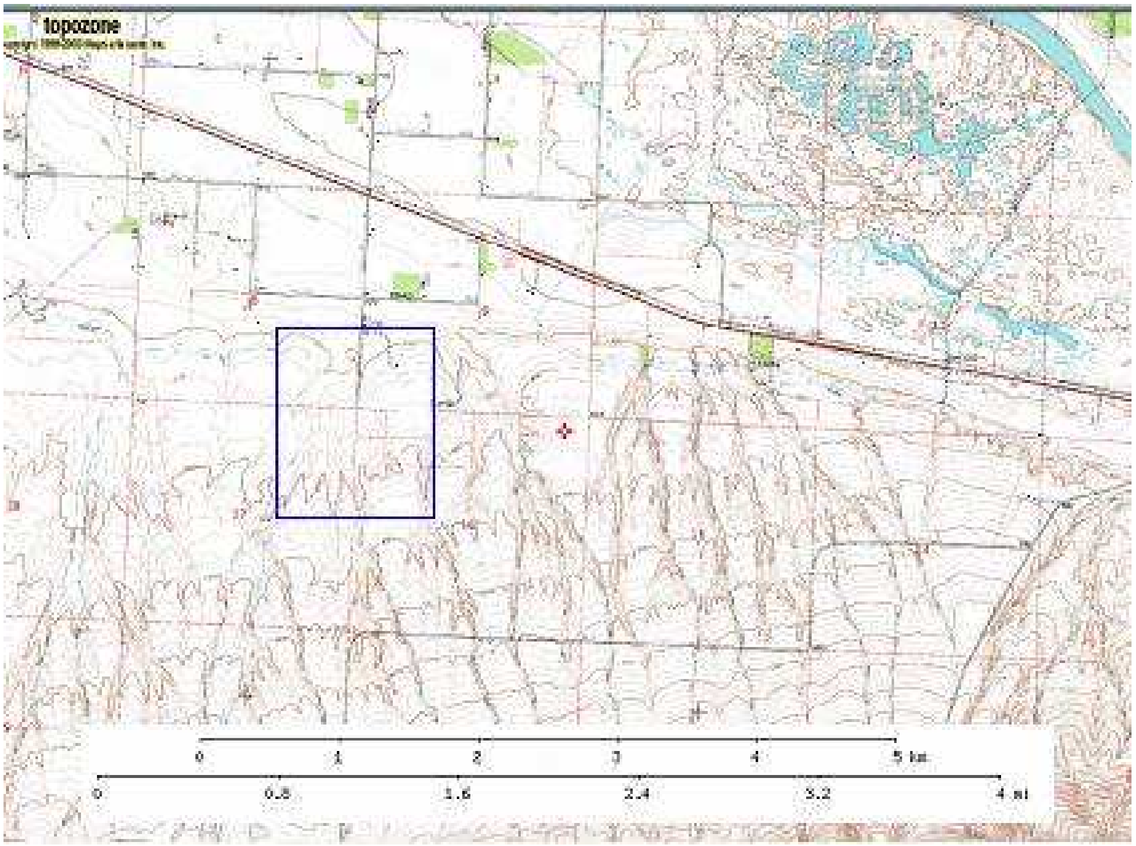

Figure 6. USGS Topographic Map of area.
Height interval is 10 ft Location of farm is indicated by blue rectangle. Prevailing winds are from the SW.

SMP WI5A
SITE MONITORING PLAN FOR DAIRY FARM IN WISCONSIN
(LAGOON COMPONENT)

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Site Description

The Midwest freestall dairy facility is located in St Croix County, WI (Fig. 1) on the side of a river valley (Fig 2). The elevation at the farm is approximately 332 m (1088 ft). The farm has a total of 6 barns, a milking parlor with holding pen, and a special needs area. The farm has a capacity of 1700 Holstein cows.

Logistics

Measurements will be made by one of the rotating measurement teams from the Purdue Applied Meteorology Laboratory (PAML) in West Lafayette, IN. The nearest airport is located in Minneapolis/St. Paul, MN, an approximately one-hour drive of 79 km (49 mi) W of the site.

Climate (Table 1)

The climate for the area is approximated by the Minneapolis/St Paul National Weather Service weather station, which is approximately 79 km (49 mi) W of the farm. The area typically receives an average of 659 mm (26 in) of precipitation (NCDC, 1981). Over the course of the year, the prevailing winds vary from N in April, ESE during May and June, S from July through September, and NW from October through March (Fig. 3, Table 1). Maximum chances of days with precipitation are during the summer. Mean monthly wind speeds range from 4 m/s (9 mph) to 5 m/s (12 mph). Average relative humidity (RH) ranges from 78% in the morning to 60% in the afternoon, while average air temperature ranges from 12.1 ºC (53.8 ºF) to 1.2 ºC (34.3 ºF). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm Operations Characteristics (Table 2)

Manure from the freestall barns and the milking parlor complex is removed by flushing three times daily. The manure flushed from the parlor, holding pen, and freestall barns flows to a solids separator, from which the solids are removed and stacked on a pad until they are spread on fields (the nearest of which is approximately 100 m from the barns). The liquid effluent from the solids separator is pumped back into vertical tanks for reuse to flush the barns. Once a week, enough water is removed from the third stage of the three-stage lagoon and added to the flush tanks to makeup for water lost in the recycled flush system. The three-stage lagoon receives effluent from the two freestall barns (Barns 1 and 2) that are being measured by the barn component of the National Air Emissions Monitoring Study (NAEMS), as well as the other barns and milking parlor. The lagoons are pumped out into trucks twice yearly. The first and second stages of the three-stage lagoon system will be monitored in this study. These lagoons have an outer berm height of 6 m to the W, and between 1 and 6 m to the N.

Surrounding Sources

The nearest identifiable NH_3 or H_2S emission sources include: Three barns 30 m E of the three-stage lagoons, 2 barns approximately 200 m SE of the lagoons, a lagoon about 110 m S, the manure stacking pad which is about 130 m S of the three-stage lagoons (Fig 4), manure spread on nearby fields 30 m W and approximately 100 m to the N, a swine farm 1.6 km to the W, and an open heifer lot 300 m to the NE.

Monitoring Plan

The NH_3 emissions from the lagoon will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the lagoon during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) in conjunction with NH_3 emissions calculated by the RPM emissions model (SOP O2) by ratiometric methods (PAML 2006a). VOC emissions from the lagoon during the same periods will be monitored using S-OPS sample collection (SOP C4) and PAS equipment (SOP G7) in conjunction with NH_3 emissions calculated by the RPM emissions model (SOP O2) by ratiometric methods (PAML 2006a).

The NH_3, H_2S and VOC PIC measurements are not expected to be strongly influenced by the flow conditions surrounding the relatively high berm of the lagoon. In a study of a slightly lower (4 m high) berm the upwind outer berm of a lagoon contributed to region of vertical flow convergence at the berm top at a height of 2 m, with a mean vertical flow between 10 and 20 degrees upward (PAML, 2006b). This upward flow on the upwind berm was not anticipated to cause problems in the emissions calculations from PIC measurements, since the upwind conditions provide the background concentration for emissions calculations. The high downwind berm results in a recirculation at heights lower than the berm height, but did not appear to change the mean, nearly horizontal flow above the berm height (PAML, 2006b). The positioning of the S-OPS systems at 1 m abl should represent the concentration of gases in the air from over the lagoon.

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, creating vertical measurement planes on each side of the two lagoon complex (Fig. 5). Fixed towers will be located at the SE corner of the 2nd stage lagoon and at the NW corners of the 1st stage lagoon. The scanning TDLAS instruments will be mounted at 1-m height above berm level (abl) on anchored tripods at the NE berm corner of the 1st stage lagoon and off the SW berm corner of the 2nd stage lagoon. Retro-reflectors at the approximate ⅓ and ⅔ distance down the lagoon sides will be mounted at 1-m abl on anchored tripods located on the berms (Fig. 5). Fetch from the TDLAS beamline along the N berm of the 1st stage lagoon is 1:2.5 (42 m distance, 16 m tree height) (Fig. 5). Fetch to the S from the TDLAS beamline on the S berm of the 2nd stage lagoon is greater than 1:100 while that to the N is 1:8.6. Fetch to E from the TDLAS beamline along the E of the three lagoons is 1:4.6 (7 m high at a distance of 31 m) with the 2nd barn, 1:3.1 (6 m high at a distance of 20 m) with the 1st barn and 1:3.5 (4 m high at a distance of 14 m) with the 3rd barn. Due to poor fetch to the E of the beamlines, there will be no monitoring when winds are from the N through SE (Fig. 3), as typically prevails during May and June (Table 1), and represents about 35.6% of the year overall (Fig. 3). The TDLAS laser beam is eye-safe, so no special safety precautions are necessary.

Two S-OPS will be used to collect air along linear paths at 1 m abl along the lagoon berm on two sides of the lagoon for the measurement of H_2S and VOC. Each 50-m S-OPS consist of ten orifices spaced at a 5 m interval along the line. Since the prevailing winds are NW, N, and ESE, the S-OPS will be positioned on the N berm of the 1st stage lagoon and off the S berm of the 2nd stage lagoon (Fig. 5) at 1-m height above berm height. Fetch from the S-OPS path along the N berm of the 1st stage lagoon is 1:3 (42 m distance, 16 m tree height) (Fig. 5). Fetch to the S from the S-OPS path S of the S berm of the 2nd stage lagoon is greater than 1:100, while that to the N is 1:8.6.

Volatile organic compounds, including methane, methanol, ethanol and total VOCs, will be measured using an INNOVA 1412 multi-gas photoacoustic analyzer (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the basin.

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be mounted on the meteorological tower located on the berm between the 1st and 2nd stage lagoons, 20 m to the E of the 2nd lagoon NW corner (Fig. 5). The meteorological data will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2-m height between the 1st and 2nd stage lagoons (Fig. 5), and at 4-m and 16-m heights above berm level (abl) on the SE corner tower (SOP U5).

Configuration specifics:
The TDLAS/scanners will be located on the lagoon berm at the NE corner of the 1st stage lagoon and SW corner of the 2nd stage lagoon, and will be mounted at 1 m abl on anchored tripods (Fig. 5). The TDLAS retro-reflector towers are located 12 m SE of the SE berm corner and located 20 m NW of the NW berm corner are fixed triangular towers (Fig. 5). For the northernmost beamlines on the 1st stage lagoon, the fetch to the trees and buildings to the N is 1:2.2 (42.6m distance, 16.2m height). Details of the position of each measurement path associated with the paths indicated in Fig. 5 follows:

N side of 1st stage lagoon

- 50 m length S-OPS path beginning 2.5 m NE of the NE lagoon corner and running W parallel to the berm.
- TDLAS retro-reflectors will be located 31 m and 60 m west from the TDLAS/scanner on the NE berm

N side of lagoon looking E along the berm . Lagoons are on right.

corner, and mounted at 1 m abl using anchored tripods.

- Three retro-reflectors are mounted on the NW tower at 1 m abl, 7 m abl, and 15 m abl, with an approximate pathlength of 111 m.

E side of lagoons

- TDLAS retro-reflectors will be located along the berm at 34 m and 73 m south of the TDLAS/ scanner at the NE corner. Retro-reflectors will be mounted at 1 m abl using anchored tripods.
- Three retro-reflectors will be mounted on the SE corner tower located off the berm and W of the fenceline at 1 m abl (approx. 2 m agl) at 7 m agl, and 15 m agl, with a pathlength of 102 m.

E side of lagoons looking S along W side of fenceline. 1st stage lagoon is on right.

S side of 2nd stage lagoon

- 50 m length S-OPS path on the lagoon berm between the 2nd and 3rd stage lagoons.
- S-OPS begins at the SW berm corner of the 2nd stage lagoon and extends E.
- TDLAS retro-reflectors will be located at 25 m and 54 m east along the berm from the TDLAS/scanner on the platform 3 m SW of the SW berm corner of the 2nd stage lagoon. The retro-reflectors will be mounted at 1 m abl on anchored tripods.
- Three TDLAS retro-reflectors will be mounted on the SE tower with an approximate path length of 83 m.

E side of lagoon looking N along the berm E of the fenceline. Lagoons are on left.

S side of lagoon looking E along the berm. 2nd stage lagoon is on right.

W side of lagoons

- TDLAS retro-reflectors will be located 60 m and 108 m north of the TDLAS/scanner located at the SW corner. Retro-reflectors will be mounted at 1 m abl on anchored tripods.

- Three retro-reflectors will be mounted on the NW tower, with a path length of approximately 110 m.

W side of lagoon looking S. 1st stage lagoon is on left.

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2), with data from the three sonic anemometers (SOP W2) and TDLAS data (SOP C2). Restrictions on the use of the RPM model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are <1 m/s. Wind speeds (at 7-m height) at St. Paul, MN were ≤1.1 m/s 4.4% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are >11 m/s. Wind speeds (at 7-m height) at St. Paul, MN were ≥11.1 m/s 1.3% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS path-integrated concentration (PIC) measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. Locating a TDLAS scan plane on each of the four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.
4) Sufficient fetch upwind and downwind. Fetch from the east beamlines to the E is 1:4.3 (6 m high barn at 80 m distance) to the N is 1:61 (195m distance, 3.2m height) (Fig. 5). The barns are approximately 30 m (100 ft) to the E of the lagoons (Fig. 5), and should not significantly influence wind flow under most winds (Fig. 3), since winds are usually from the NW and S. For the 4-m and 16-m wind sensors, fetch to the N is 1:74 at 16 m and 1:10 at 4 m. For the 2-m wind sensor, fetch to the N is 1:5.6. For winds from the E, the 2-m wind sensor has a fetch of 1:13, the 4-m sensor has a fetch of 1:6.5, and the 16-m sensor is above the buildings to the E. Measurements during winds from the E, which typically prevail in May and June (Table 1) and represent 35.6% of the year overall (Fig. 3) will not be included in any analysis. Careful choice of measurement periods will be needed to avoid easterly winds commonly associated with stormy weather.

VOC and H_2S emissions from the lagoon will be calculated using the ratiometric method. The ratio of VOC measured by the S-OPS/PAS or H_2S measured by the S-OPS/PF to the to ammonia measured by TDLAS and the emission of ammonia by the lagoon measured by the RPM method will be used to estimate the VOC and H_2S emission according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006). Restrictions on the use of the model are:

1) The S-OPS path and corresponding TDLAS path are equivalent such that the NH_3 PIC values can be assumed to represent that along the S-OPS path.
2) The S-OPS air samples from upwind and downwind locations are synoptic. This can be assumed since concentrations sampled from the S-OPS sampled air will be averaged over ½ hr intervals. The synoptic measurements will provide the ability to determine the ammonia and hydrogen sulfide concentration change for the air crossing over the lagoon.

The three-stage lagoon system included in the measurement area will not each emit NH_3 , VOC, or H_2S only in proportion to the lagoons' surface areas, but will vary due to their differences in composition. To sample only one lagoon of the three does not provide enough pathlength for good sensitivity.

Animal inventory will also be obtained from the producer, and will be verified every six months by the study personnel (SOP S2).

Communications

The instrumentation trailer (SOP U4) will be located just E of the road between the 1st and 2nd stage lagoons (Fig. 5). Telemetry of TDLAS, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All measurements telemetered to the trailer will be sent to Purdue nightly via cellular DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the producer-supplied sources already located between the 1st and 2nd stage lagoons and the 2nd and 3rd stage lagoons. All wiring will be buried directly in the ground from the producer-supplied source and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weather proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use and furthermore by training sessions to be held with the farm staff about the project, its' instruments, and requirements at the time of initial setup, and periodically during the measurement period as needed.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed.

Emissions determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the N and 3 m from the W shore at the SW corner of the 1st stage and from a float positioned 3 m S and 3 m E from the NW corner of the 2nd stage lagoon (SOP U5) (Fig. 5). The lagoon characterization measurement data will be collected by the data logger (SOP W6). Lagoon sludge depth measurements (SOP L5) will be made at nine locations: six locations in the 1st stage lagoon and three locations in the 2nd stage lagoon (approximate locations indicated in Fig. 5), at the beginning or end of each measurement period. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted or if winds prohibit being able to keep the boat stationary for the measurements.

Analyses of the lagoon effluent is conducted bi-annually for the producer by an external laboratory at the time of each lagoon sludge removal. This information, as well as the time of removals and other pertinent operations events will be provided by the producer according to SOP S7, and will be utilized in assessing the relationship of lagoon composition and emissions.

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Figure 1. Overall layout of farm lagoons and nearby barns (looking N).

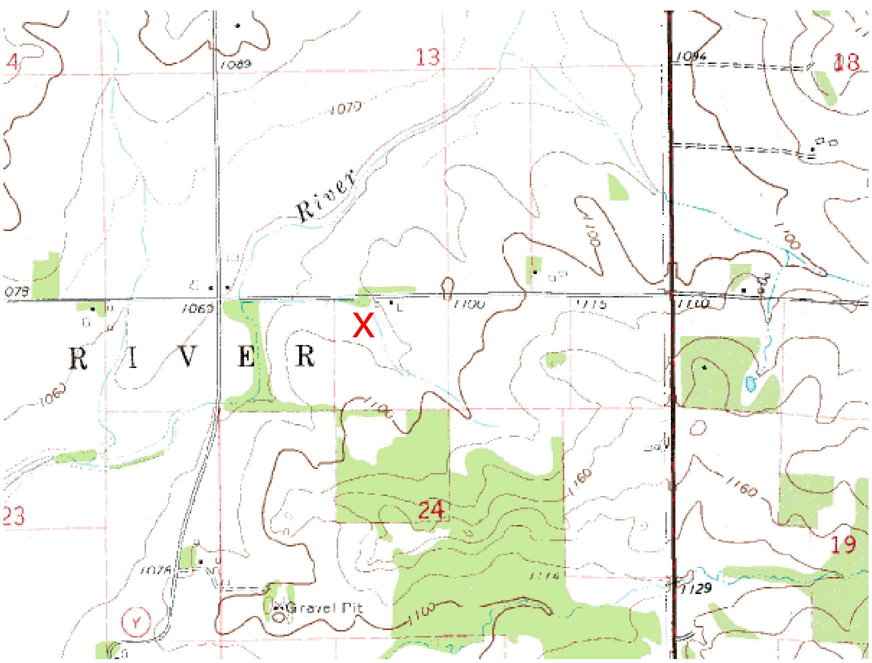

Figure 2. Terrain of surrounding area. Farm is indicated by the red cross.

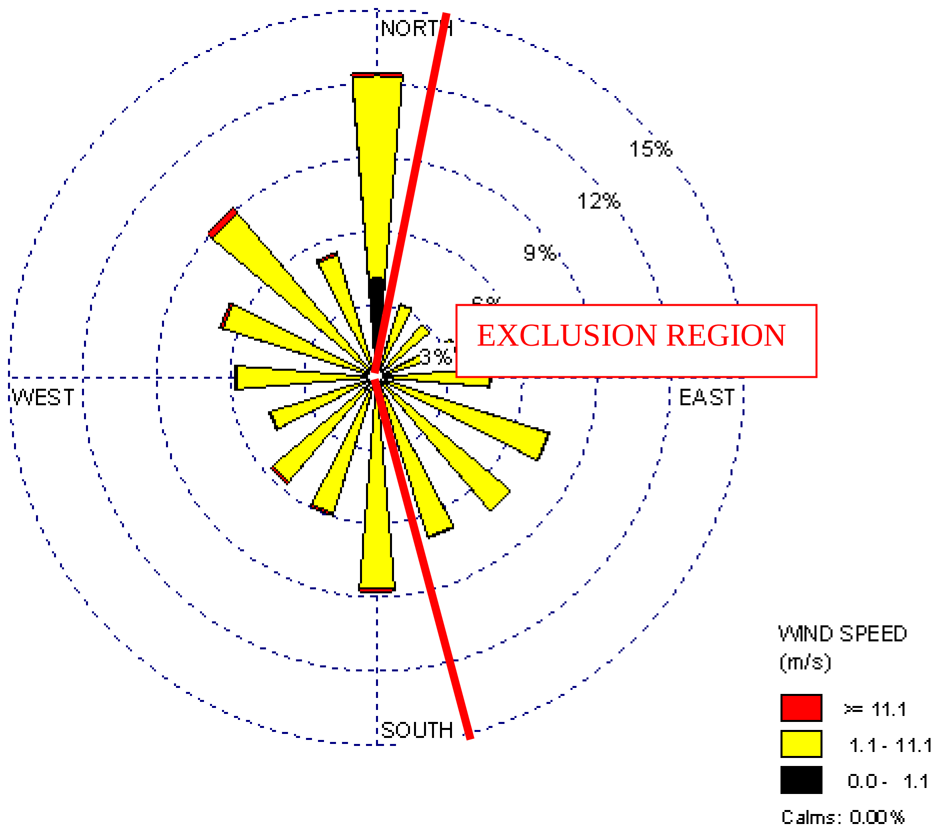

Figure 3. Wind Rose for Minneapolis/St. Paul NWS weather station.
Measurement exclusion region is bounded by red lines. Wind speeds below 1.1 m/s are below the range of the NWS anemometers, and are all assigned a northerly direction.

Table 1. Monthly climate description for St. Paul, MN.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with >=0.01 in of precipitation[1]	9	7	10	10	11	12	10	10	9	8	8	9
Wind speed (mph)[2]	11	10	11	12	11	11	10	9	10	11	11	10
Wind direction[2]	NW	NW	NW	N	ESE	ESE	S	S	S	NW	NW	NW
Morning RH (%)[1]	72	73	76	75	76	79	81	84	86	81	80	77
Afternoon RH (%)[1]	66	64	63	54	51	54	54	56	60	58	65	69
Maximum T (°F)[1]	21.2	25.9	36.9	55.5	67.9	77.1	82.4	80.8	70.7	60.7	40.6	26.6
Minimum T (°F)[1]	3.2	7.1	19.6	34.7	46.3	56.7	61.4	59.6	49.3	39.2	24.2	10.6

[1] NCDC (1981)
[2] NCDC (1998)

Table 2. Characteristics of lagoons and Basins at the Wisconsin dairy site.

Descriptive parameters.	Unit 1	Unit 2	Unit 3
Livestock type	Dairy Cows	Dairy Cows	Dairy Cows
Type of storage (basin, lagoon or tank)	Lagoon	Lagoon	Lagoon
Number of units			
Year of facility construction	1991	1991	1994
Separation distance from barn fans, ft	200	200	200
Stage of lagoon (1st, 2nd, 3rd)	1st	2nd	3rd
Manure contributors to unit			
Animal 1 type (sows, cows, etc.)	Dairy cows	Dairy cows	Dairy cows
Animal 1 average weight (lb)	1400 #	1400 #	1400#
Animal 1 inventory (# head)	650	650	650
Manure collection (flush, scrape, PPR)	Flush	Flush	Flush
Source flush or recharge water (if any)	Recycled	Recycled	Recycled
Lagoon loading interval, h	Every hour	Every hour	Every hour
Minimum space around unit, ft	100	100	100
Volumetric loading rate, lb VS/d-ft^3	350,000	350,000	350,000
Surface loading rate, lb VS/d-ft^2	None	None	None
Obstructions within 3X height of unit?	None	None	None
If yes, what kind? (e.g. trees, barns)	Barns, 4th Lagoon, Stacking pad	Barns, 4th Lagoon, Stacking pad	Barns, 4th Lagoon, Stacking pad
Height of worst obstruction, ft	28.3	27.3	20
Distance from worst obstruction, ft	98	92	104
Type of cover	None	None	None
Are solids separated from influent?	Yes	Yes	Yes
Odor control	None	None	None
Sludge removal cycle, years	2x/year	2x/year	None
Last time sludge removed (e.g., 1999)	2006	2006	None
Agitation prior to pumpout?	Yes	Minimum	No
Manure removal frequency, days	180	180	180
Pump out (contractor or producer)	Producer	Producer	Producer
Type of liner (clay, plastic, etc.)	Clay	Clay	Clay
Volume, ft^3	373,000	226,700	226,700
Surface area, ft^2	45,900	31,200	30,400
Berm slope (e.g. 3:1, 3.5:1, 4 :1, etc.)	2 :1	2 :1	2 :1
Maximum side length, ft	270	260	190
Minimum side length, ft	170	120	160
Actual freeboard, ft	1	1	1
Inner berm height, ft	12	12	12
Outer berm height, ft	12	13	14
Liquid depth, ft	11	11	11
Sludge depth, ft	1	1	2
Number of inlets	1	1	2
Shape	rectangular	rectangular	rectangular

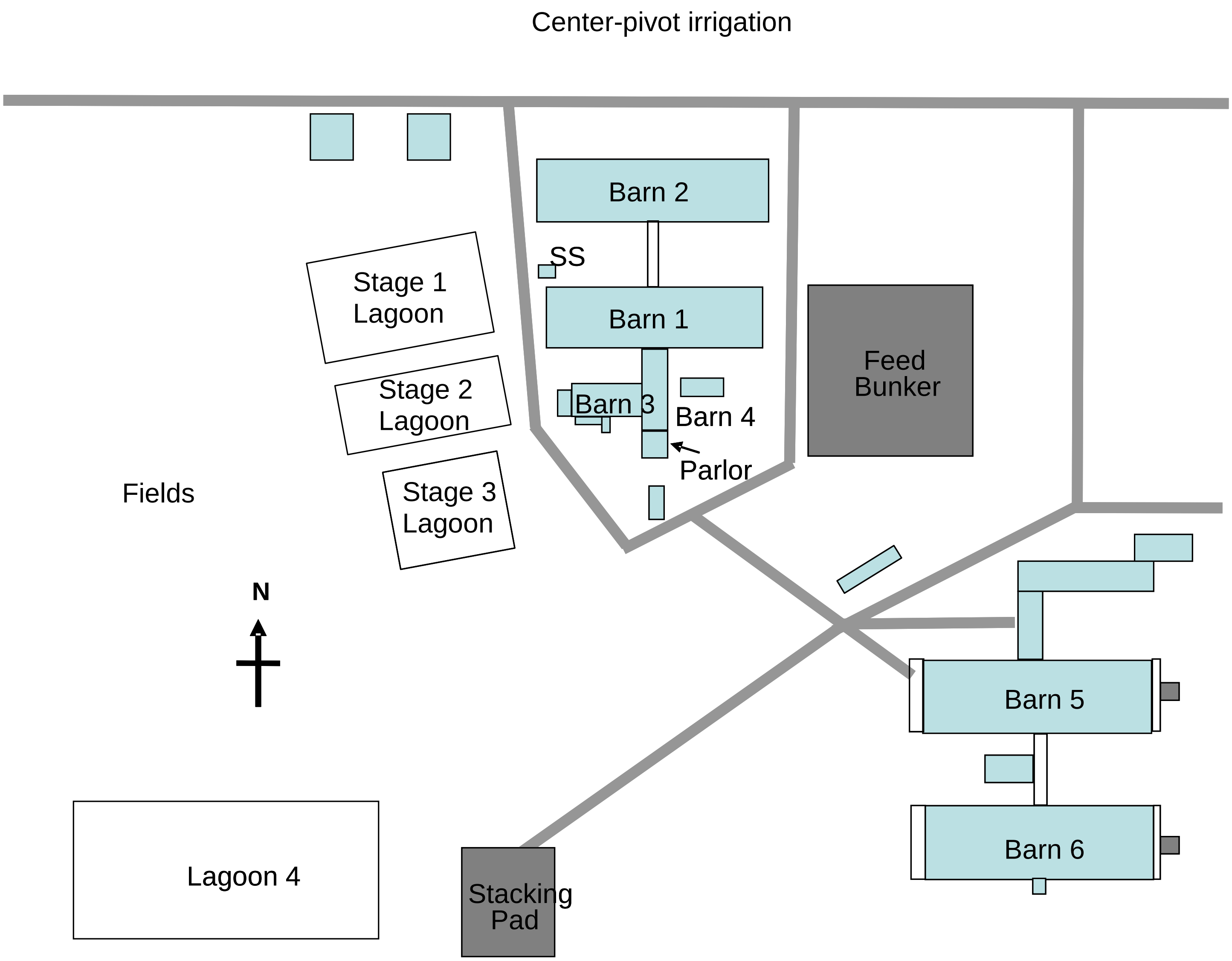

Figure 4. Diagrammatic overall layout of farm.
Stage 1 and 2 Lagoons will be monitored. SS = sand separator.

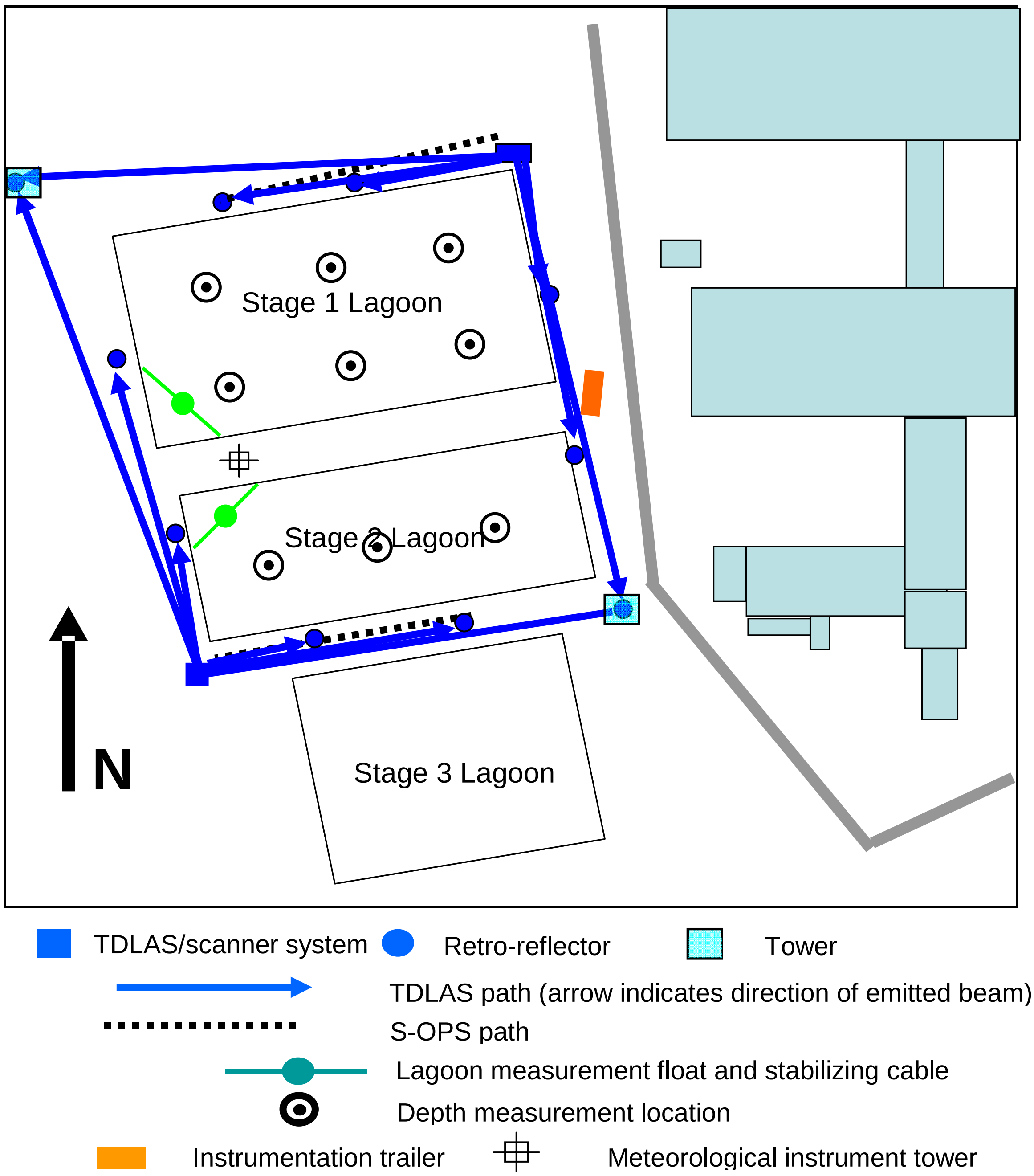

Figure 5. Dimensional plan of the lagoon