National Air Emissions Monitoring Study

An Update for the AAQTF on May 14, 2008

Albert J. Heber, Professor
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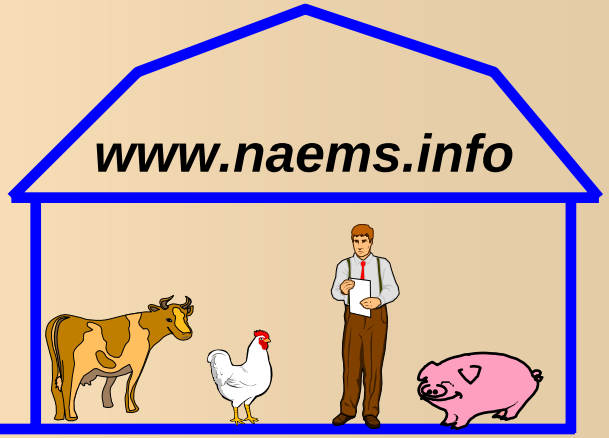
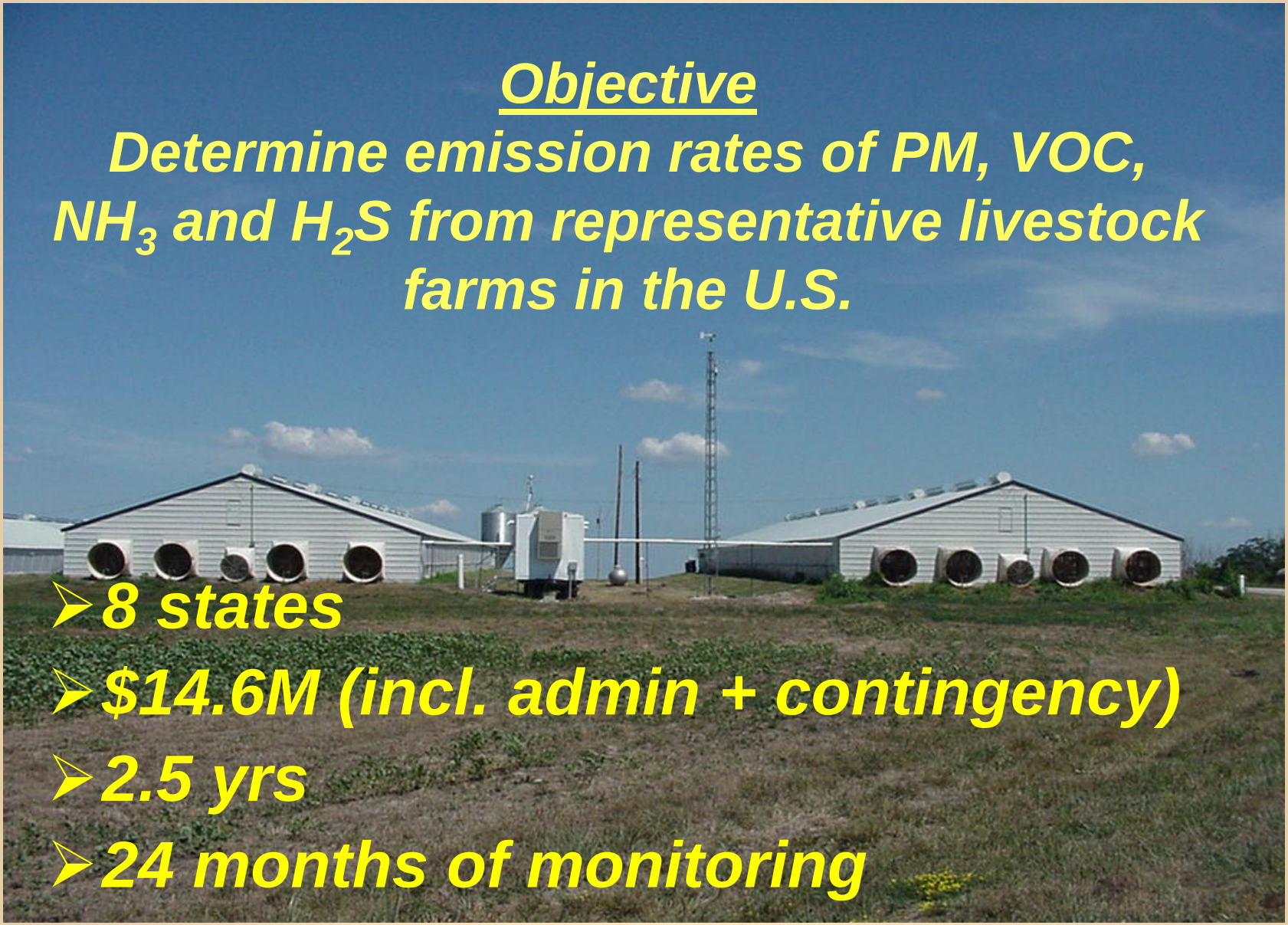


Purdue Agricultural Air Quality Laboratory

Agricultural and Biological Engineering

PURDUE UNIVERSITY

Purdue University



Air emissions from two to three barns per site are being measured for 24 months using EPA-approved methods.

Study Design Summary

- Twenty representative livestock production sites.
- Outdoor manure facilities (9) and corral (1) monitored every season
  - Hydrogen sulfide (UVDOAS or pulsed fluorescence w/ S-OP).
  - Ammonia (TDLAS, UVDOAS, photoacoustic spectroscopy)
  - Ethanol, methanol, NMVOC (photoacoustic spectroscopy w/ S-OP)
  - Radial Plume Mapping with TDLAS
  - Backward Lagrangian stochastic (bLS) modeling
- Barns (38) monitored continuously
  - Hydrogen sulfide (pulsed flourescence)
  - Ammonia (photoacoustic spectroscopy)
  - Ethanol, methanol (photoacoustic spectroscopy)
  - Non-methane hydrocarbons (GC-FID)
  - Carbon dioxide (photoacoustic spectroscopy)
  - TSP, $PM_{2.5}$, PM_{10} (TEOM)
  - Barn airflow (fan speed, pressure, velocity, portable fan tester)
- Integrated Sampling
  - VOCs: GC-MS (canisters, tubes), IC (impingers)
- EPA-approved standard operating procedures

Timeline

2006 ***Development of Quality Assurance Project Plan***

2007 ***Setup of Field Monitoring Sites***

2008 ***Data Collection, Analysis and Reporting***

2009 ***Data Collection, Analysis and Reporting***

2010 ***Final Report to EPA***

Activities Since Last Update

- Last barn site was set up in December
- Completed audits of each barn site.
- Data analysis in full swing.
- Solved various problems at sites.
- Revised protocol documents.
- New VOC lab manager pilot tested VOC sampling and analysis methods.
- VOC filter in Innova deemed invalid.
- Wrote proposals to add GHG.
- Started up synthetic open path at area sources.

Summary of Site Setup Milestones

Progress of Barn Sites

Site	OFIS	On-line	Day 1	Audit	Sensors	DA
CA1B	5/29/07	6/10/07	9/28/07	**9/5/07**	125	EC
CA2B	6/25/07	7/15/07	10/17/07	**10/30/07**	104	TL
IN2B	5/11/07	8/24/07	11/2/07	**1/15/08**	297	BB
IN2H	12/4/06	12/7/06	5/9/07	**1/16/08**	169	JN
NC2B	5/23/07	8/24/07	9/24/07	***9/12/07***	140	KW
IN3B	3/9/07	5/24/07	7/13/07	**8/24/07**	154	RL
NC3B	8/24/07	8/30/07	11/30/07	**11/14/07**	98	SH
NC4B	8/2/07	8/11/07	12/14/07	**1/30/07**	85	KW
IA4B	5/7/07	5/18/07	7/19/07	**8/30/07**	147	EC
OK4B	5/30/07	6/4/07	7/20/07	***8/16/07***	121	EC
CA5B	5/31/07	9/23/07	9/27/07	**9/6/07**	239	JR
IN5B	5/10/07	5/17/07	8/24/07	**9/15/07**	186	JH
NY5B	5/31/07	6/12/07	10/24/07	***11/13/07***	107	BB
WA5B	6/15/07	8/30/07	9/28/07	**10/31/07**	214	JR
WI5B	5/16/07	6/10/07	9/12/07	***8/29/07***	121	EC

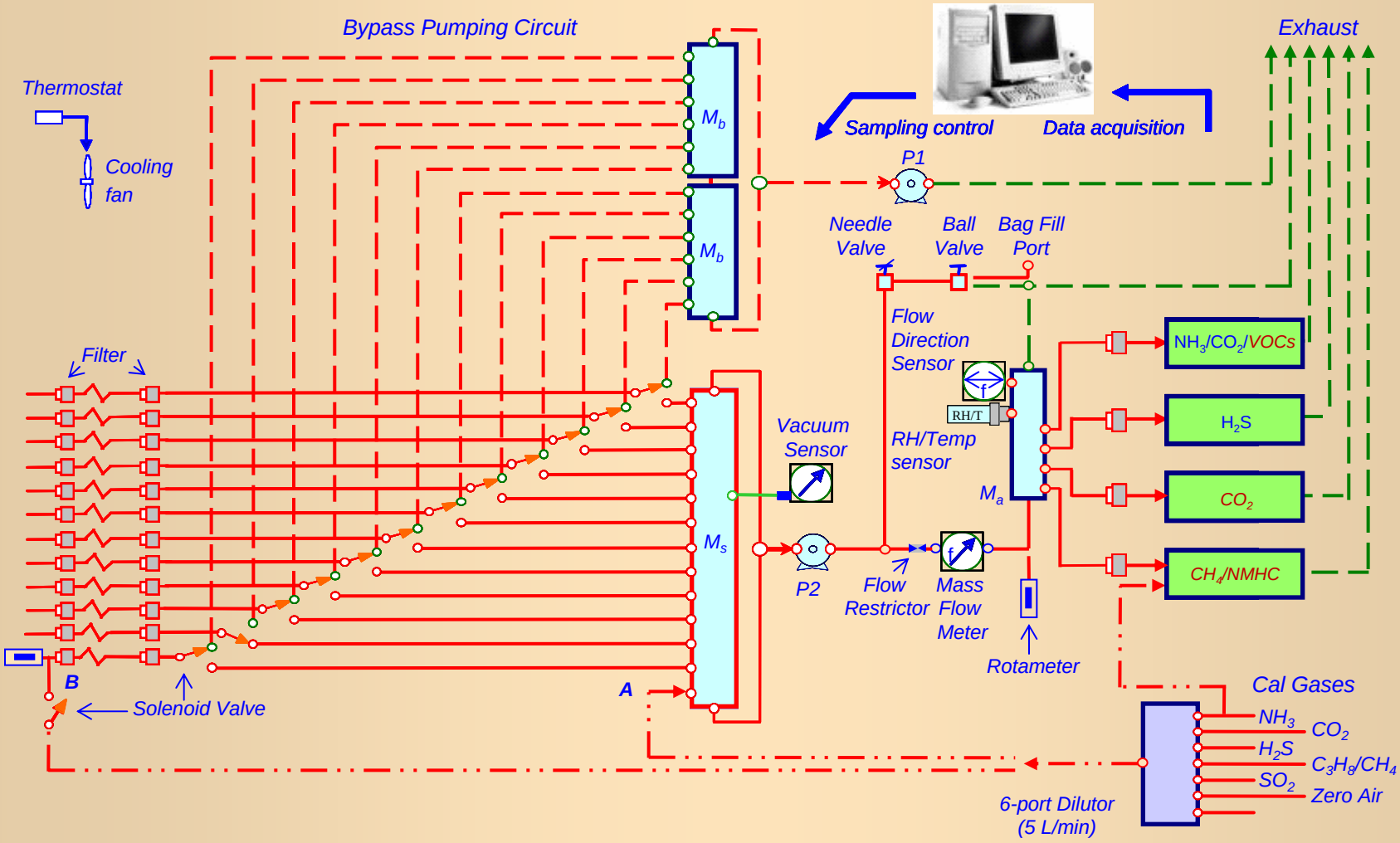
Funded Add-on Studies

PI	Topic/Sponsor	Site(s)
Ni	*Air emissions (USDA-NRI)*	IN2B
Jacobson	*Odor emissions (USDA NRI)*	IA&OK4B, IN&WI5B
Lim	*Dairy Odor Setback Model (Purdue Ag)*	IN5B
Koziel	*GHG emissions (Iowa State University)*	IA4B
Jacobson	*GHG emissions (University of Minnesota)*	WI5B
Zhang	*GHG emissions (CARB)*	CA1B, CA2B
Mitloehner	*VOCs @ GHGs (CA Dept. of Food, Ag. & Dairy)*	CA5B
Wang	*PM size distribution (USDA-NRI)*	NC2B
Lim	*Test of a commercial biofilter for exhaust fans*	IN3B
Ndegwa	*Bioaerosols (PNASH)*	WA5B

NH3 and VOC Measurements

Site	Species	1	2	3	4	5	NMHC	VOC
CA1B	Broilers	NH3	CO2	THC	CH4	Eth		IC
NY5B	Dairy	NH3	CO2	None	None	None		
WA5B	Dairy	NH3	CO2	None	None	None		
WI5B	Dairy	NH3	CO2	None	None	None		
CA5B	Dairy	NH3	Meth	THC	CH4	Eth	55C	
IN5B	Dairy	NH3	CO2	THC	CH4	Eth		IC
CA2B	Layers	NH3	CO2	N2O	CH4	Ethg		
IN2B	Layers	NH3	CO2	None	None	None		
NC2B	Layers	NH3	CO2	None	None	None		
IN2H	Layers	NH3	CO2	THC	CH4	Eth		IC
NC3B	Swine	NH3	CO2	None	None	None		
NC4B	Swine	NH3	CO2	None	None	None		
OK4B	Swine	NH3	CO2	None	None	None		
IA4B	Swine	NH3	CO2	THC	CH4	N2O		
IN3B	Swine	NH3	Meth	THC	CH4	Eth	55C	IC

Gas Sampling System



Tubing and Fitting Material:

- Teflon
- Nylon
- Stainless Steel

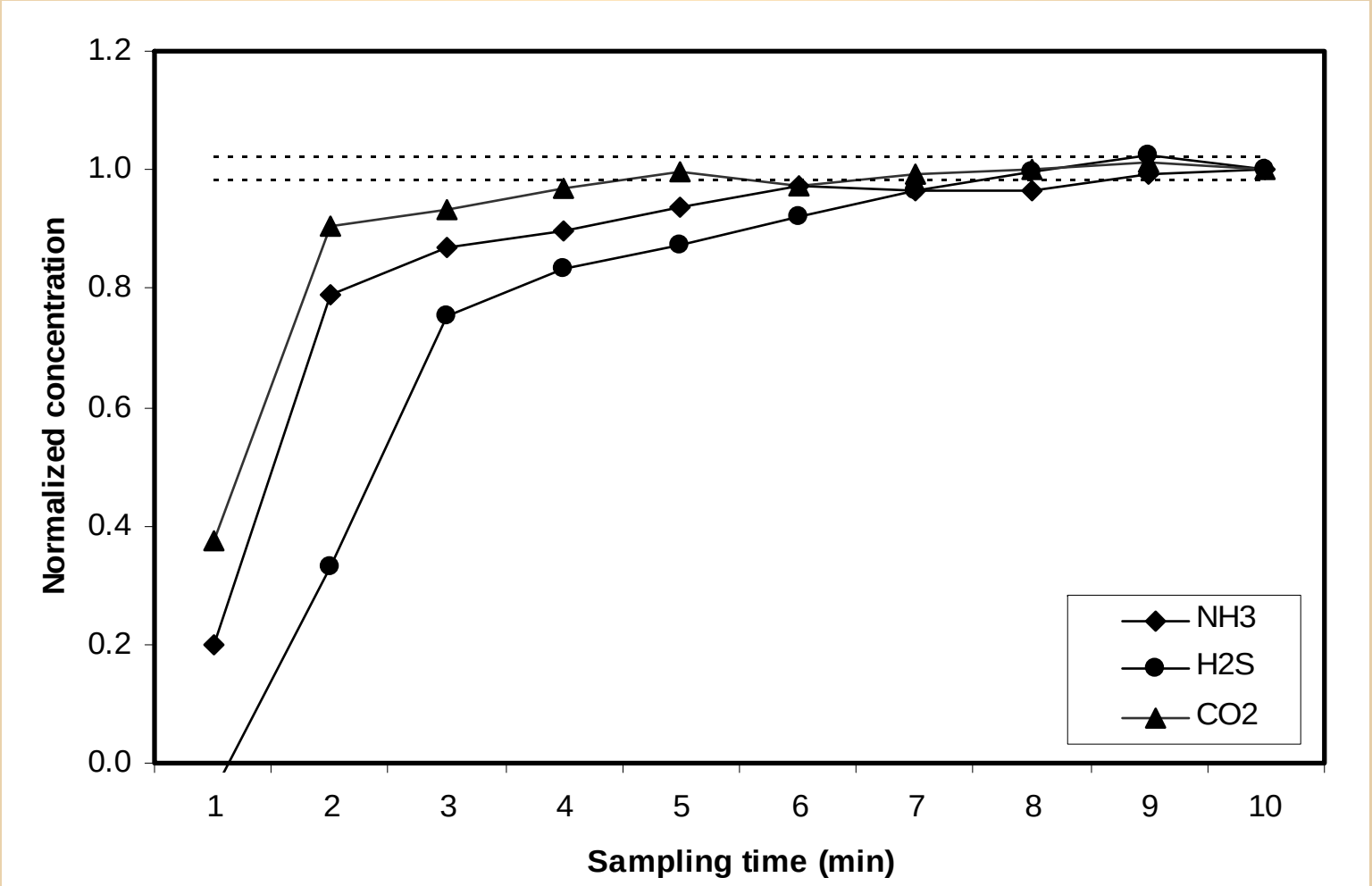
Type of Line:

- Sampling
- Exhaust
- Calibration

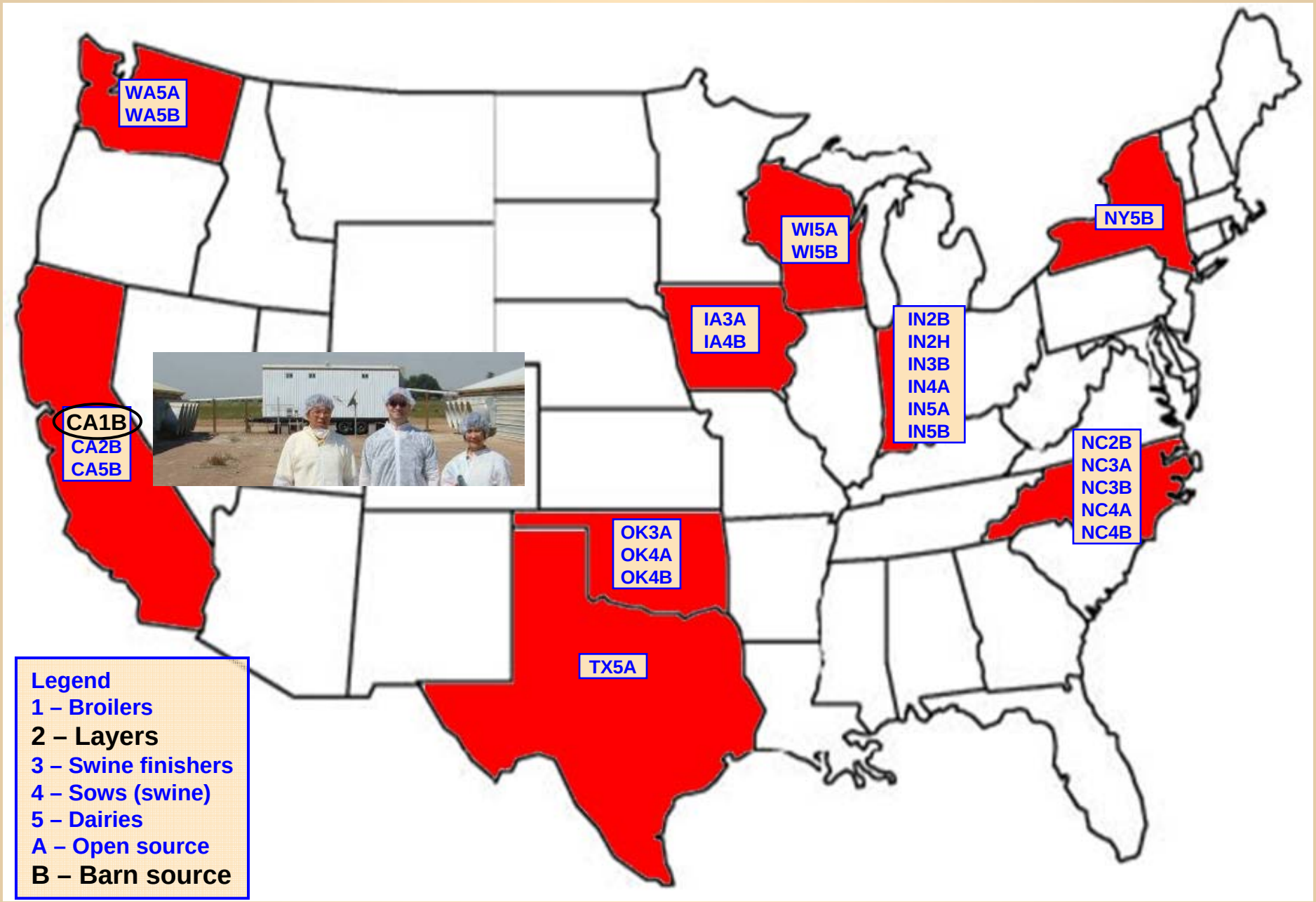
Abbreviation:

- *P* Pump
- *M* Manifold

Response of Gas Measurements at a Dairy Freestall



NAEMS Broiler Site



NAEMS Layer Sites

Layer and Broiler Sites

Layer Sites

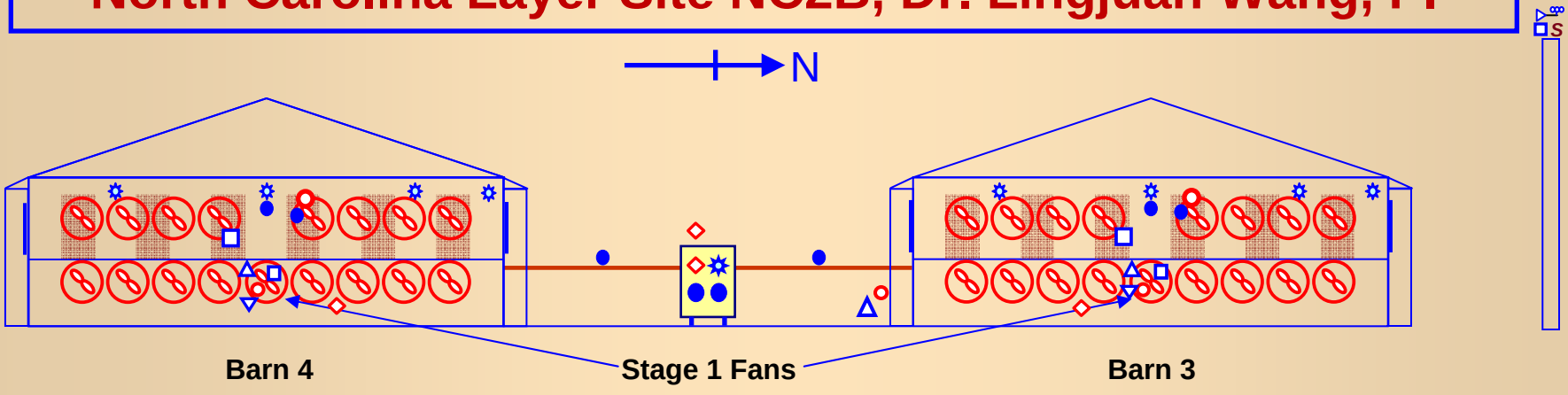
SMP #	Site Type	Ventilation Type	# of Units Measured	Manure Collection	Manure Storage	PI
East						
NC2B	**High-rise**	**MV (tunnel)**	**2**	**CBC[1]**	**Inside**	**Wang**
Midwest						
IN2B	**High-rise** **Belt battery** **Manure shed**	**MV (sidewall)** **MV (sidewall)** **MV**	**2** **2** **1**	**CBC** **Belt** **Loader**	**First floor** **Shed** **-**	**Ni**
West						
CA2B	**High-rise**	**MV (side wall)**	**3**	**DB[2]**	**Inside**	**Zhang**

[1]CBC = curtain backed cages
[2]DB = dropping boards under cages

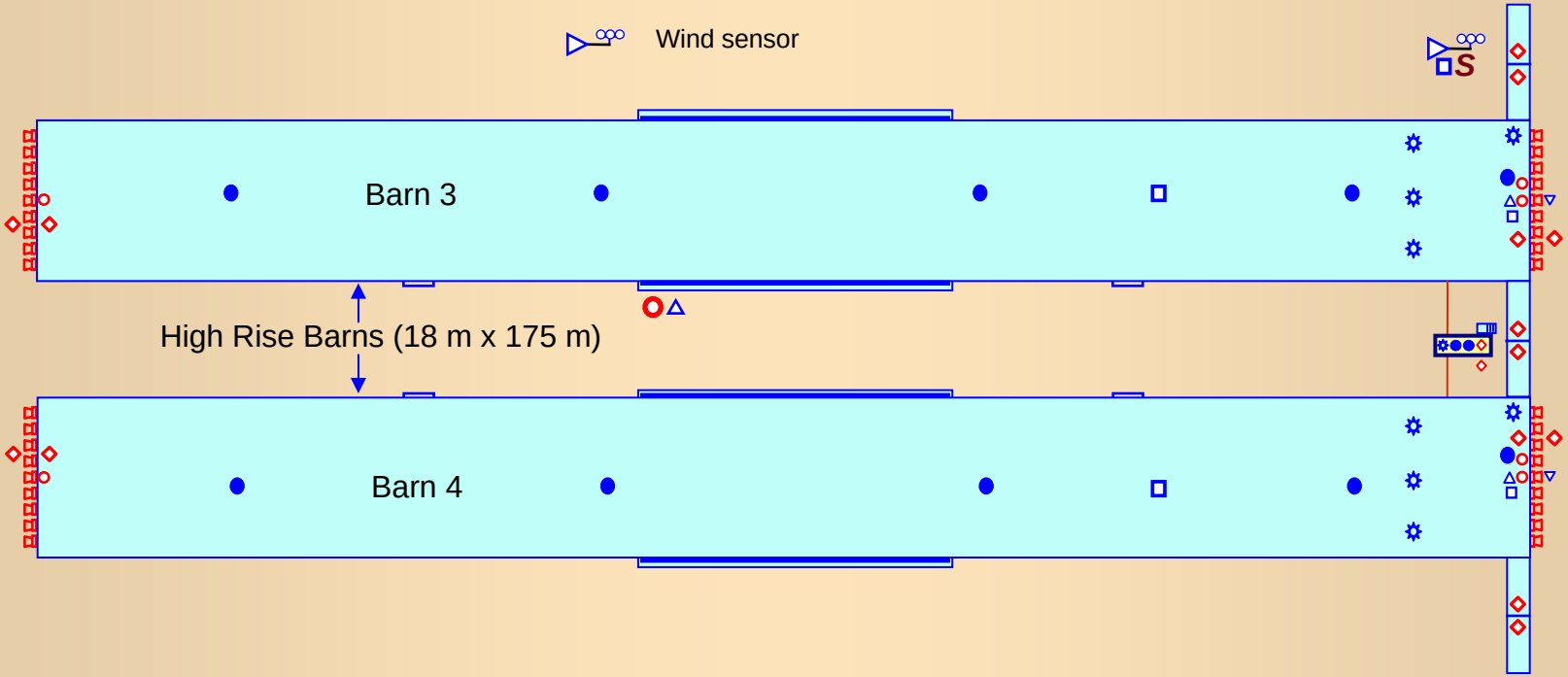
Broiler Sites

SMP #	Site Type	Ventilation Type	# of Units Measured	Manure Collection	Manure Storage	PI
West						
CA1B	**Litter on floor**	**MV (tunnel)**	**2**	**Scraper**	**None**	**Zhang**

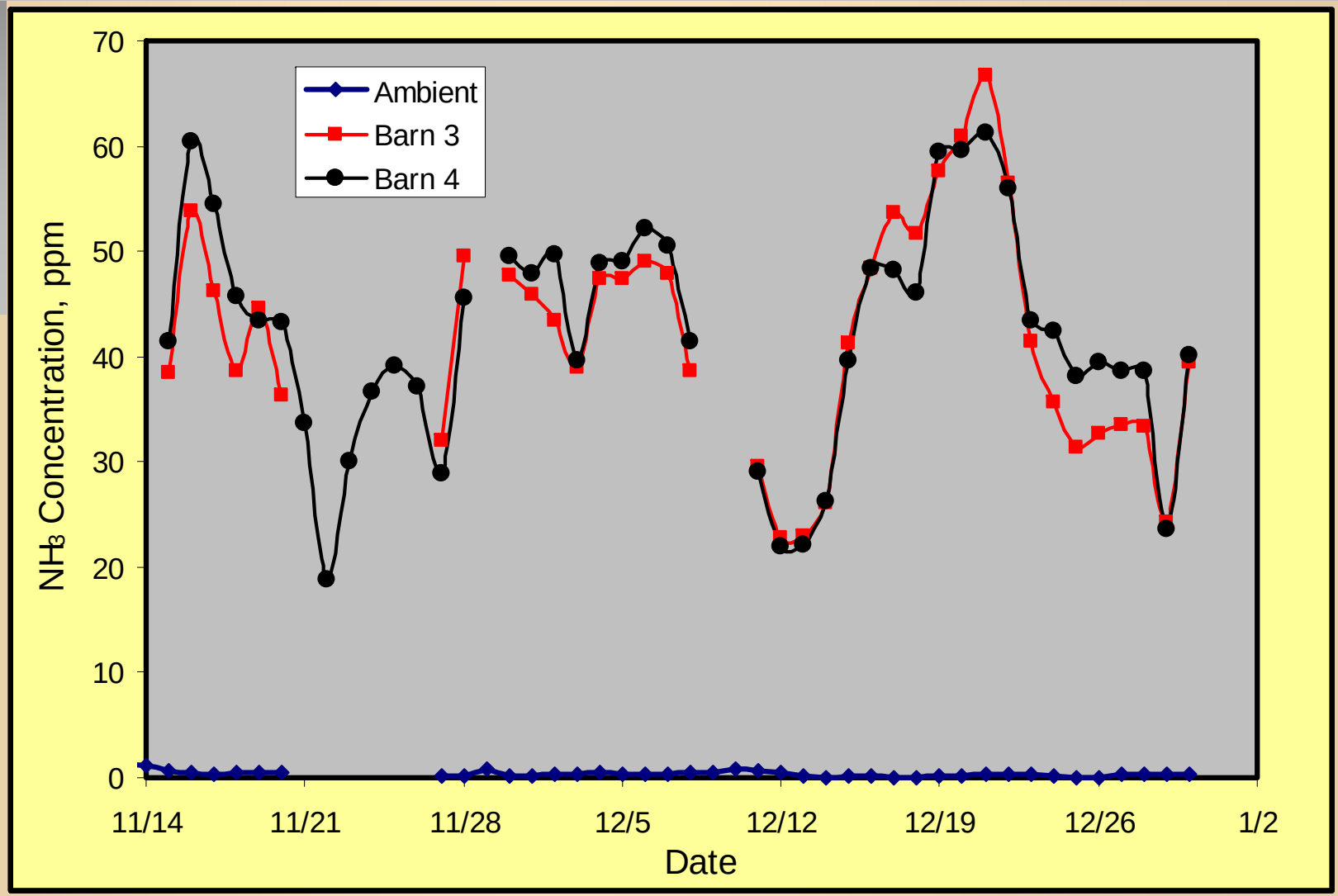
North Carolina Layer Site NC2B, Dr. Lingjuan Wang, PI



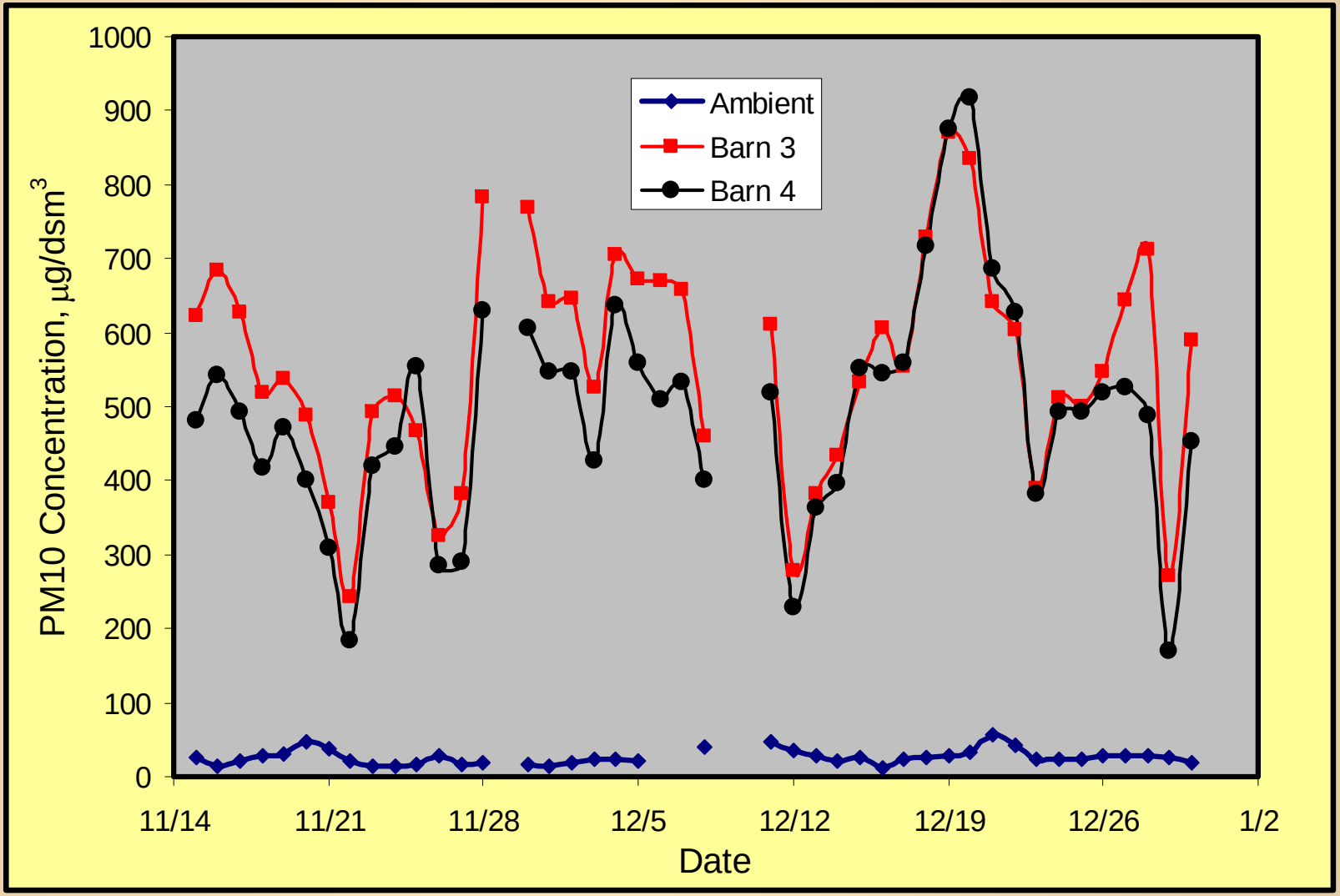
Instrument shelter
Static pressure port
Thermocouple
S Solar sensor
Anemometer
RH/Temp probe
Air sampling
Exhaust fan
Activity sensor
PM monitor
Air inlet
Heated raceway
Wind sensor



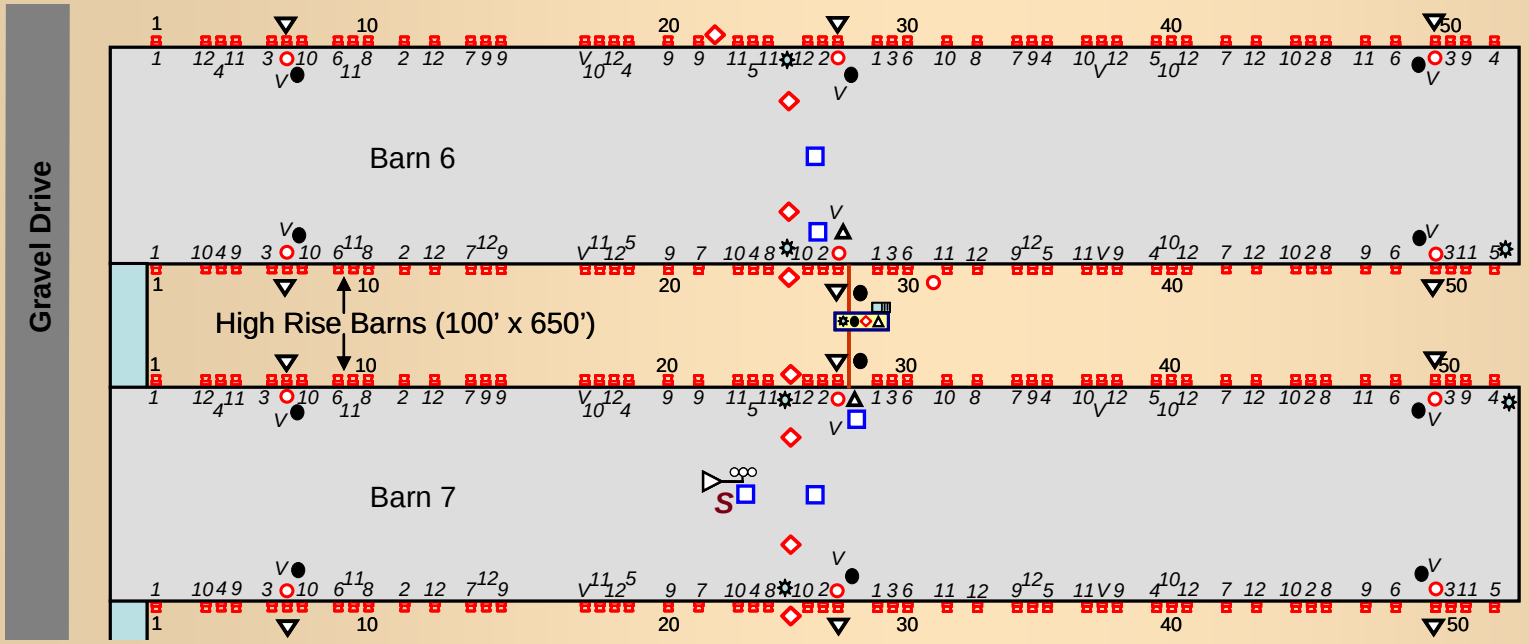
NC2B Ammonia Concentrations

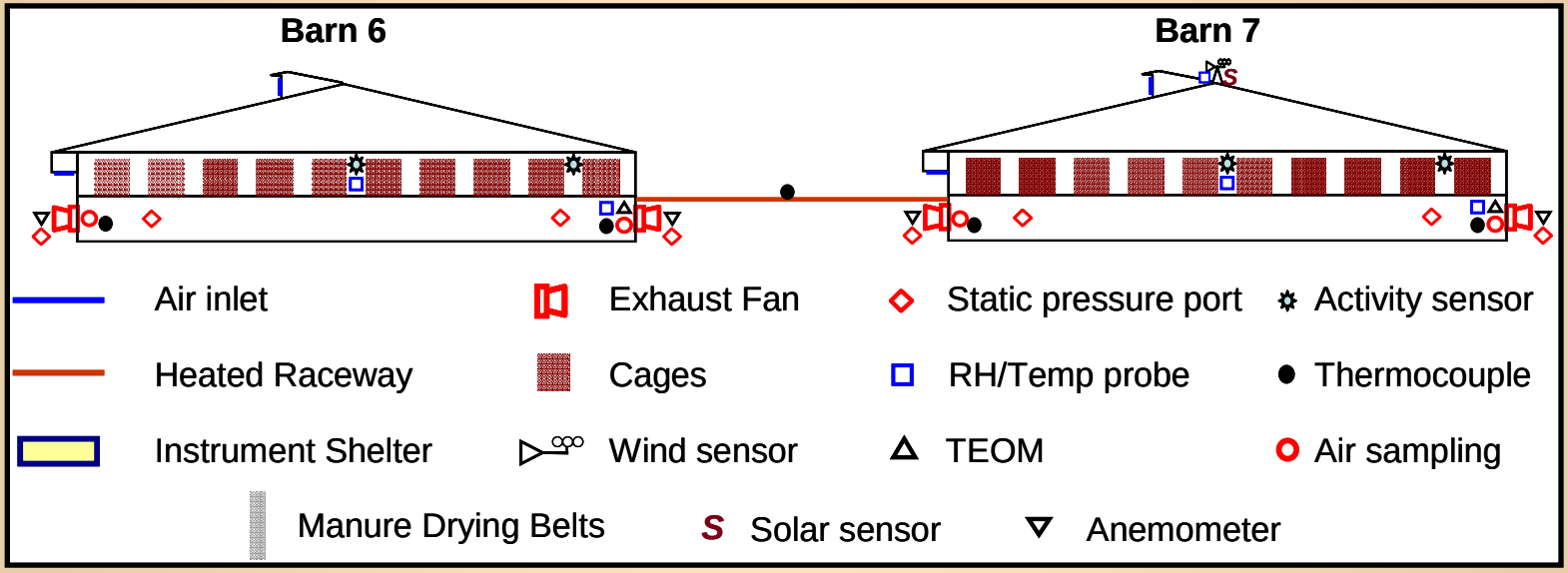


NC2B PM10 Concentrations



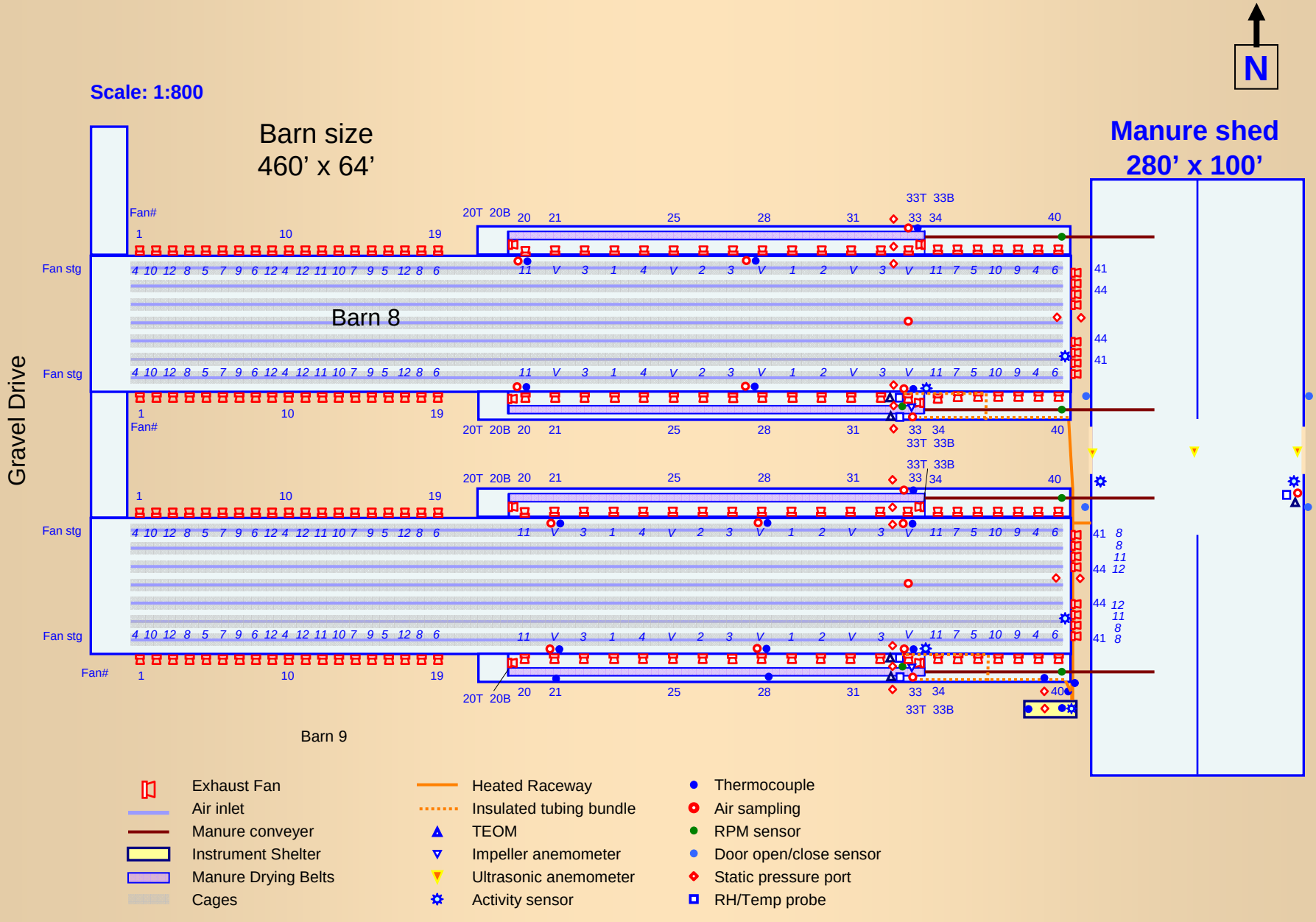
Indiana Layer Site IN2H, Dr. JiQin Ni, PI



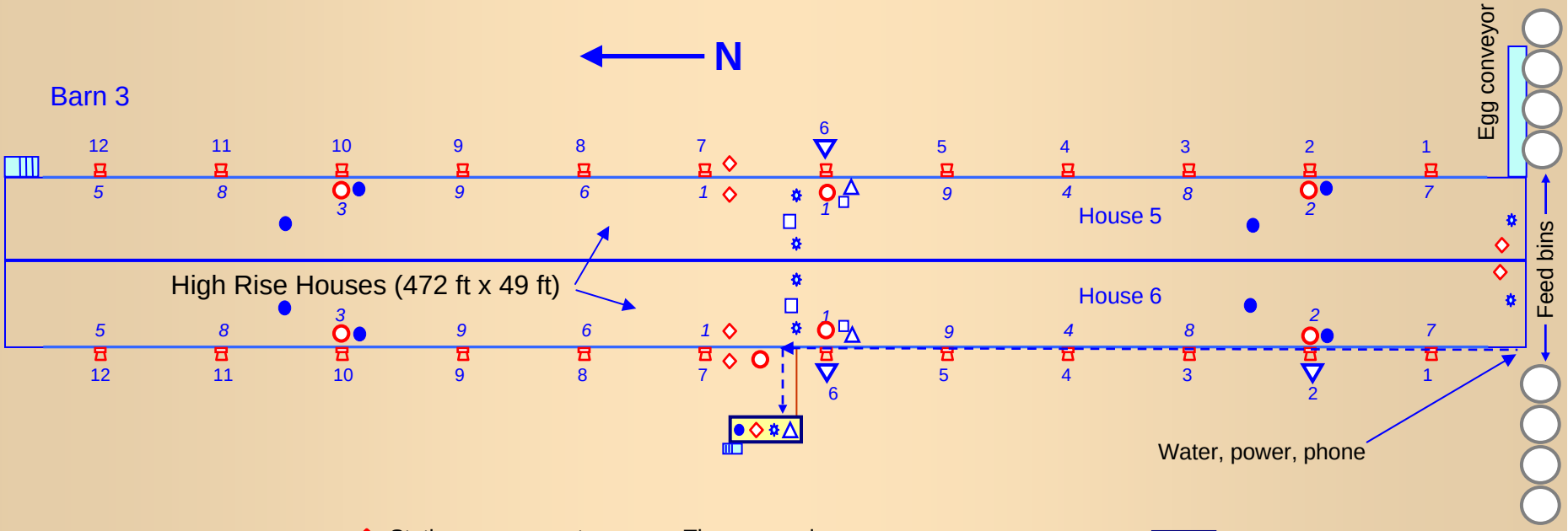


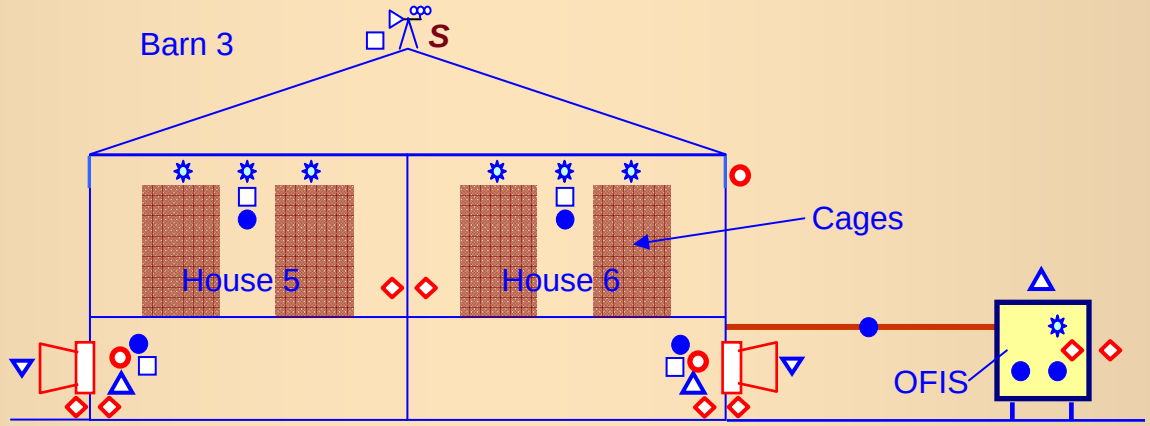
Cross section of the barns showing measurement locations.

Indiana Layer Site IN2B, Dr. JiQin Ni, PI

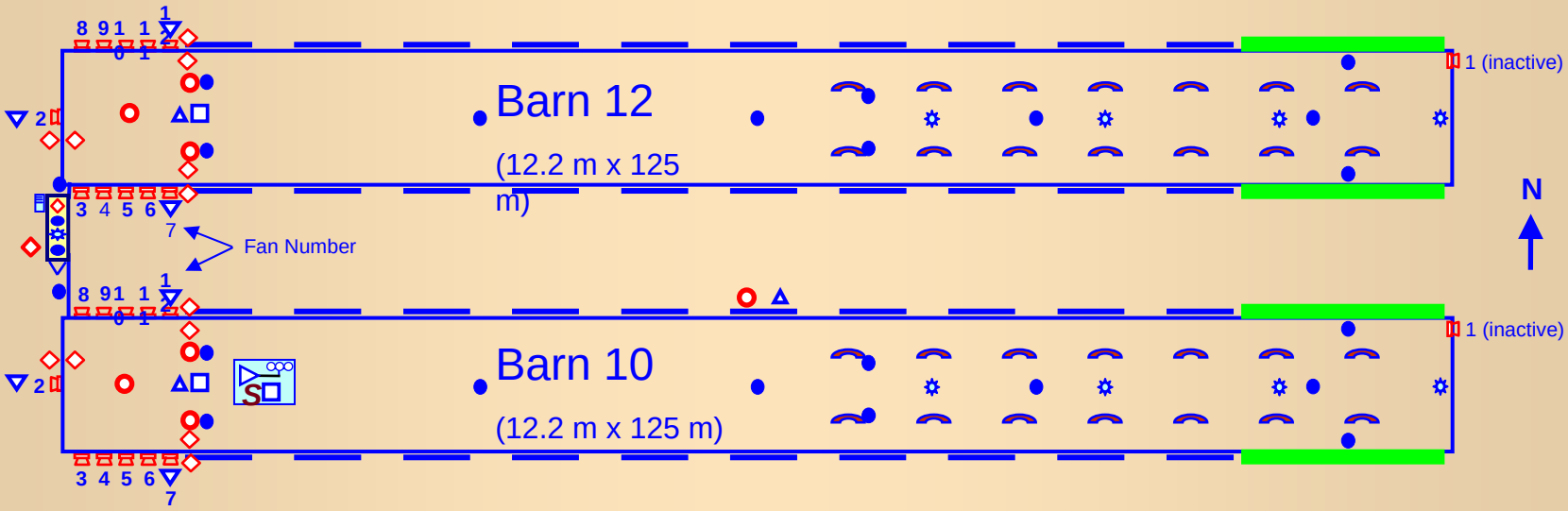


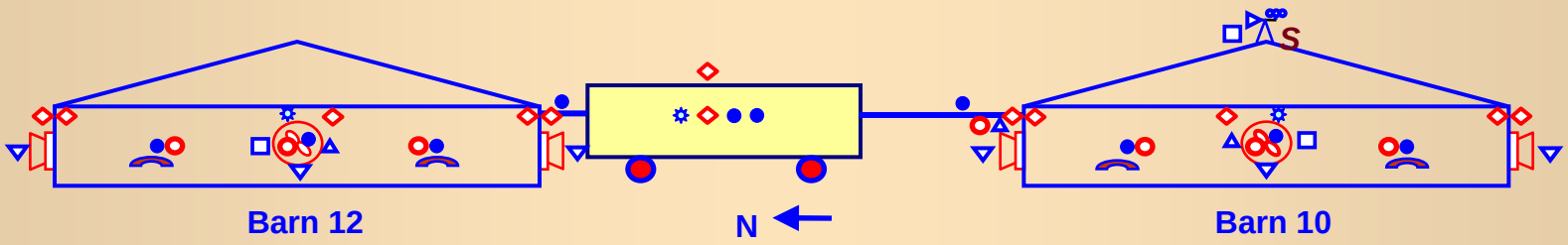
California Layer Site CA2B, Dr. Ruihong Zhang, PI





California Broiler Site CA1B, Dr. Ruihong Zhang, PI

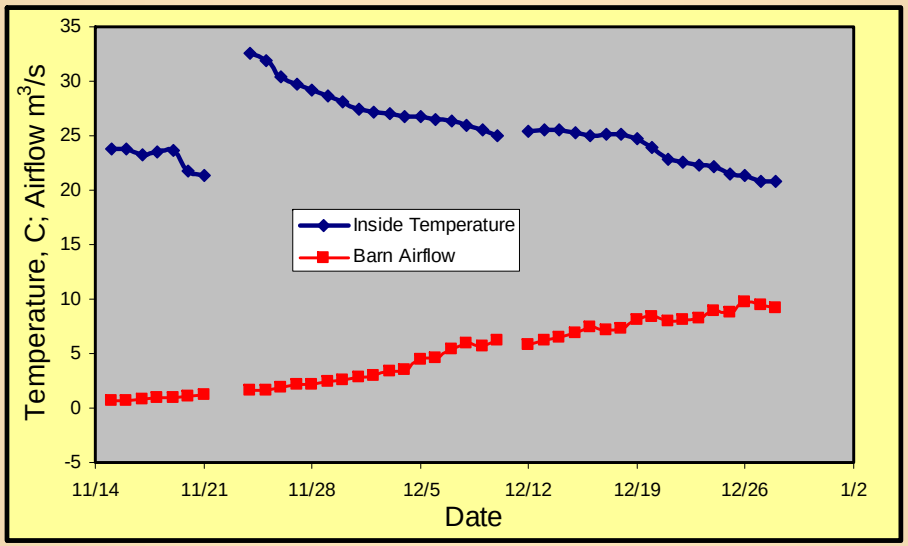


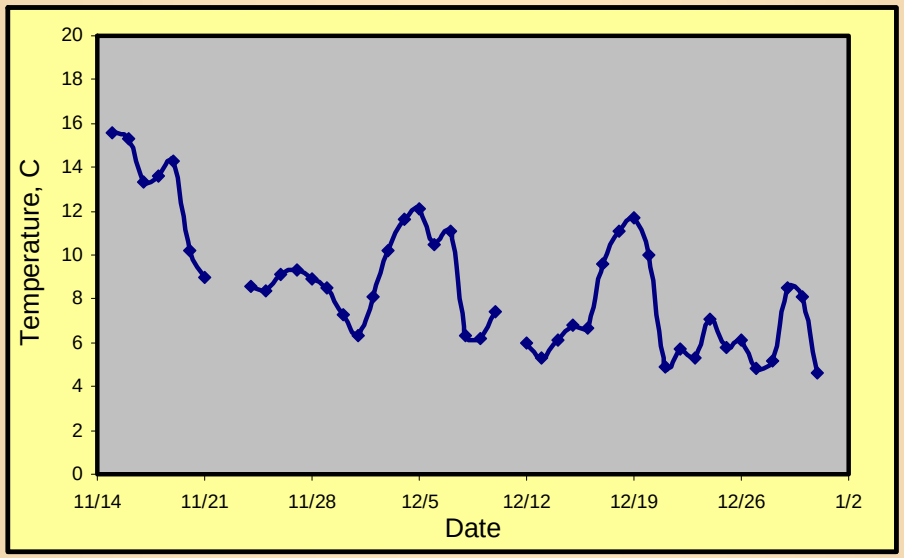


Ventilation fan
Brooders
PM, continuous
Static pressure port
Air sampling
RH/Temp probe
Thermocouple
Activity sensor
Wind sensor
Solar sensor
Anemomete r
Instrument Shelter
Air Inlet
Cool Cell

Site monitoring plan for continuous air emission testing.

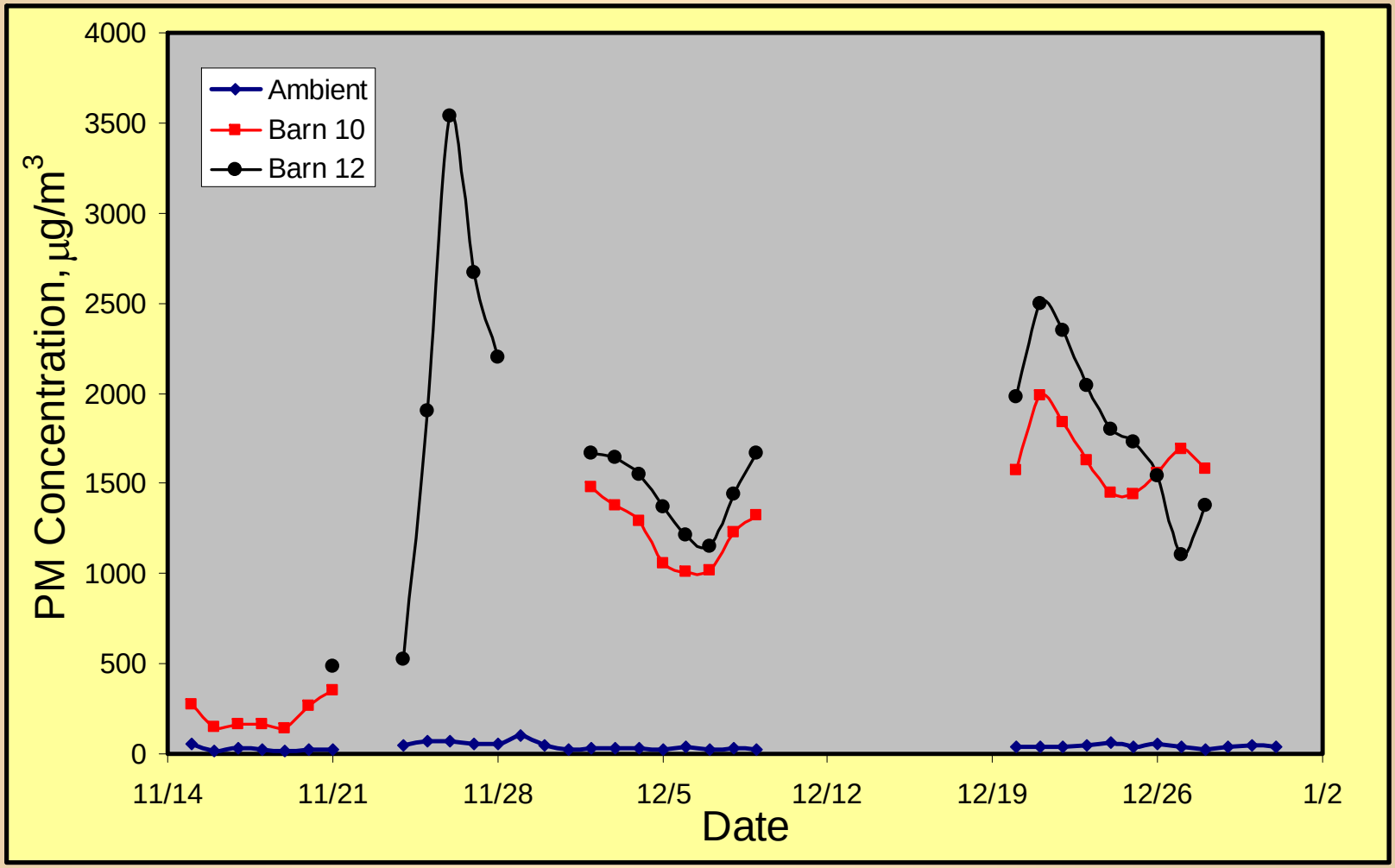
Airflow over Broiler Growth Cycle



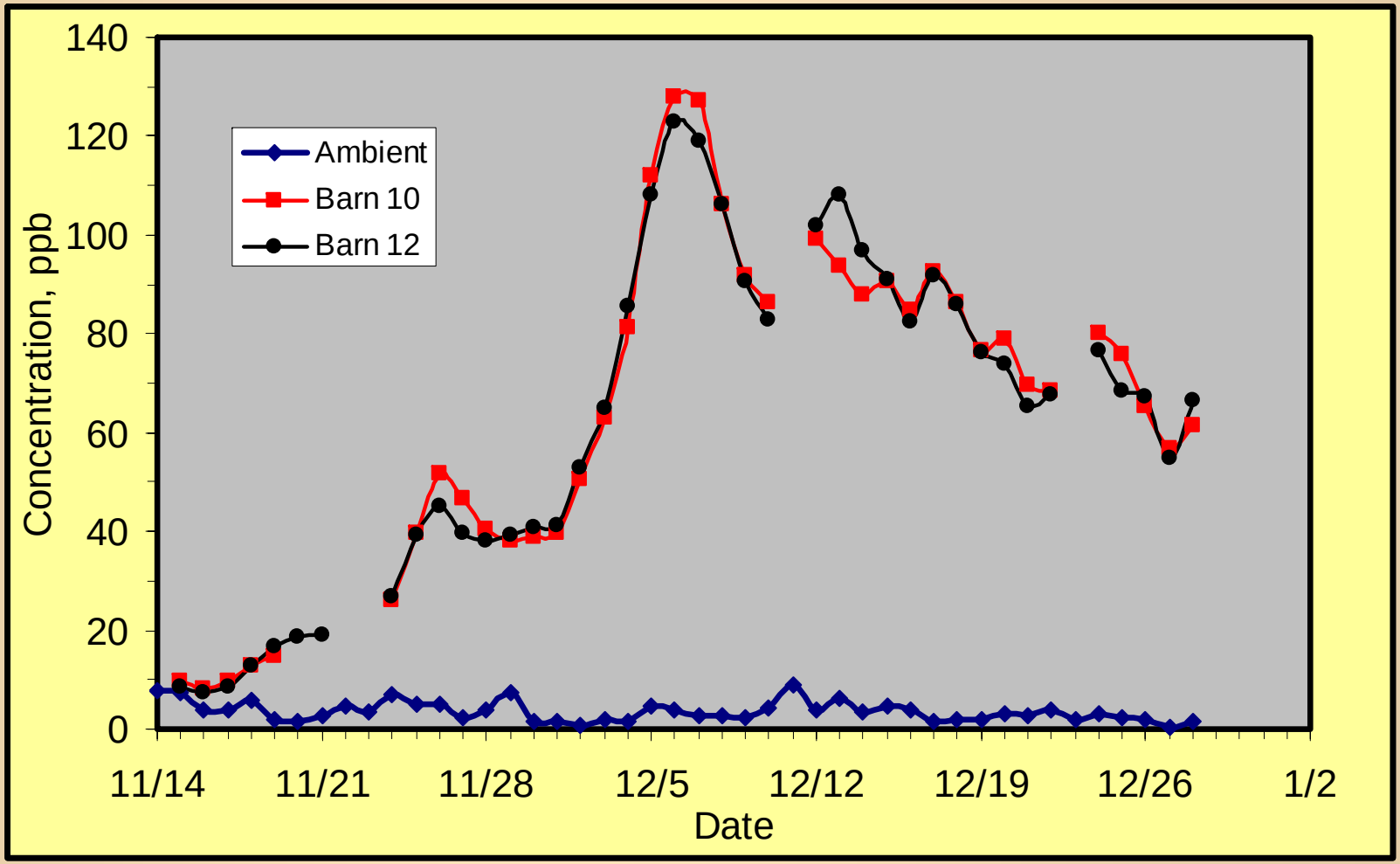


Outside temp

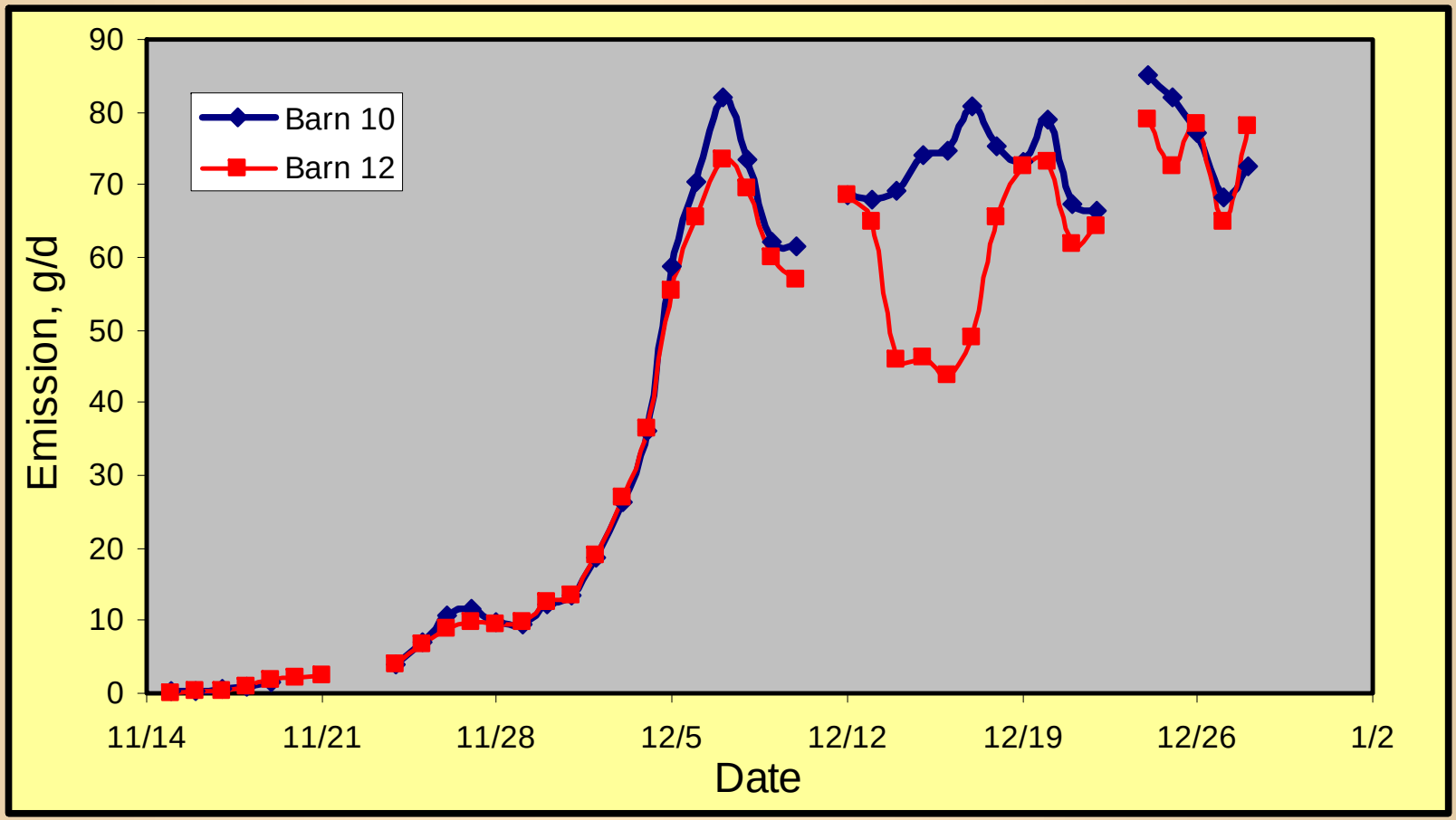
PM10 Concentrations over Broiler Growth Cycle



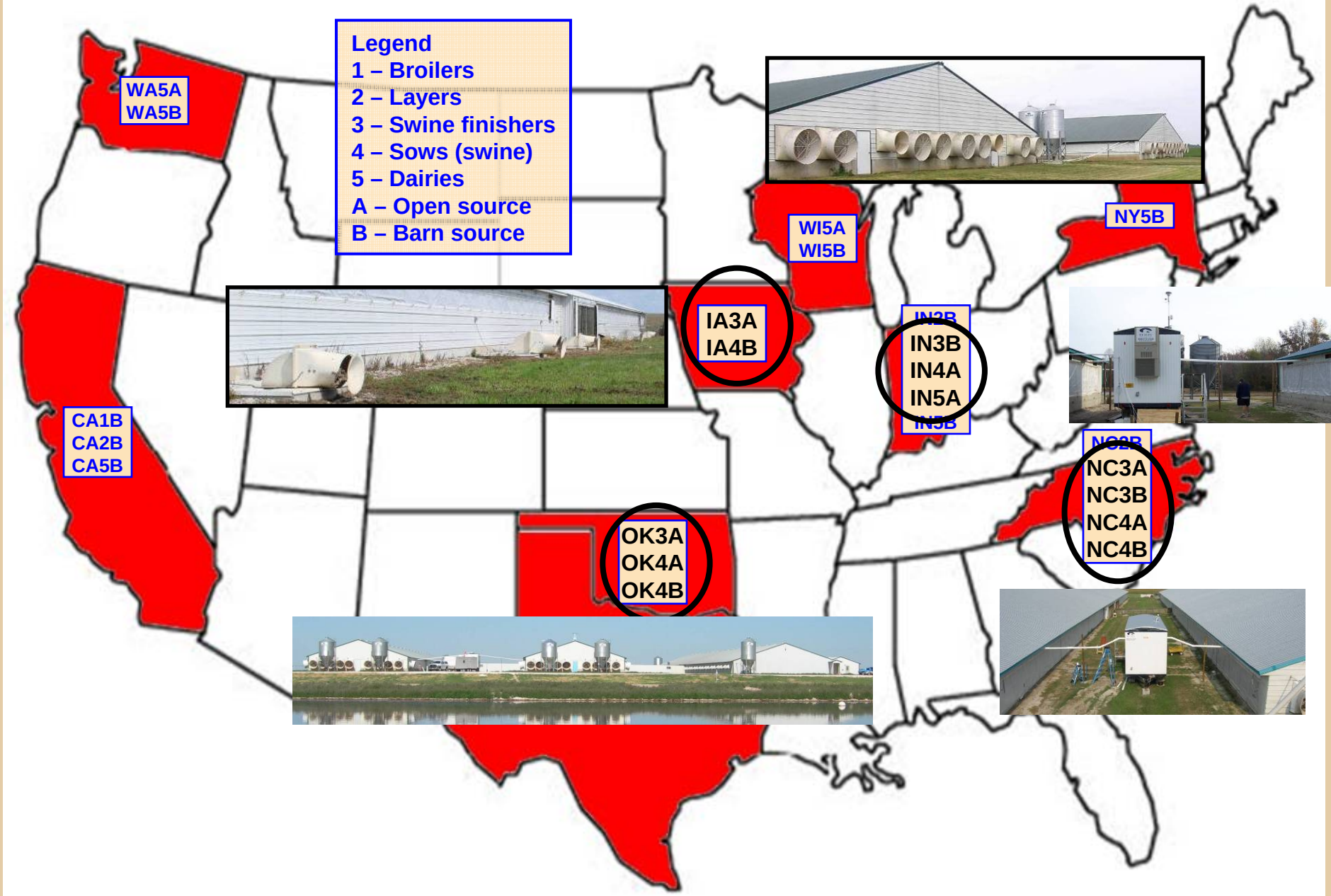
H2S Concentrations over Broiler Growth Cycle



H2S Emissions over Broiler Growth Cycle



NAEMS Swine Barn Sites

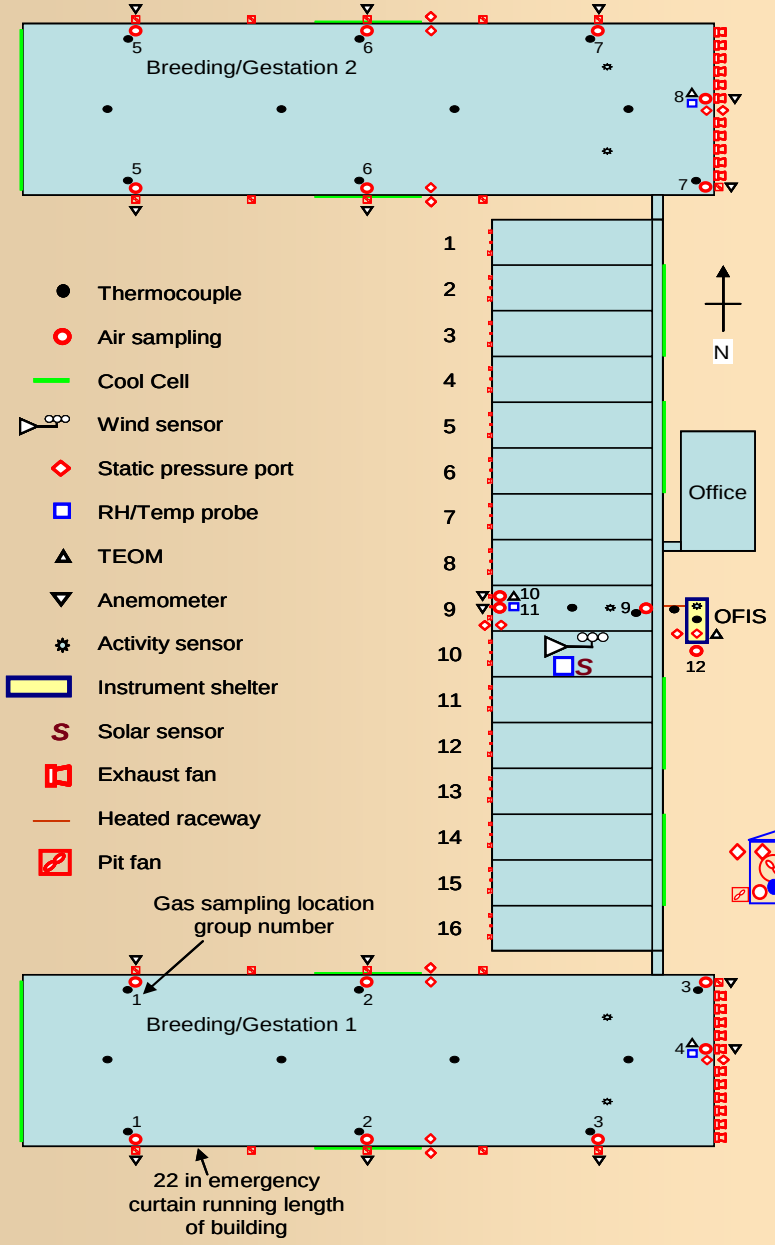


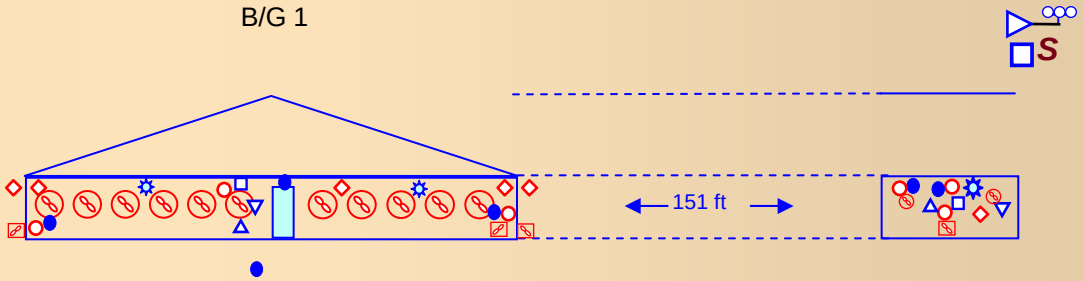
Swine Sites

SMP #	Production phase	# of units measured	Manure collection	Manure storage[2]
Southeast				
NC4B[1]	B/GF	2 1	PPR[3] PPR	Lagoon Lagoon
NC3B	Finisher	3	PPR	Lagoon
Midwest				
IA4B	B/GF	2 1	Deep pit[4] PPR	Deep pit[4] Gestation pits
IN3B	Finisher	4	Deep pit[4]	
West				
OK4B[1]	B/GF	2 1	PPR PPR	Lagoon Lagoon

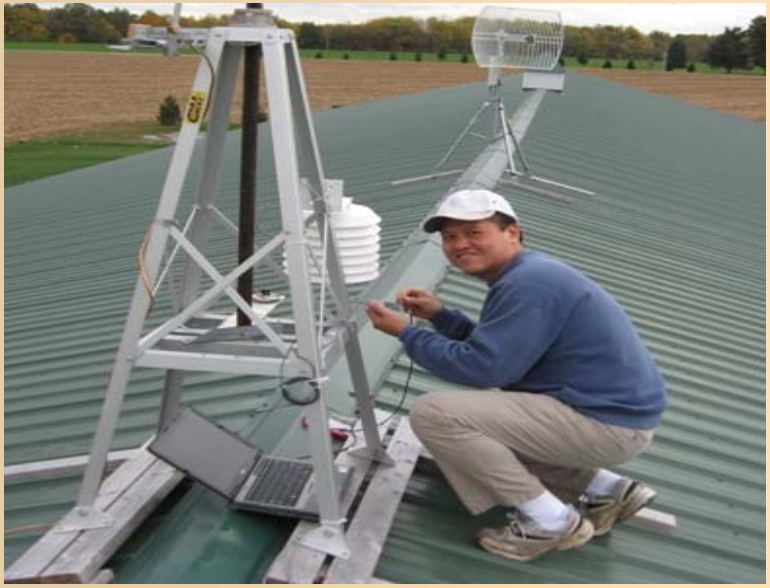
[1]Barn Sites that also have measured area sources, which are described in the open-source QAPP
[2]Characterizes type of farm, not necessarily a measurement location.
[3]PPR = pull plug with recharge
[4]Storage is inside the barn so separate measurement not needed for storage.

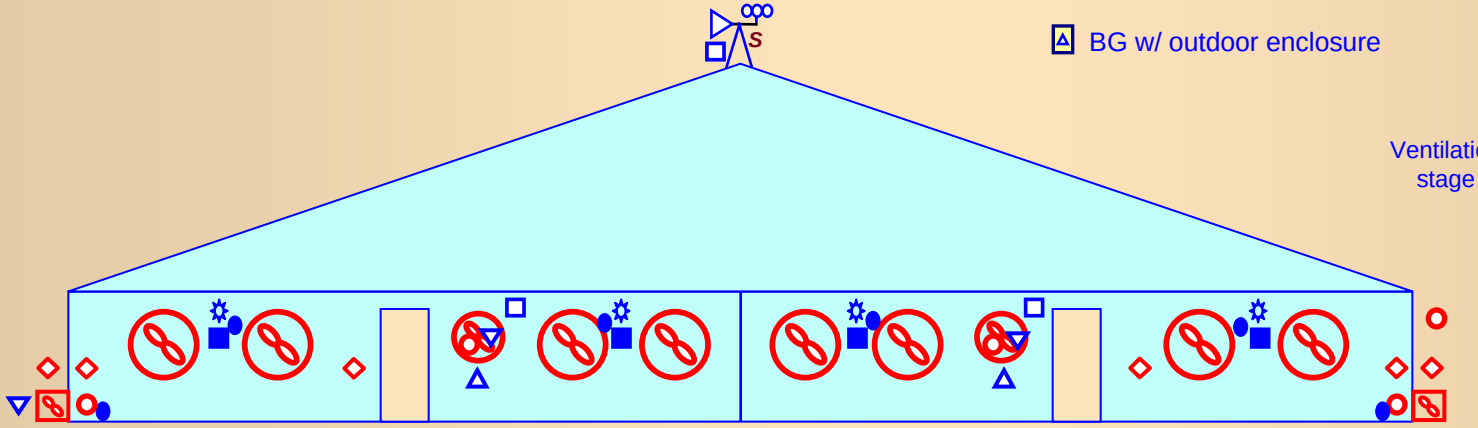
Iowa Swine Site (IA4B), Dr. Jacek Koziel





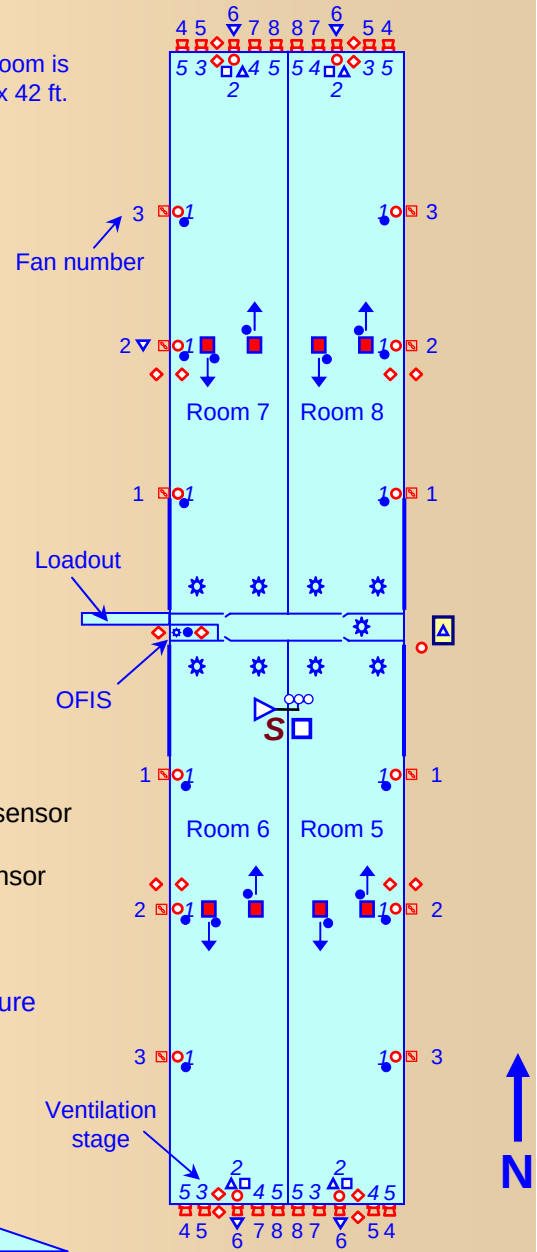
Indiana Swine Site (IN3B)
Dr. Teng Lim, PI





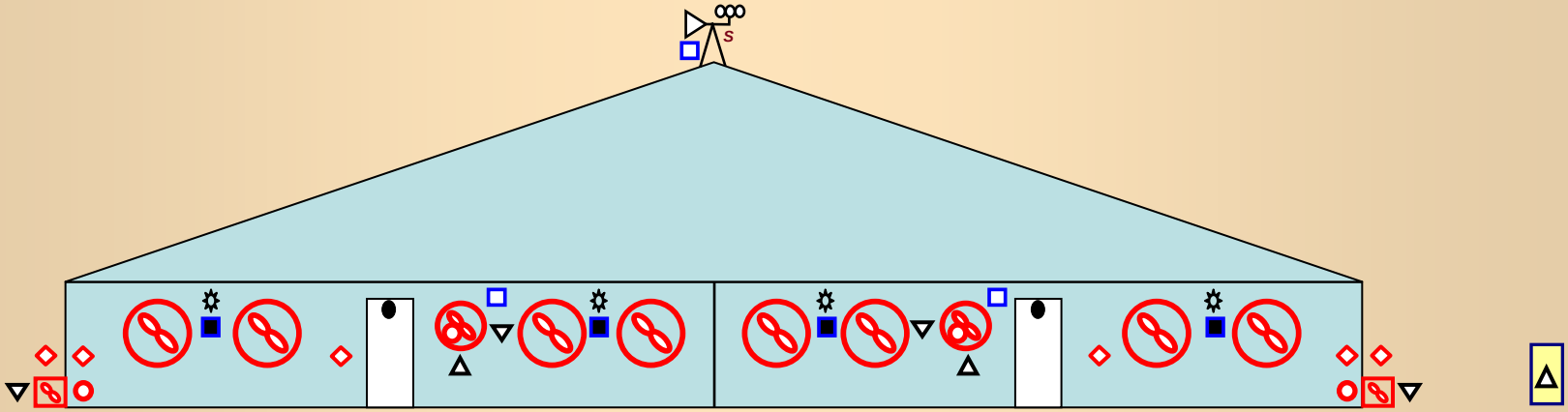
Each room is
200 ft x 42 ft.

- Heater
- Activity sensor
- Static pressure port
- RH/Temp probe
- TEOM
- Thermocouple
- Air sampling
- Wind sensor
- S Solar sensor
- Exhaust fan w/ RPM sensor
- Pit Fan w/ RPM sensor
- Anemometer
- BG w/ outdoor enclosure



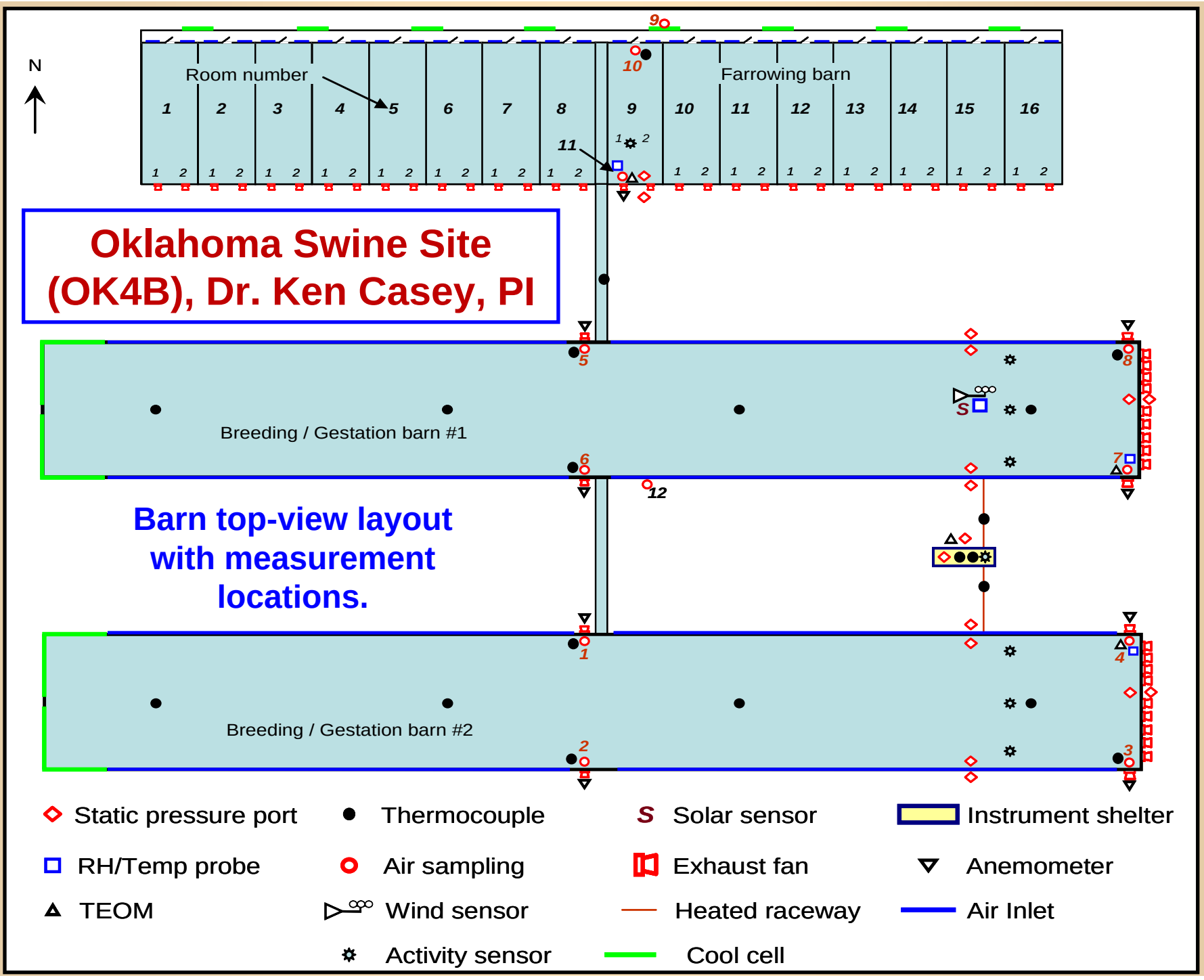
Test of Mitigation Technology at IN3B (Exhaust Fan Biofilter)

Oklahoma Swine Site (OK4B), Dr. Ken Casey, PI

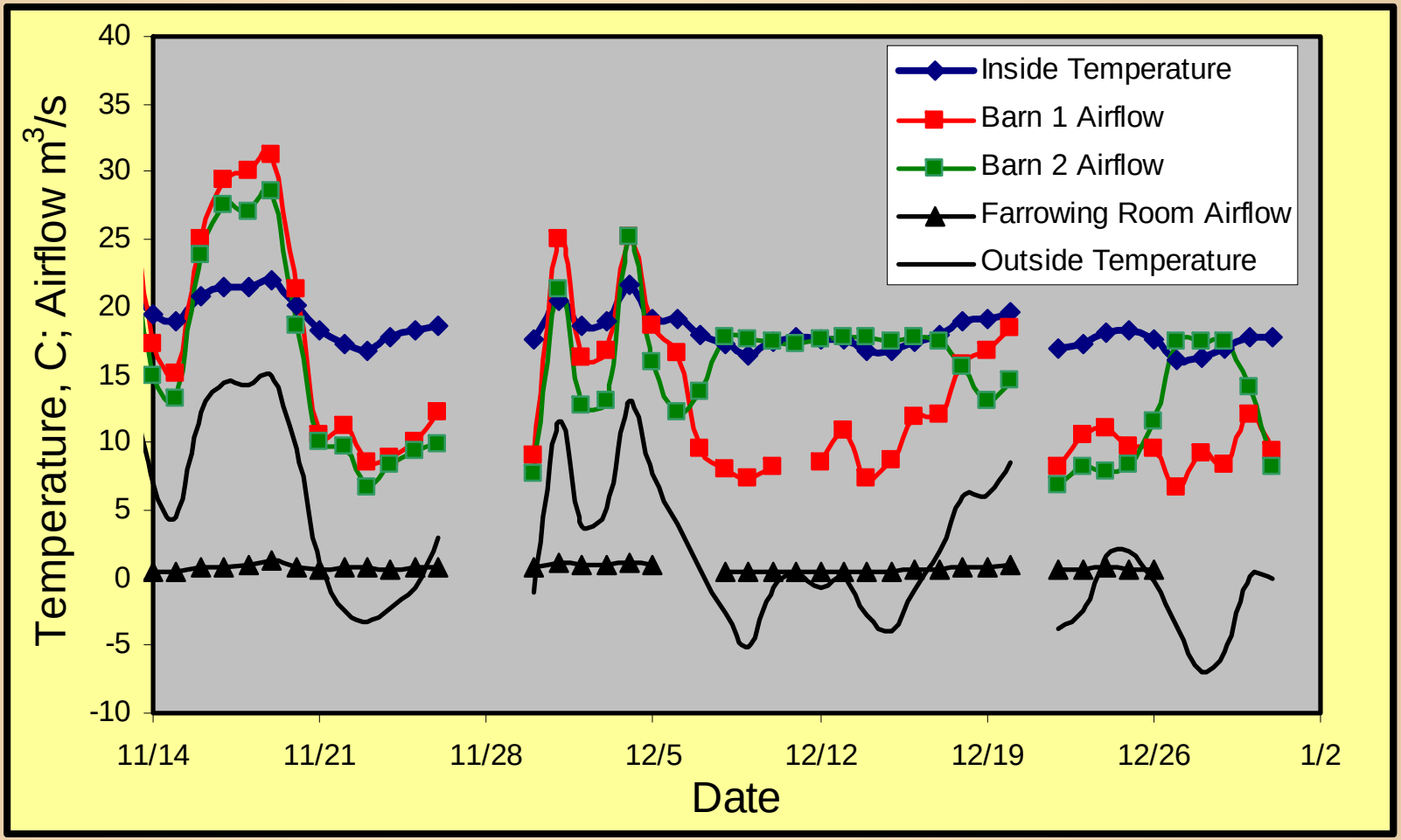


Heater
Activity sensor
Static pressure port
RH/Temp probe
TEOM
Thermocouple
Air sampling
Wind sensor
S Solar sensor
Exhaust fan
Pit Fan
Anemometer
TEOM outdoor enclosure

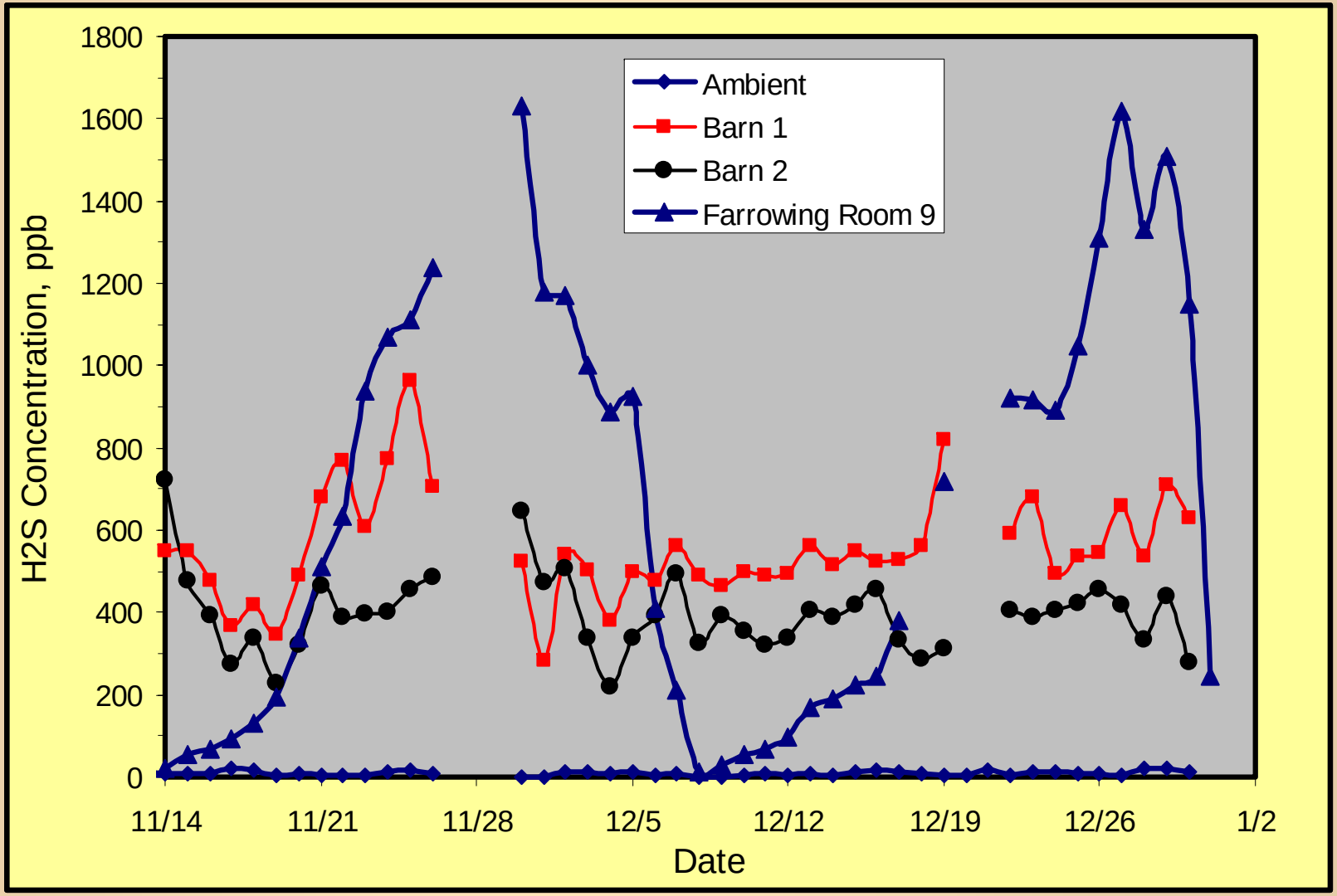
Cross section of gestation barn showing measurement locations.


N
Room number
Farrowing barn
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Oklahoma Swine Site
(OK4B), Dr. Ken Casey, PI
Breeding / Gestation barn #1
Breeding / Gestation barn #2
Barn top-view layout
with measurement
locations.
Static pressure port
Thermocouple
Solar sensor
Instrument shelter
RH/Temp probe
Air sampling
Exhaust fan
Anemometer
TEOM
Wind sensor
Heated raceway
Air Inlet
Activity sensor
Cool cell

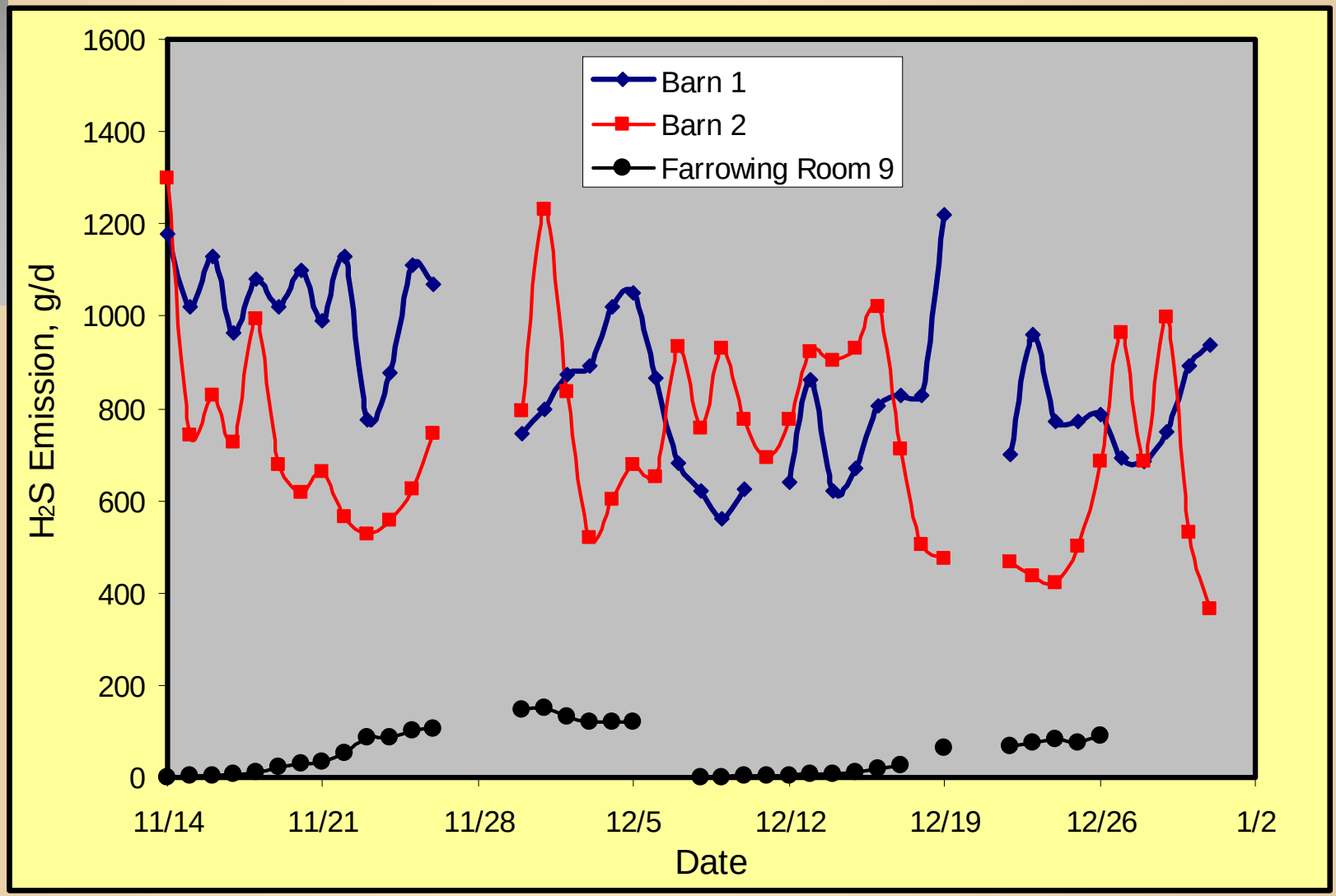
Airflows and Temperatures at OK4B



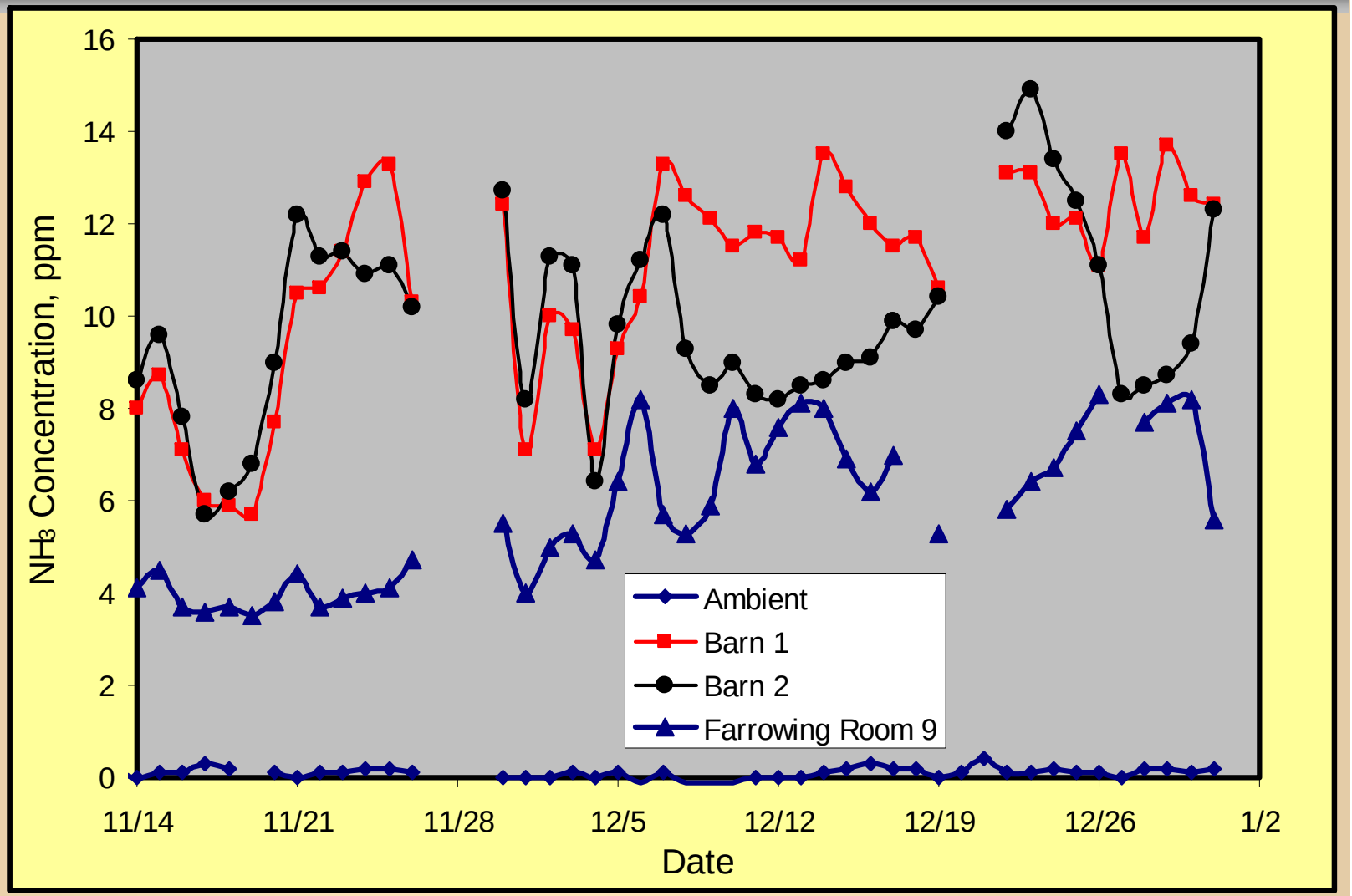
H2S Concentrations at OK4B



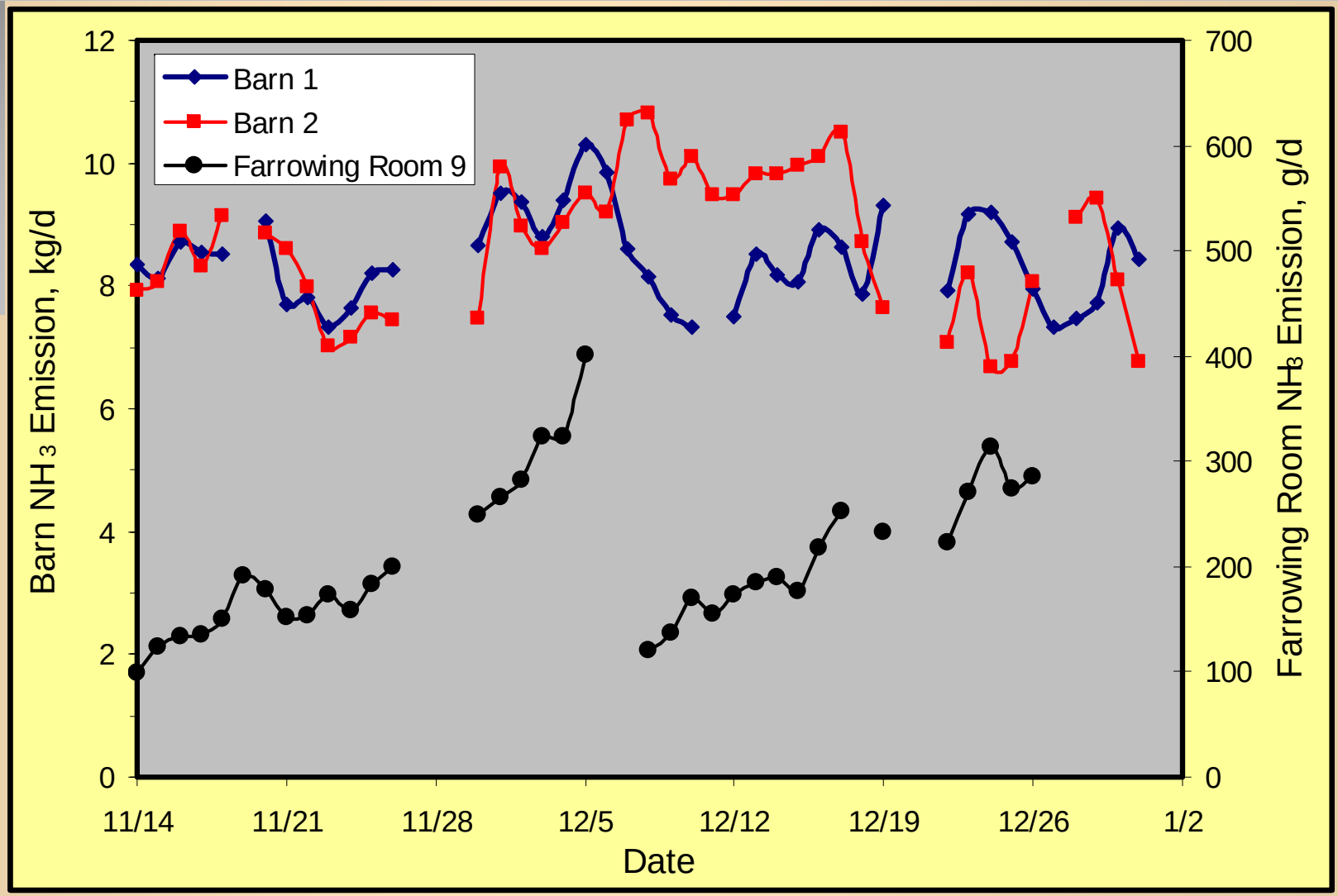
H2S Emissions at OK4B



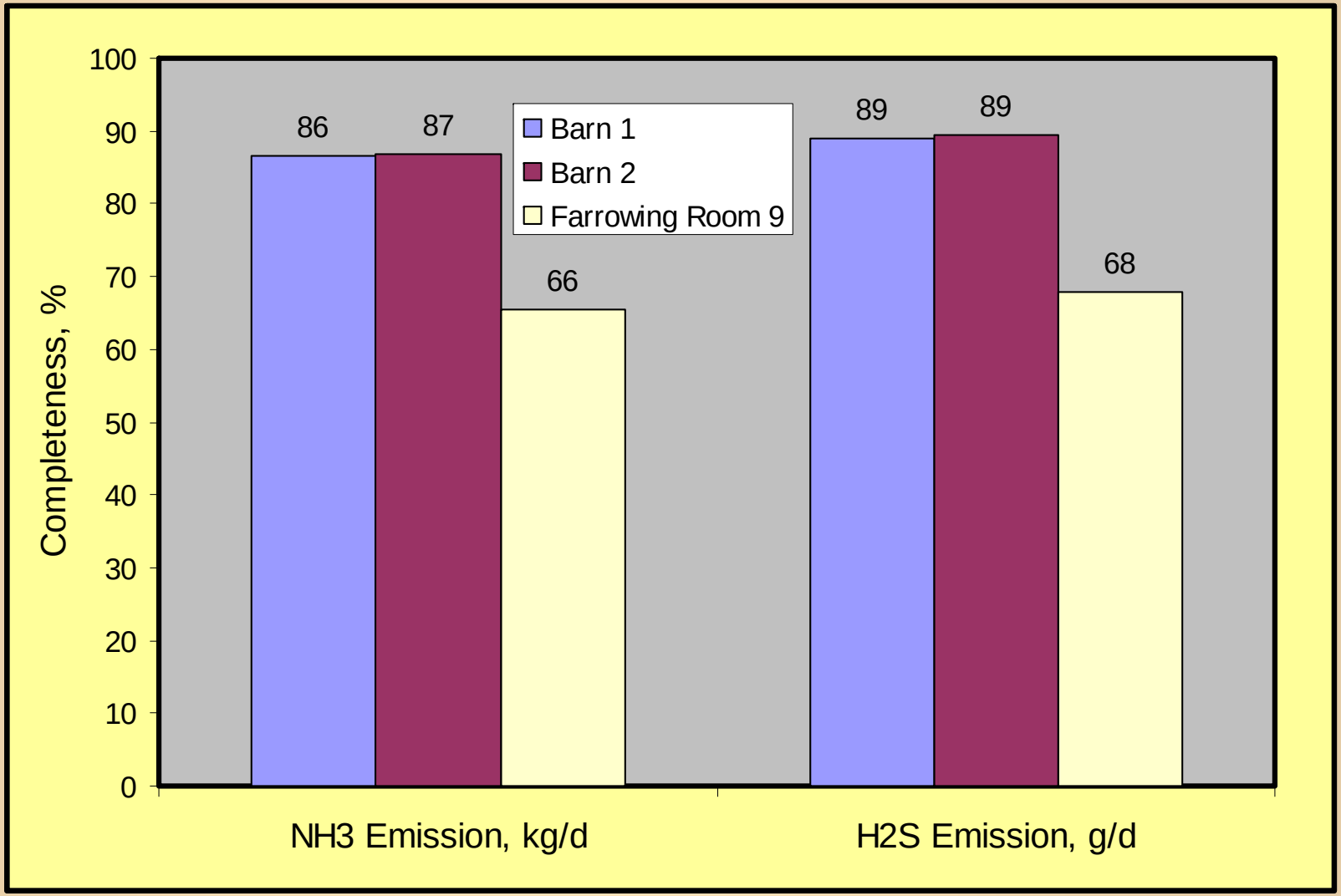
NH3 Concentrations at OK4B



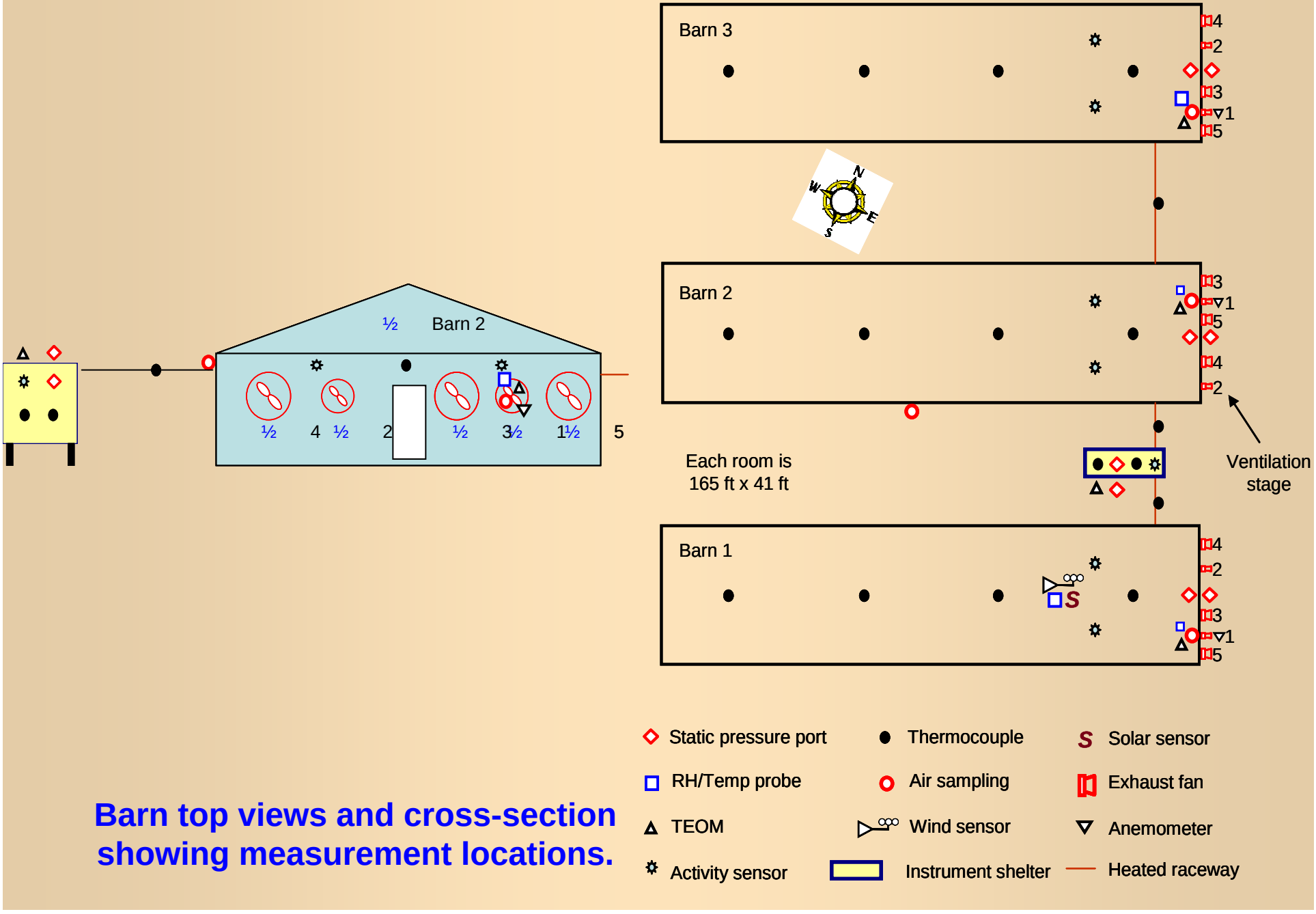
NH3 Emissions at OK4B



Data Completeness at OK4B 2007

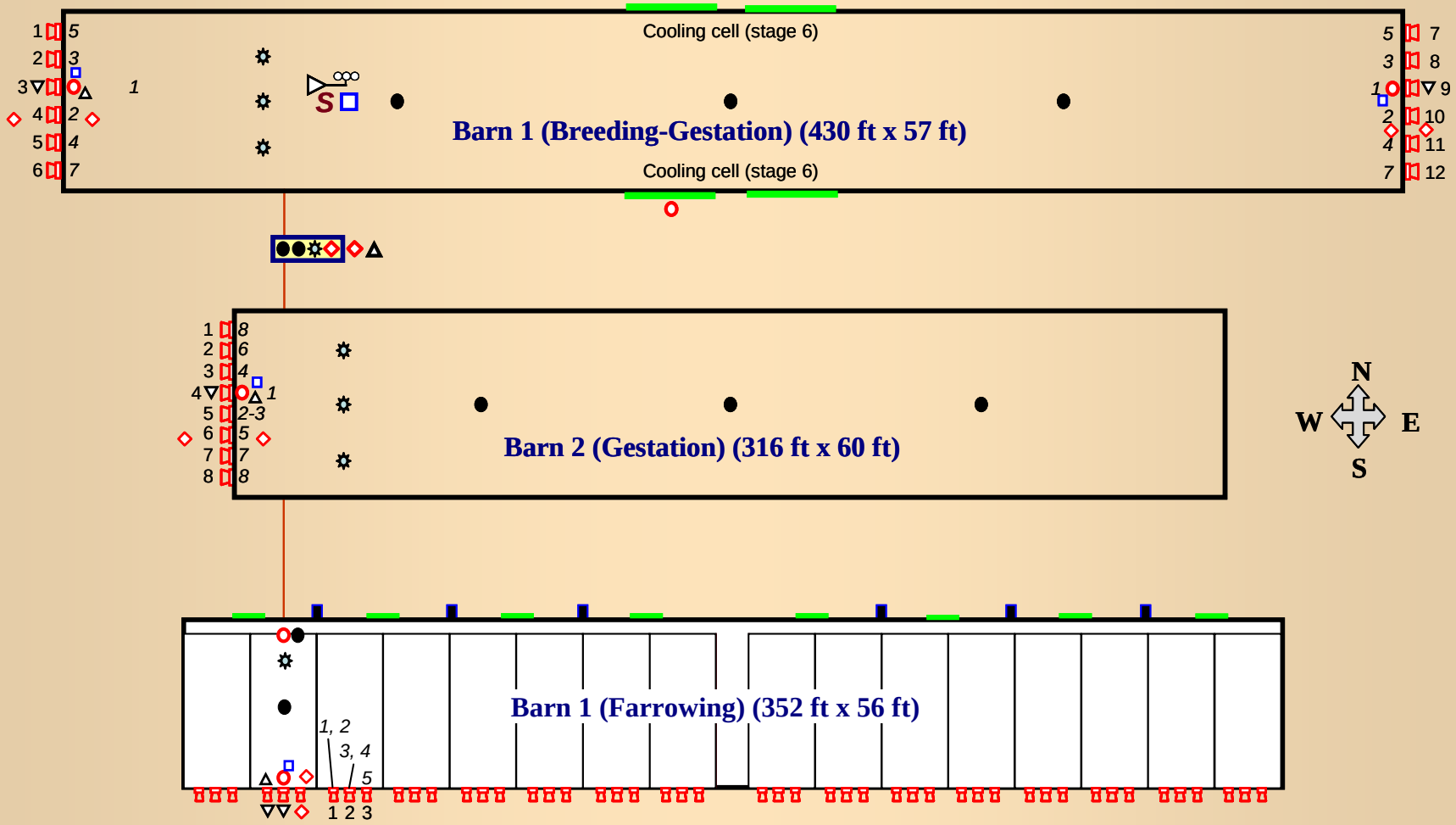


North Carolina Swine Site (NC3B), Dr. Wayne Robarge, PI



Barn top views and cross-section showing measurement locations.

North Carolina Swine Site (NC4B), Dr. Wayne Robarge, PI



Barn top-view layout showing measurement locations.

NAEMS Dairy Sites

WA5A
WA5B

WI5A
WI5B

NY5B

IA3A
IA4B

IN2B
IN2H
IN3B
IN4A
IN5A
IN5B

CA1B
CA2B
CA5B

NC2B

OK3A
OK4A
OK4B

TX5A

Legend
1 – Broilers
2 – Layers
3 – Swine finishers
4 – Sows (swine)
5 – Dairies
A – Open source
B – Barn source

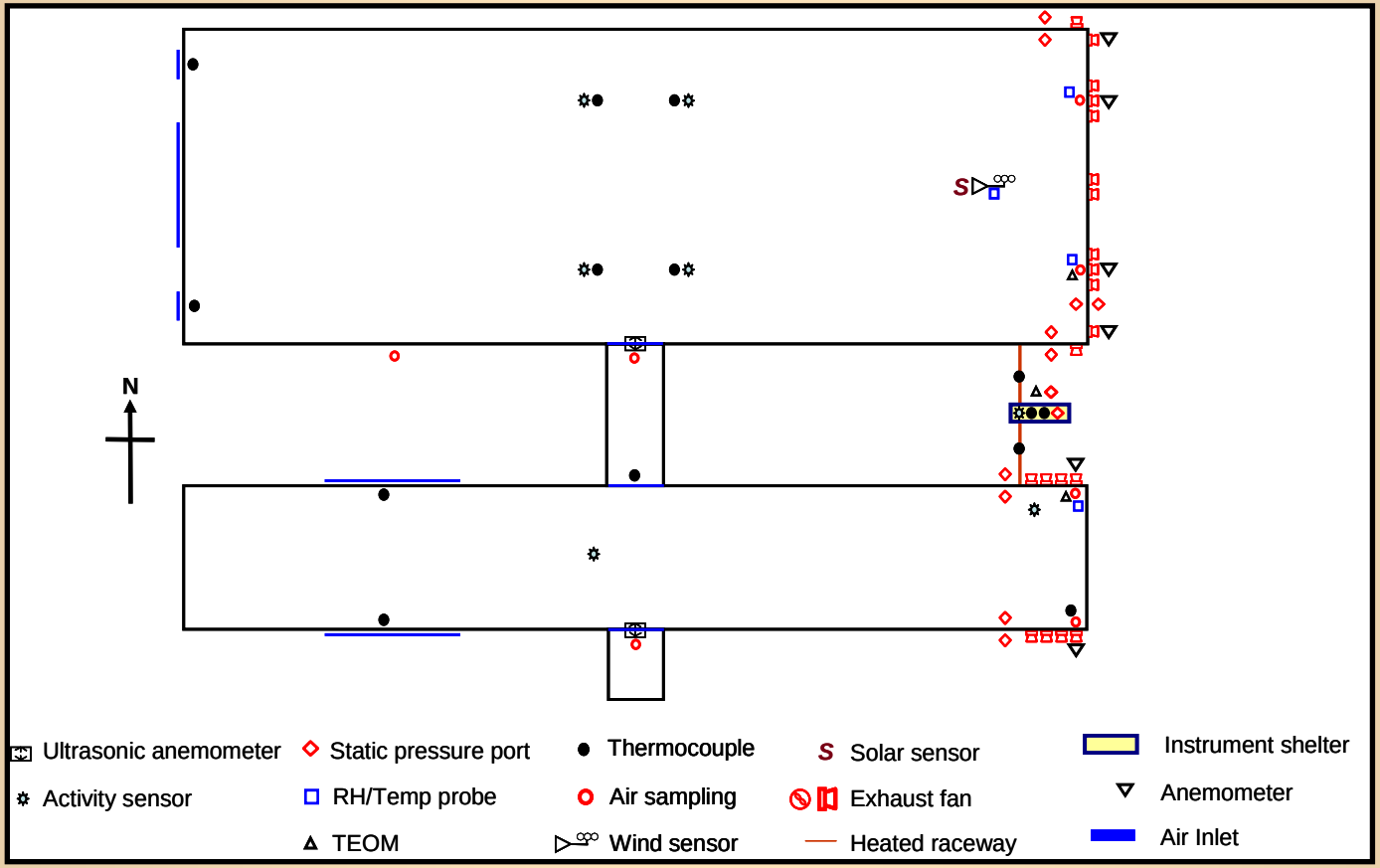
Dairy Sites

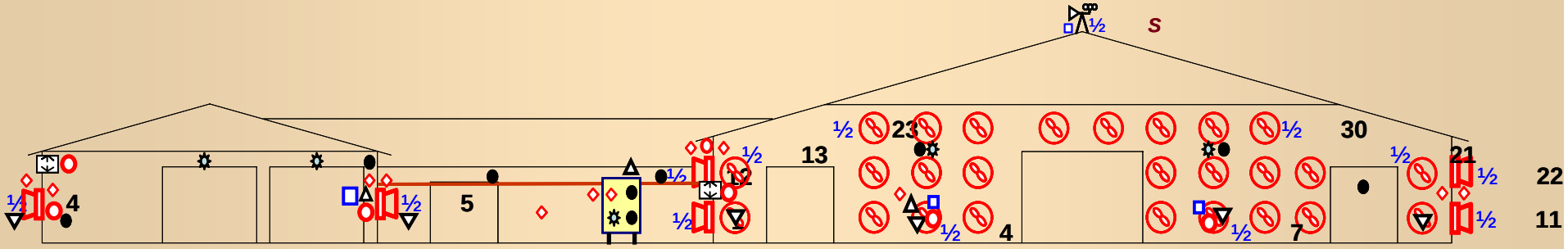
SMP #	Site Type	Ventilation Type	# of Units Measured	Manure Collection	Manure Storage[4]	Bedding Type[5]	PI
Northeast							
NY5B	Freestall	MV	2[3]	Scrape	Dig./SS/Basin	SDS	Gooch
Midwest							
IN5B	Freestall	MV	2	Scrape	Dig./SS/Basin	SDS	Lim
WI5B	Freestall	MV	3[3]	Flush	SP/Basin	Mattress/ shavings	Jacobson
West							
CA5B	Open Freestall[2]	NV	2	Flush	SP/Basin	Soil/MS/ Almond shells	Mitloehner
WA5B[1]	Open Freestall[2]	NV	2	Flush	SP/SS/Basin	MS	Ndegwa

[1]Barn sites that also have measured area sources, which are described in the open-source QAPP
[2]Cattle are free to walk from open freestall barn into dry lots between the barns.
[3]Monitored units include the milking center.
[4]SP = settling pond
[5]MS = Manure solids; SDS = Separated digested solids

Open source sites include the underlined basins, a basin at another IN site, and a dairy corral in TX.

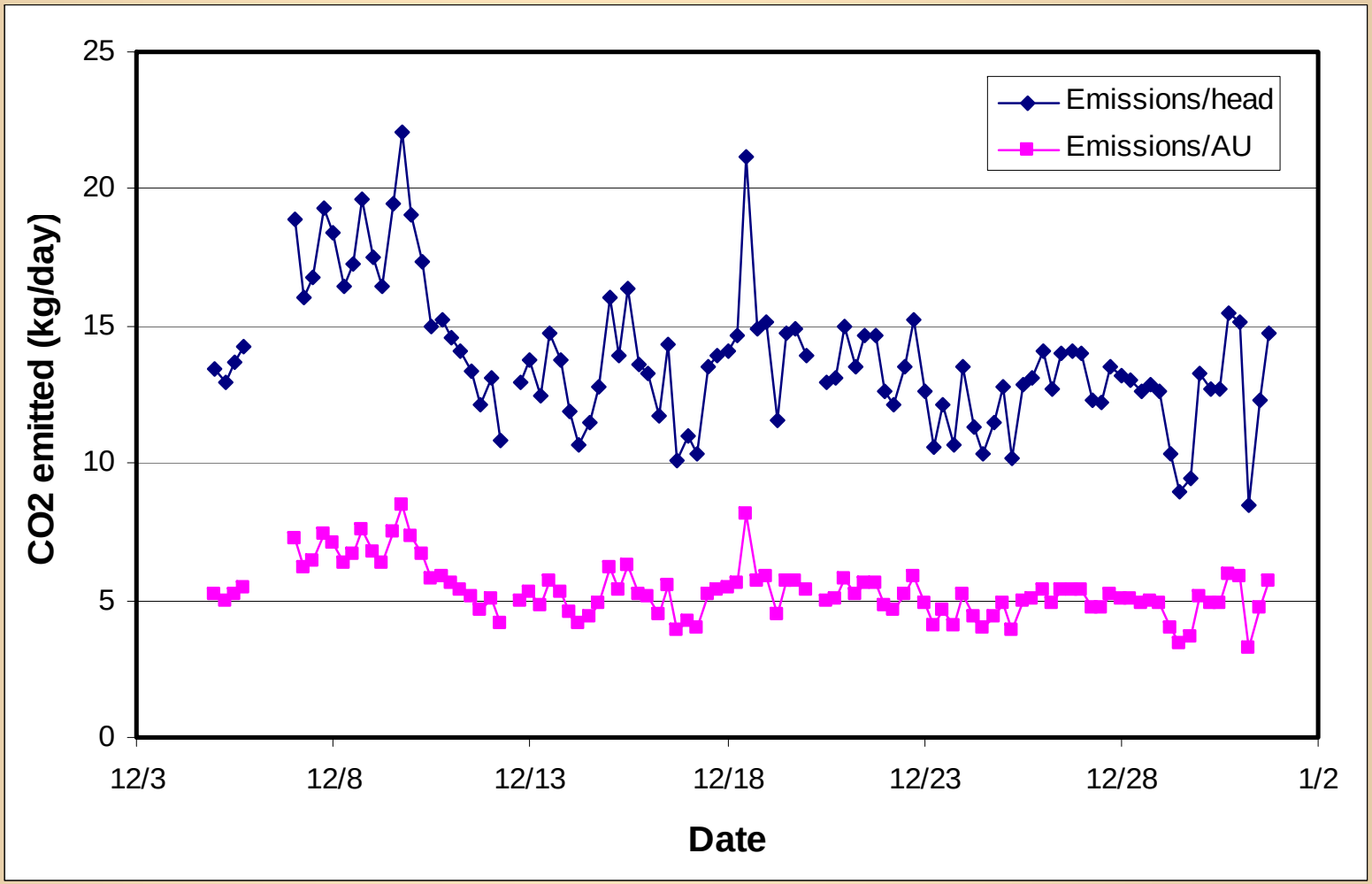
New York Dairy Site (NY5B), Curt Gooch, PI



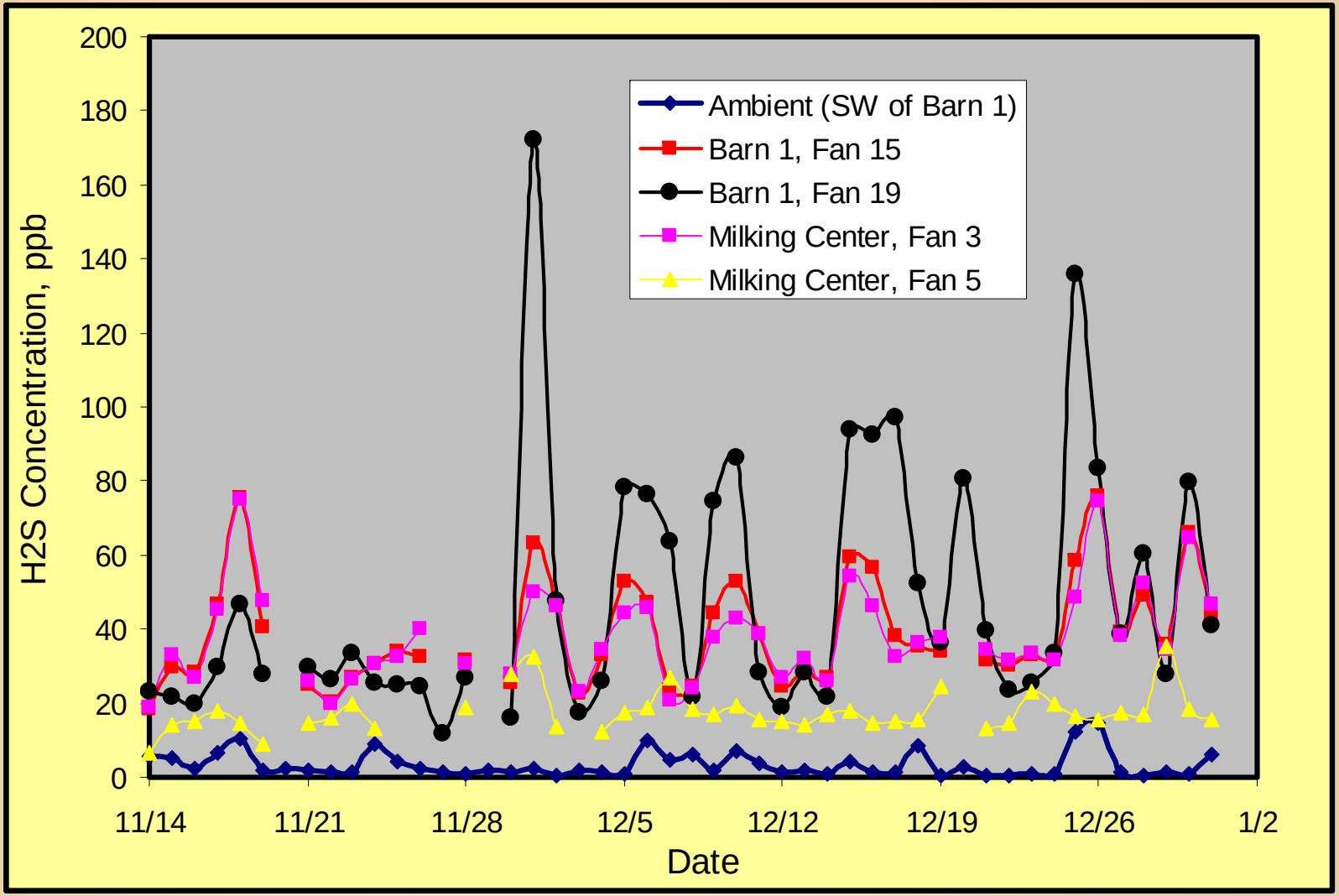


Site monitoring plan for continuous air emission testing.

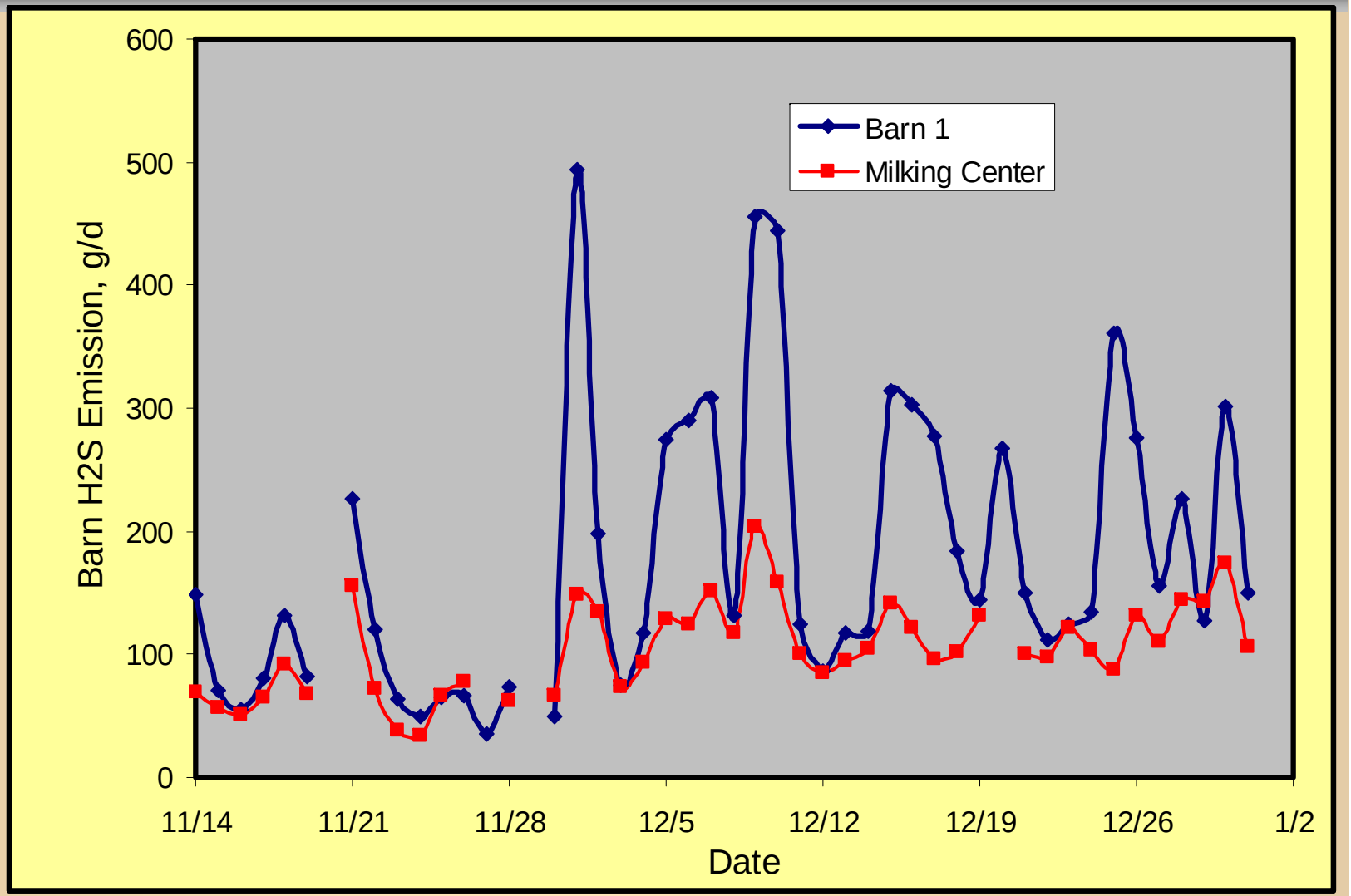
Preliminary CO2 Emissions Data from a Dairy Freestall Barn



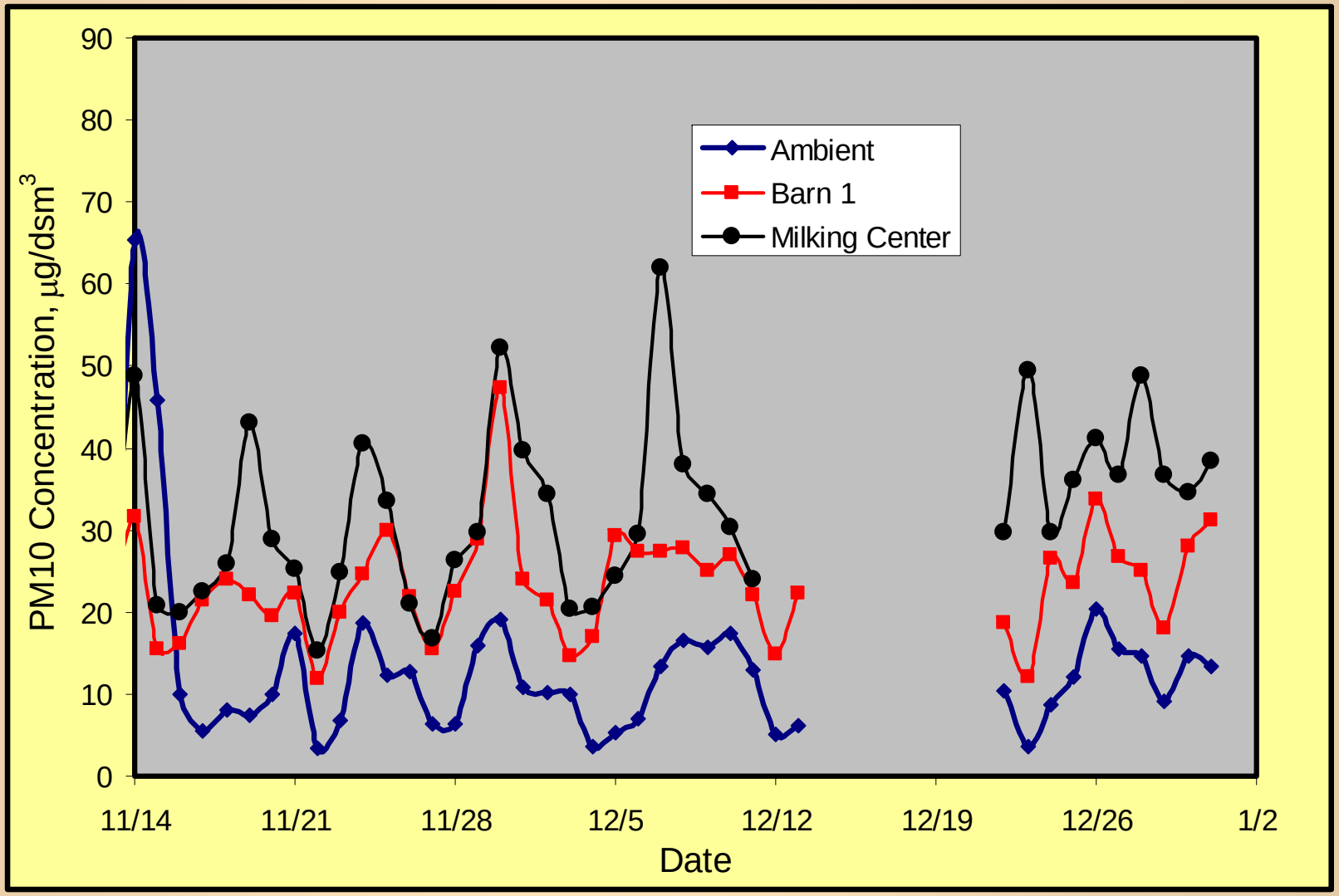
H2S Concentrations at NY5B



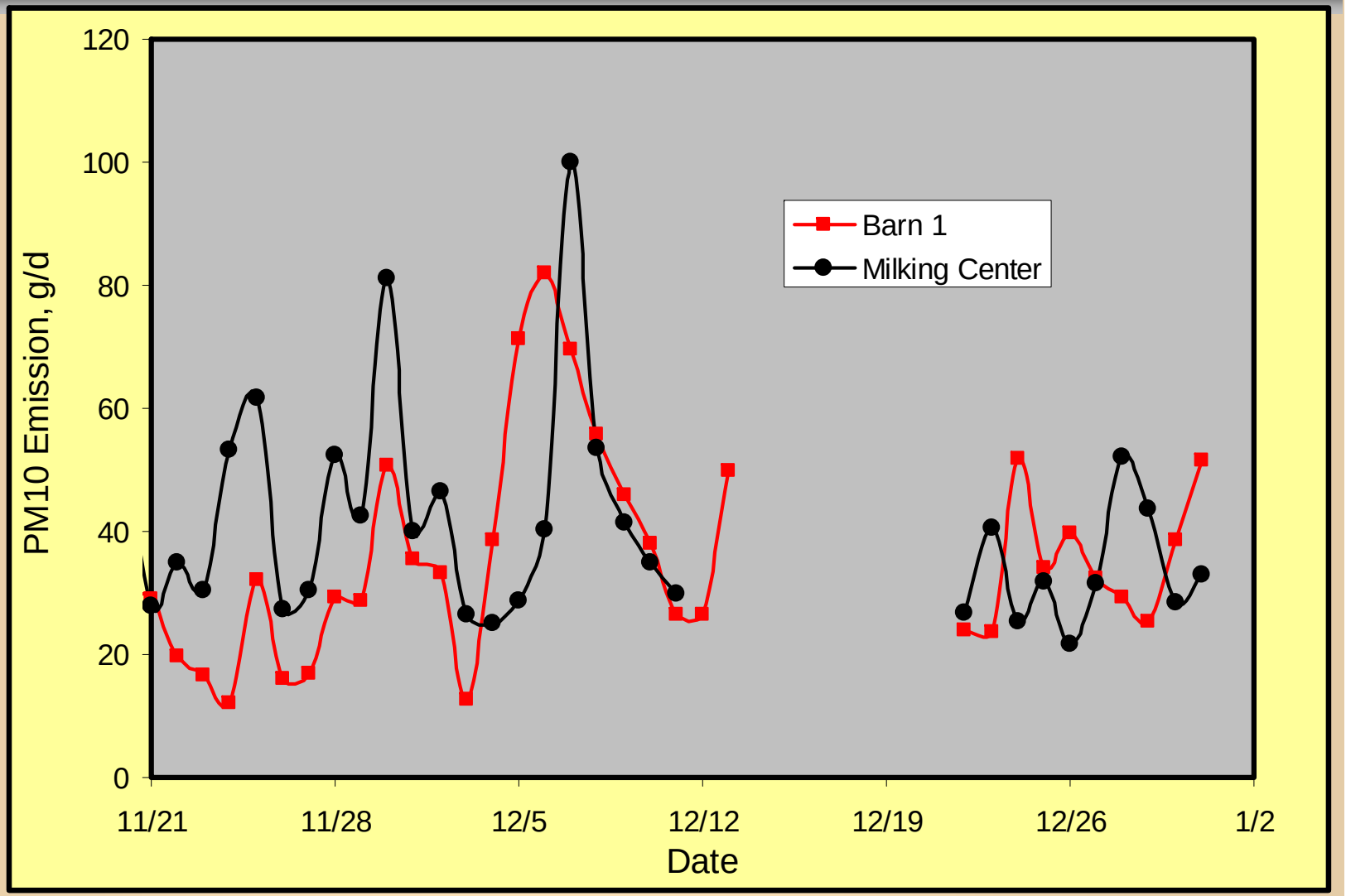
H2S Emissions at NY5B



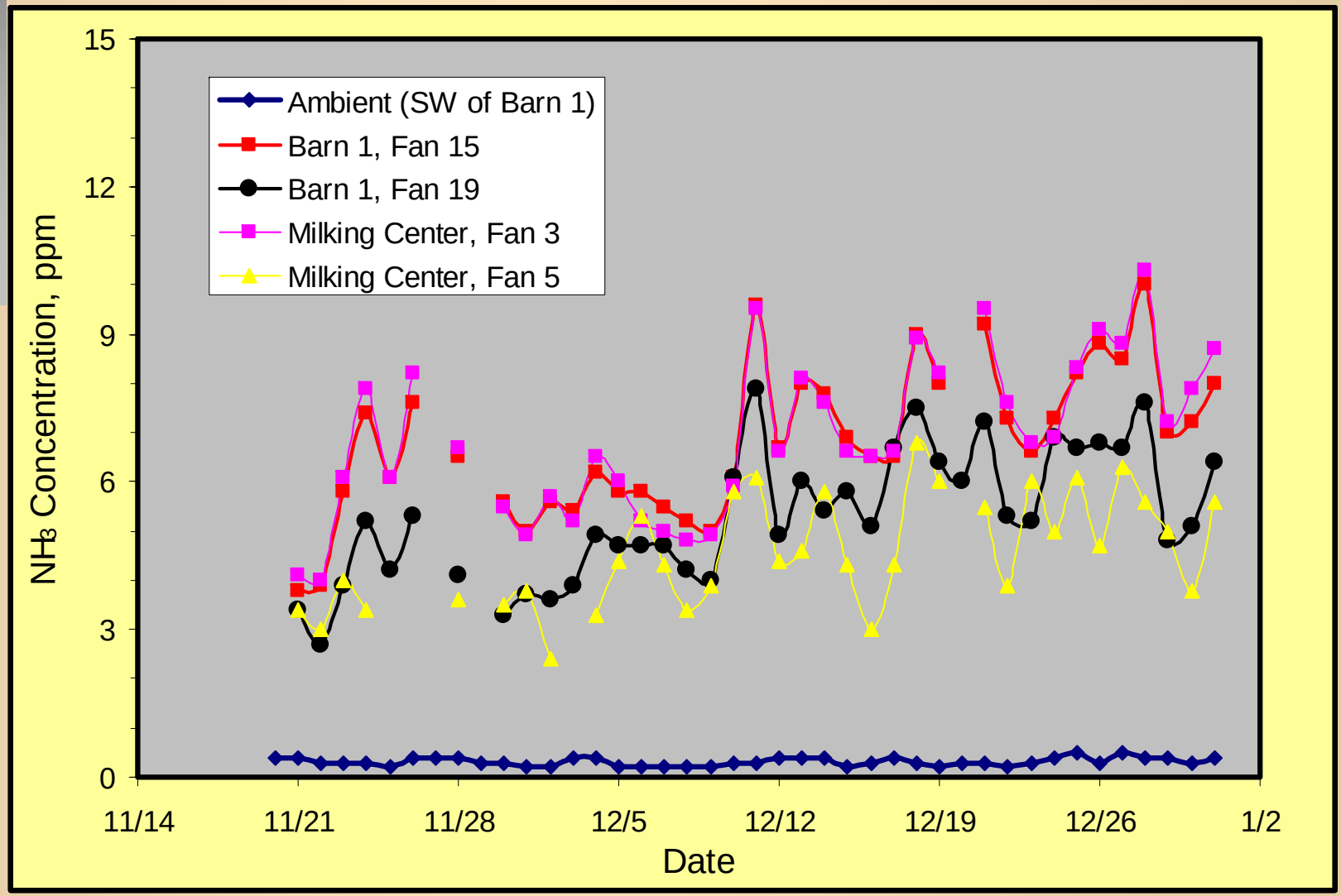
PM10 Concentrations at NY5B



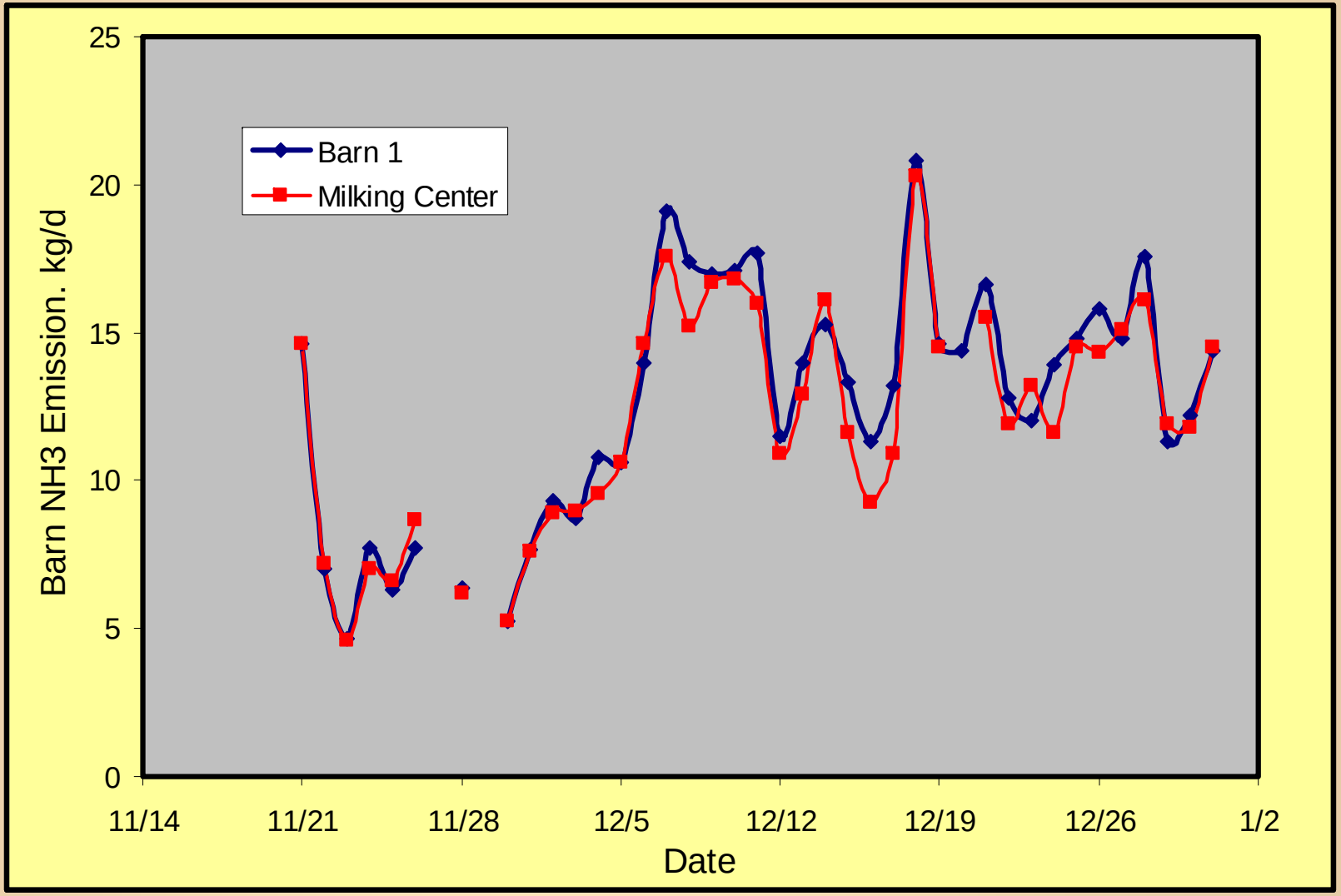
PM10 Emissions at NY5B



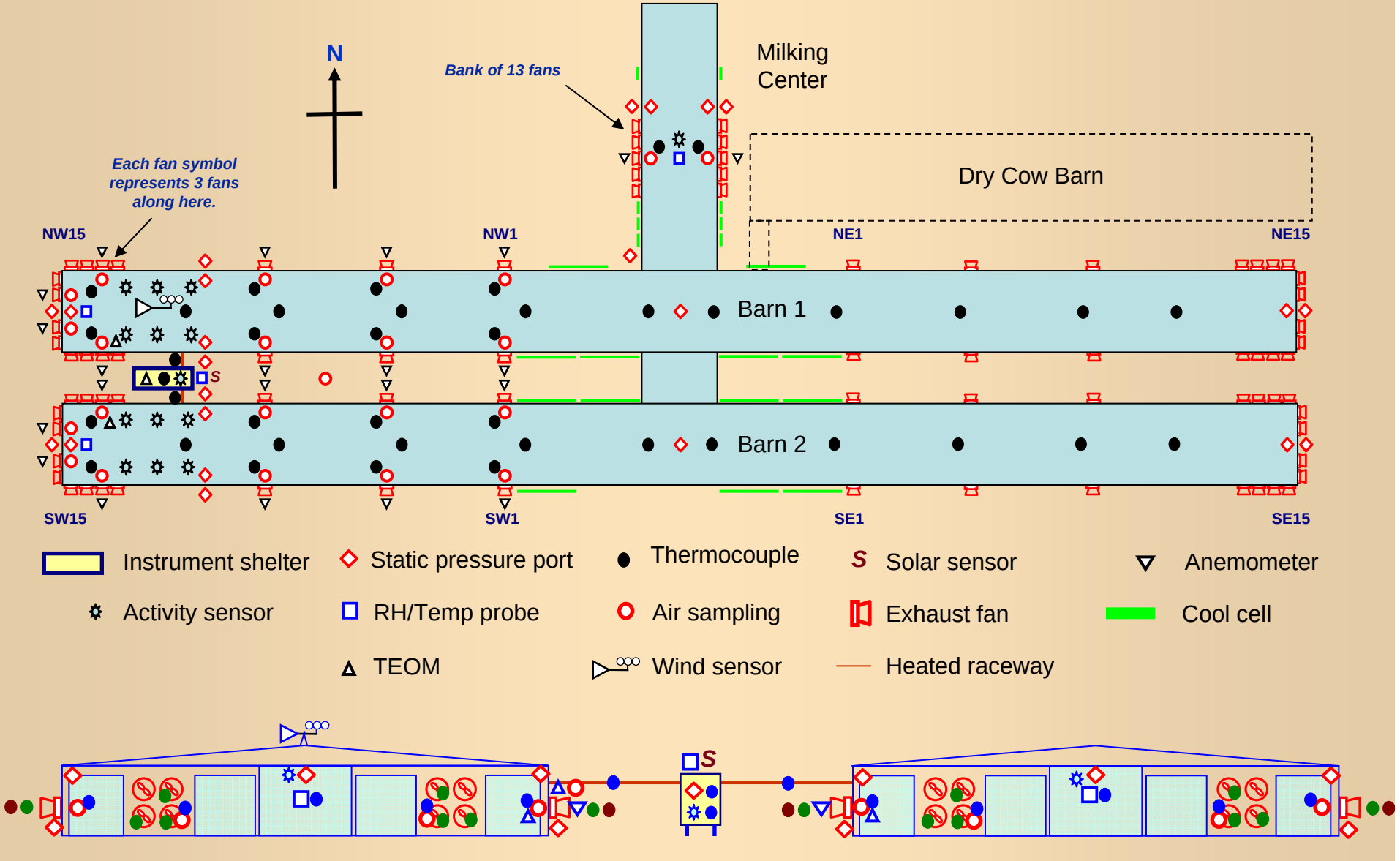
NH3 Concentrations at NY5B



NH3 Emissions at NY5B

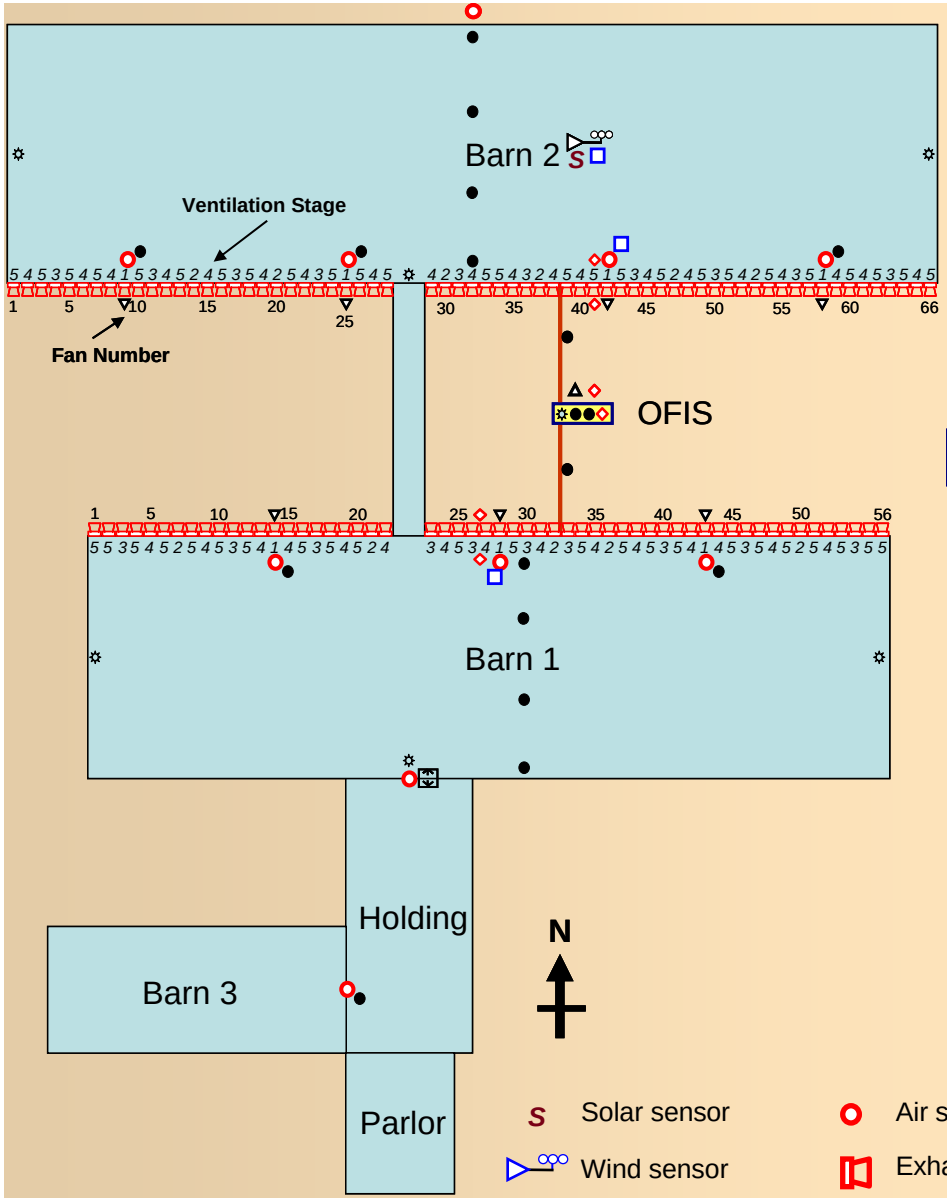


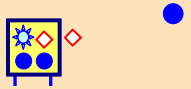
Indiana Dairy Site IN5B, Dr. Teng Lim, PI

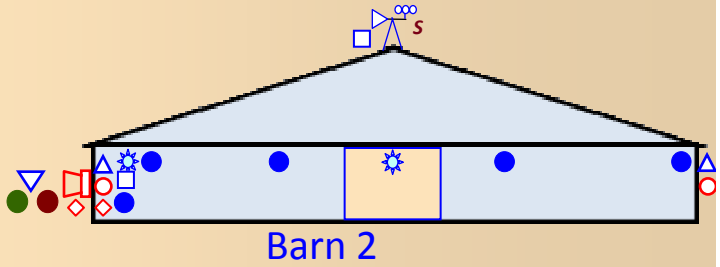


Site monitoring plan for continuous air emission testing at freestall barns 1 and 2, and in the holding barn associated with the milking parlor.

Wisconsin Dairy Site, (WI5B), Dr. Larry Jacobson, PI



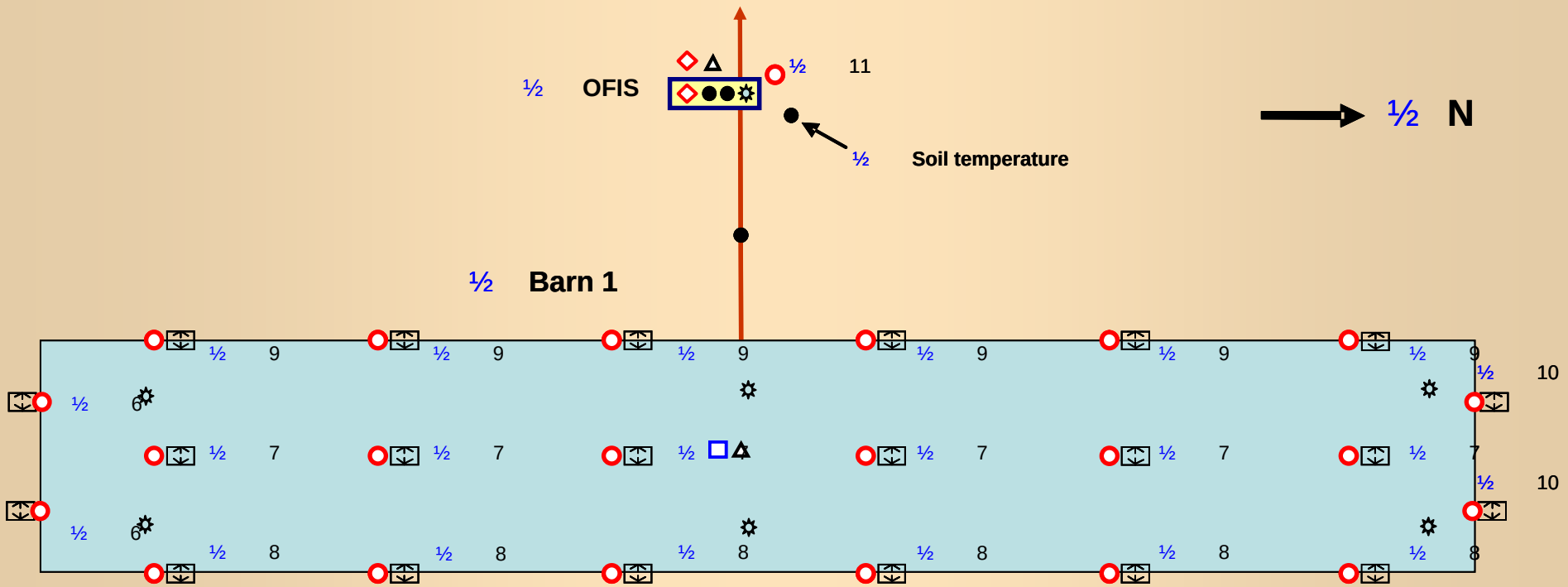




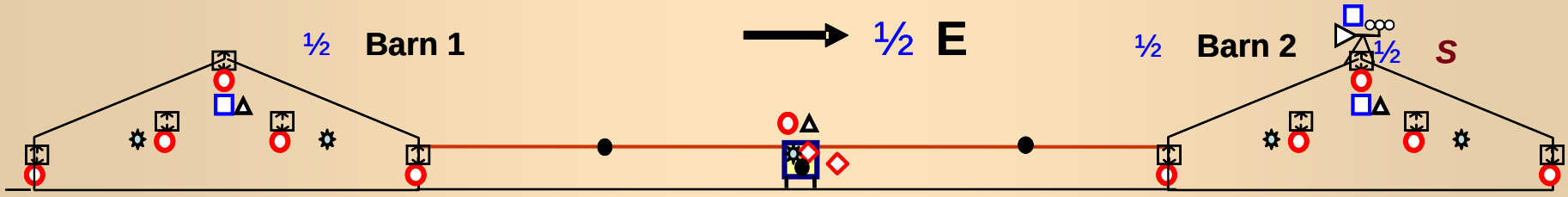
Solar sensor
Wind sensor
RH/Temp probe
Air sampling
Exhaust Fan
PM_{10} monitor
Anemometer
Thermocouple
Ultrasonic anemometer
Activity sensor
OFIS
Raceway
Static pressure port

Site monitoring plan for continuous air emission testing.

California Dairy Site (CA5B), Dr. Frank Mitloehner, PI

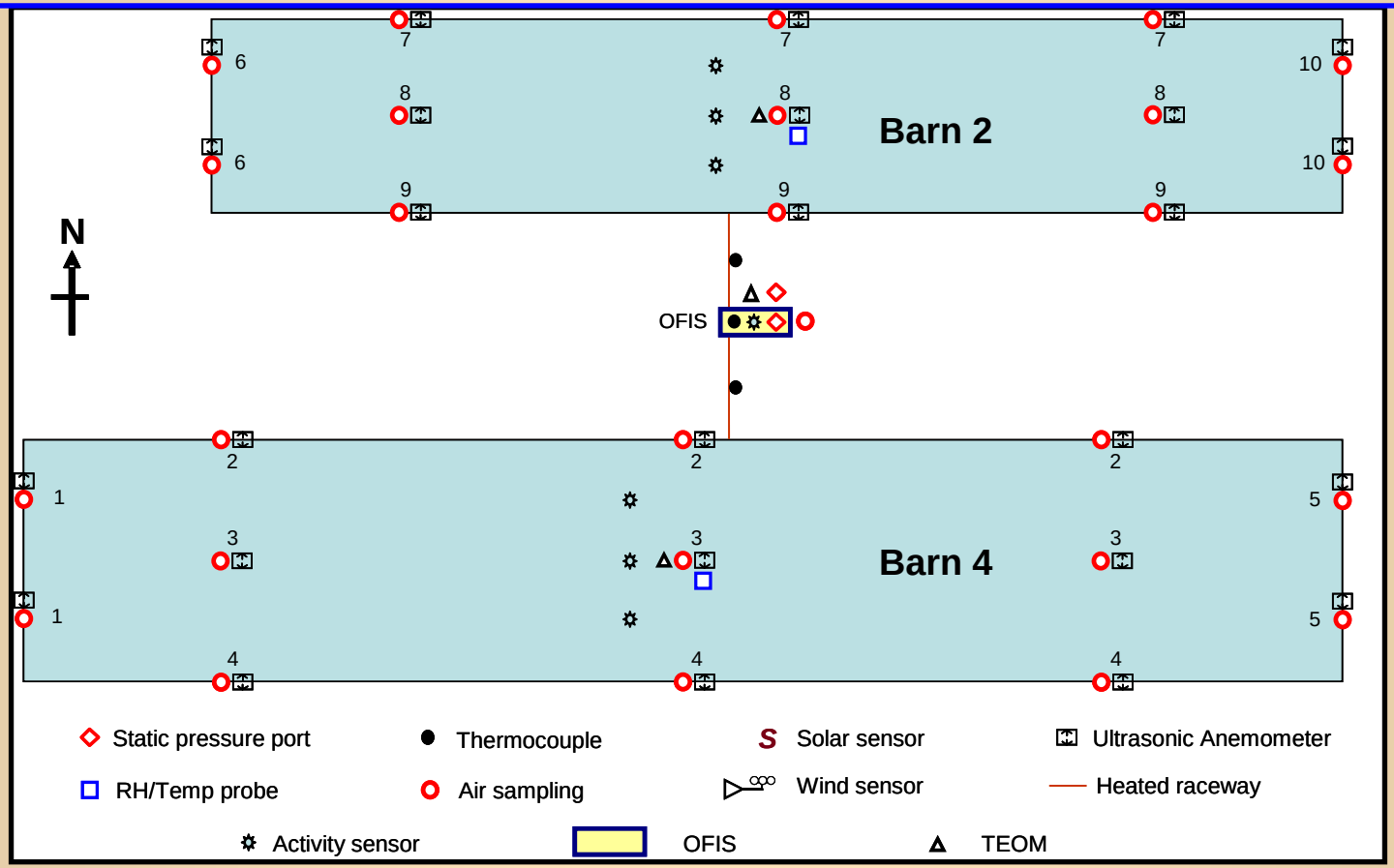


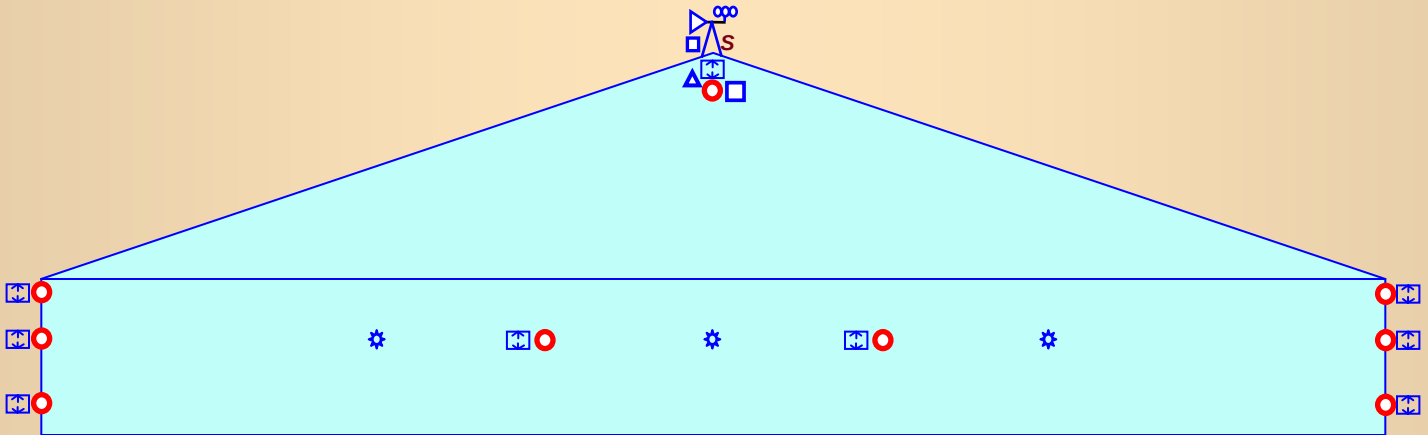
½ Activity sensor
½ Differential Pressure
½ Ultrasonic anemometer
½ RH/Temp probe
½ TEOM
½ Thermocouple
½ Air sampling
½ ½S Solar sensor
½ Instrument shelter
½ Heated raceway
½ Wind sensor



Site monitoring plan for continuous air emission testing.

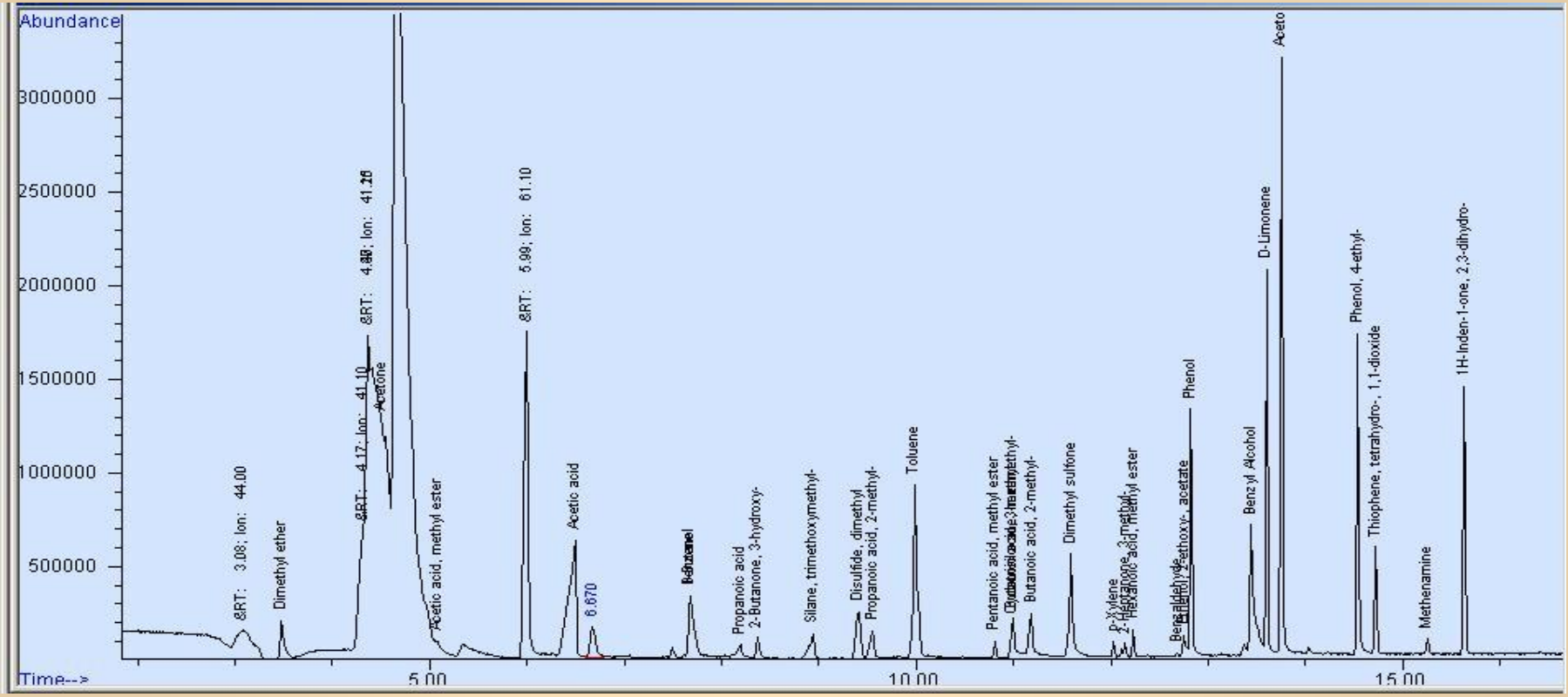
Washington Dairy Site WA5B, Dr. Phil Ndegwa, PI





VOC Lab Method Development

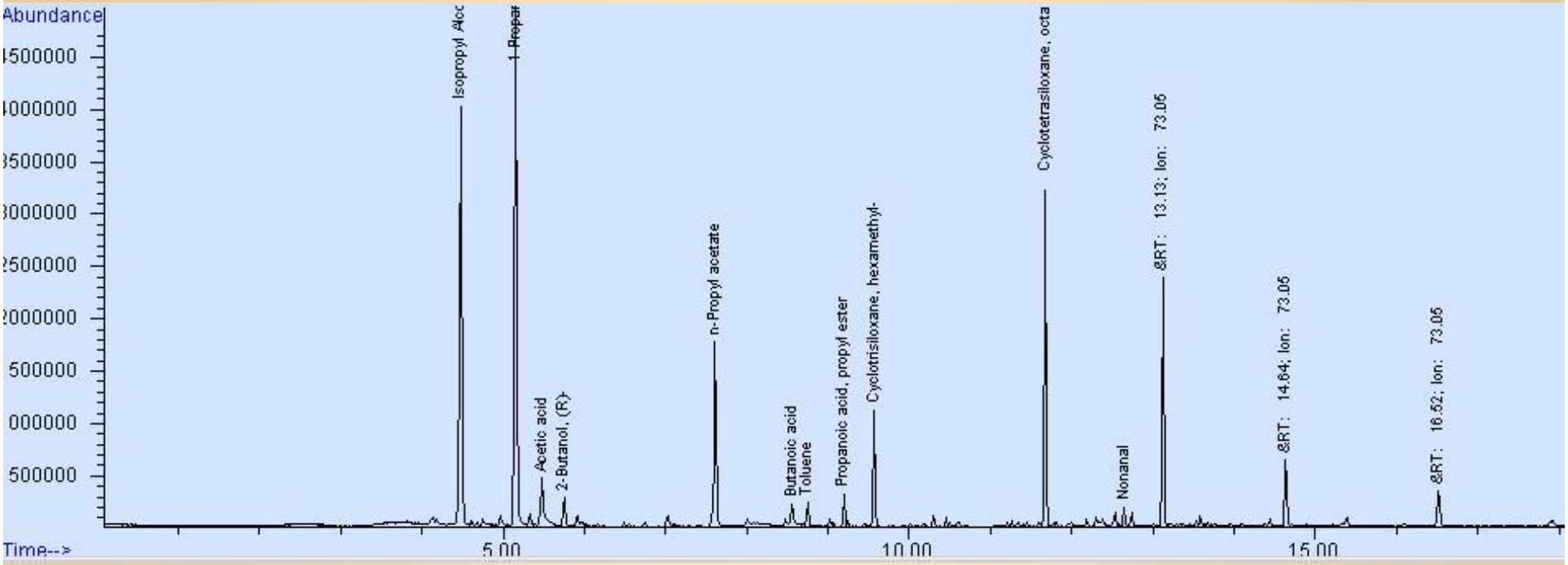
Laboratory Standards



Standards include:

i-propanol, butanol, acetic acid, propanoic acid, butanoic acid, pentanoic acid, hexanoic acid, dimethyl disulfide, dimethyl sulfone, toluene, phenol, benzyl alcohol, acetophenone

Sample from Dairy Freestall

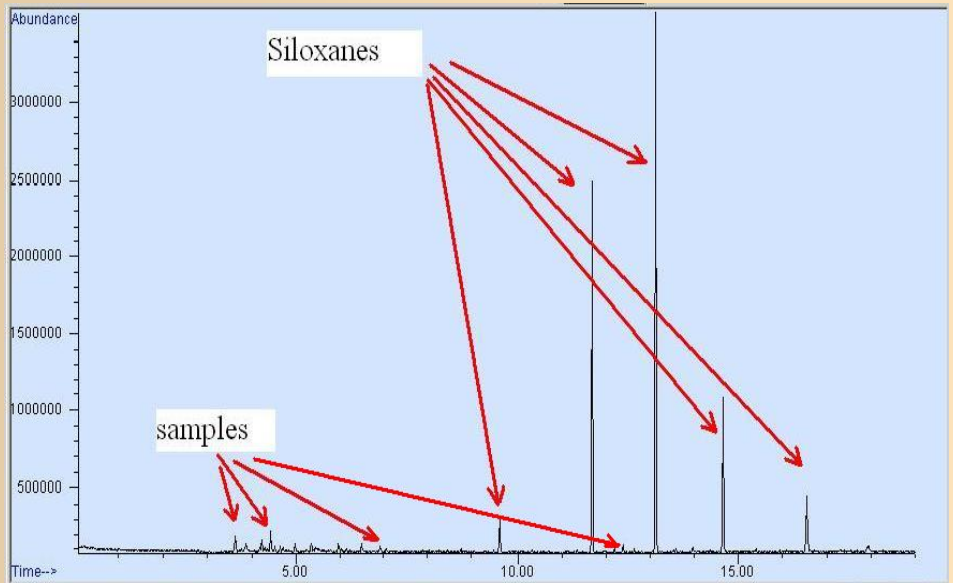


A dairy freestall air sample was analyzed and gave:

Isopropyl alcohol, 1-propanol, acetic acid, 2-butanol, n-propyl acetate, butanoic acid, toluene, propanoic acid, propyl-ester, nonanal, and siloxanes

Current Issues with VOC Analysis

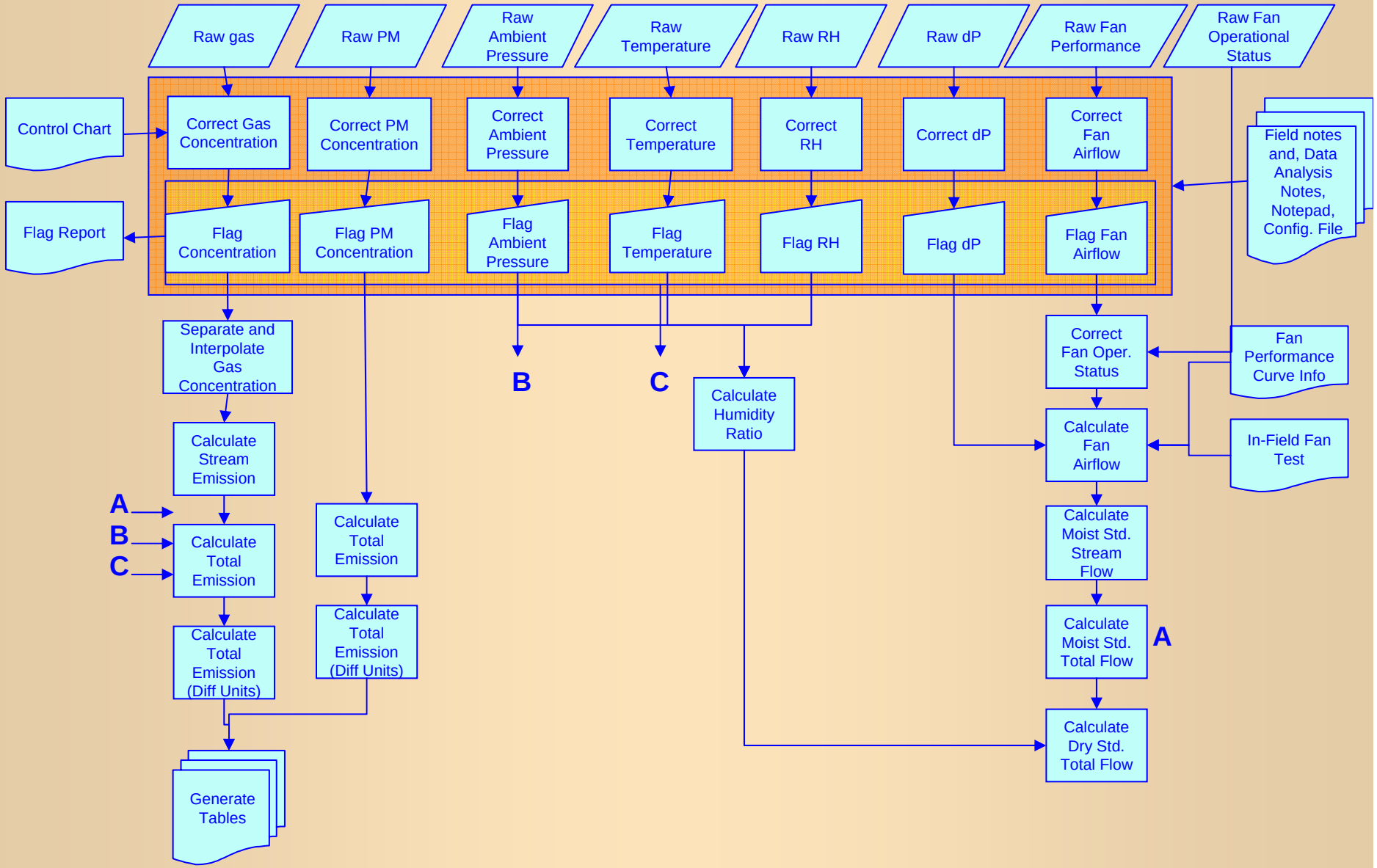
- GC-MS
  - **Lowered temperature of injection system to -110 C to retain more VOC components with sorbent tube analysis.**
  - **Abandoned solvent vent mode and using splitless mode.**
  - **Addressing problem of moisture in the sample TDS tubes**
- Recovery rates
  - **40 VOC's introduced into TDS tubes**
- Canisters
  - **SilcoCan produced siloxanes: replaced with TO can.**



Progress on Recovery Rates

- Goal is >80% recovery for each standard
- Acceptable recoveries finally achieved for 17 compounds.
- Improved recoveries obtained on 20 compounds (about half of standards).
- Unacceptable recoveries are observed on 7 of 40 standard compounds.

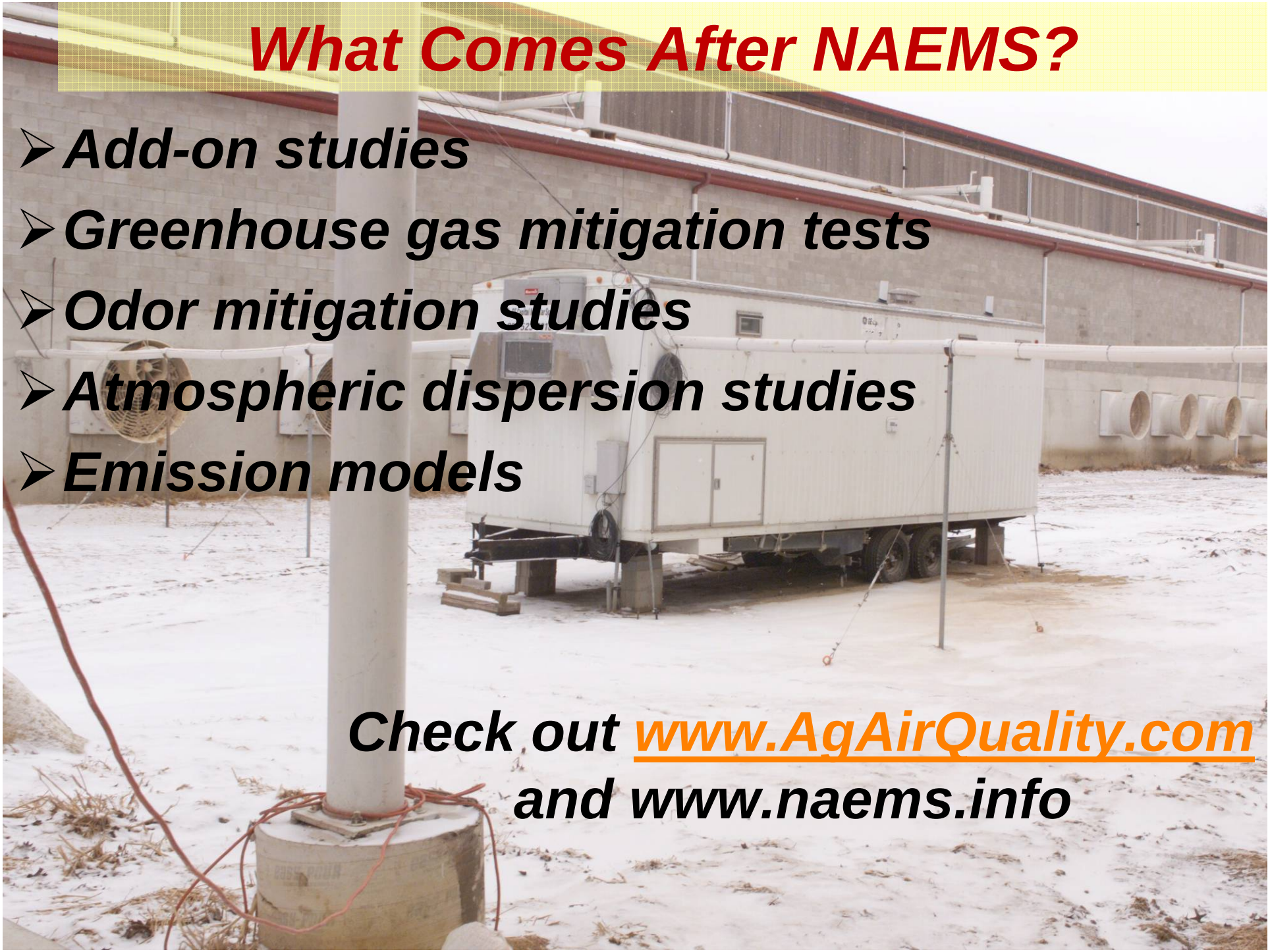
Data Processing Flowchart



Summary of NAEMS Progress

- ***Over 2300 sensors collecting data at barns.***
- ***All sites checked remotely nearly daily and problems quickly addressed.***
- ***2007 barn data being submitted to EPA.***
- ***VOC analysis methods nearly ready.***
- ***NAEMS web site is www.naems.info.***

What Comes After NAEMS?



- Add-on studies
- Greenhouse gas mitigation tests
- Odor mitigation studies
- Atmospheric dispersion studies
- Emission models

Check out www.AgAirQuality.com
and www.naems.info