

**REPORT**  
**ON**  
**WISCONSIN'S LIVESTOCK**  
**FENCELINE AMMONIA AND**  
**HYDROGEN SULFIDE MONITORING**  
**PROJECT**

**CONDUCTED BY WISCONSIN DNR**

**2010**

## **Natural Resources Board**

*Jonathon P. Ela, Chair, Madison*

*John W. Welter, Vice-Chair, Eau Claire*

*David Clausen, Secretary, Amery*

*Preston D. Cole, Milwaukee*

*Gary E. Rhode, River Falls*

*Christine L. Thomas, Stevens Point*

*Jane Wiley, Wausau*

## **Wisconsin Department of Natural Resources**

*Cathy Stepp, Secretary*

*Matt Moroney, Deputy Secretary*

*Scott Gunderson, Executive Assistant*

### **Air and Waste Division**

*Patrick Stevens, Division Administrator*

*Suzanne Bangert, Deputy Administrator*

### **Bureau of Air Management**

*John Melby, Director*

*Bart Sponseller, Air Monitoring Section Chief*

### **Author**

*David (Vid) Grande, Air Toxics Chemist, Air Monitoring Section*

## **EXECUTIVE SUMMARY**

### ***BACKGROUND***

This project investigated the fence-line air concentrations of ammonia and hydrogen sulfide at few small-to-medium dairy confined animal feeding operations (CAFOs), a single small swine CAFO, and a large egg laying CAFO during the summer months of 2010. Ammonia is considered a hazardous air contaminant because it can cause adverse health effects at ambient concentrations. Ammonia's toxicity is based upon its caustic properties. At low concentrations, ammonia is irritating to wet tissues of the lungs, airways, and eyes. Likewise, hydrogen sulfide is a hazardous compound, most dangerous when it is concentrated enough (perhaps more than 600 ppm) to cause respiratory paralysis through the nervous system, leading to collapse and loss of consciousness while in a dangerous air environment such as a sewer or enclosed manure pit.

Using a combination of both passive and active sampling methods, the measurements provide valuable information related to the application of NR445, the hazardous air contaminant rule, to animal agriculture. The limited nature of the study prevents an all-encompassing answer to all questions relating to application of this rule. It should also be noted that our sampling was not intended to measure emissions or determine emission factors, nor was any effort made to address quality of life issues. This report transmits the findings of our study.

This project was funded entirely with state funds, and on an extremely limited budget. The budgetary constraints led to several limitations in study design and application, including the inability to employ continuous monitoring methods which would have provided a statistically significant body of data on which to base conclusions. Limited time was available for sampling on each farm, so that we do not know whether peak concentrations were recorded. Participation in the study was entirely voluntary and limited to those operations with a WPDES permit located within a relatively small geographic area. The budgetary constraints eventually culminated in a shortened project. These factors indicate that the conclusions drawn from this study may not be applicable to the full range of CAFOs in Wisconsin.

The basic protocol for each farm was to set up an array of passive samplers around the property lines of each farm, and a meteorological station for recording wind speed and direction. The passive samplers were for the evaluation of ammonia concentrations only, and would provide a weekly average concentration. Each sampler was exposed for approximately a week, after which it was collected for analysis and replaced with another sampler. This process would be repeated over the course of a month, after which the next farm would be sampled.

During the month of passive sampling, three active sampling trips were planned for each farm. These sampling trips consisted of collecting both ammonia and hydrogen sulfide samples along the downwind side of the farm on a single day. These samples provided additional short term and potentially worst case results, as well as some information about hydrogen sulfide.

To limit travel expenses, the subject farms for this project were selected through a review of WPDES permitted farms within a 9-county area surrounding Dane and Dodge counties. Attempts were made to include one each of poultry, swine and beef operations, with 3 or 4 dairies, for an anticipated total of 6 or 7 farms. Farms were evaluated on a basis of accessibility to and distance of facilities from the property lines; travel distance, and suitability for monitoring. Farms acceptable for the project were approached and asked to volunteer to participate in the study. Among the farms whose participation was solicited were several of the largest dairies and poultry operations in the state.

Interested farms were visited to ensure the farm's suitability, and to outline the project for the farm owner. A total of 9 farms agreed to participate in the study initially, including 2 poultry operations, a combination dairy, beef and swine operation, and 6 dairies. While the combination farm's beef operation proved to be unsuitable, both the dairy and swine operations were included in the project as separate entities. Additional participants include one of the poultry farms and two of the other dairies, for a total of 5 case studies, although the second dairy was monitored for only 2 of the 4 anticipated weeks. In the 9-county area, none of the dairies housing more than 3000 animals agreed to participate.

While the project focus was on property line concentrations, the combination farm dairy operation provided a unique opportunity to evaluate changes in concentration at different distances from the facility, which led to the incorporation of a set-back study on that farm. This portion of the study can provide important information to ground-truth air pollution dispersion models applied to agricultural operations.

A total of 18 rounds of weekly passive sampling and 13 active sampling runs were conducted over the course of the study. During this study, a total of 315 passive samples for ammonia, 128 active air samples for ammonia and 64 active air samples for hydrogen sulfide were collected, mostly from the perimeters of the farms. This report documents the air sampling procedures and compiles the results.

## ***KEY FINDINGS***

### **PASSIVE AMMONIA (NH<sub>3</sub>) SAMPLING**

Ambient fence-line concentrations of ammonia at any particular spot around a farm will vary according to weather and conditions on the farm leading to emissions. This natural variability is countered in the study design by placing samplers somewhat evenly spaced around the perimeter of the farm, and by exposing the sampler for a week of changing conditions. In spite of this, the relatively few sampling rounds conducted on each individual farm combined with the overall short term nature of the project, yields a situation where we were not able to collect a statistically significant quantity of samples over a representative portion of a year. Accordingly, the results contain some ambiguity.

It is also important to keep in mind that, outside of the poultry operation, none of the study farms exceeded 3,000 animal units. Including dairy, swine and poultry, there are over 50 farms in the state with more than 3,000 animal units, including 18 with more than 5,000 animal units. Whether or not all of these results and conclusions can be extrapolated to encompass larger operations is questionable.

The following statements are solidly supported by the data from this study:

- 1) In general, concentrations of ammonia around animal feeding operations during summer months are elevated relative to non-agricultural background samples.
- 2) An increase in animal units present on the farm will tend to increase both the frequency of detectable quantities of ammonia, and the observed concentrations.
- 3) As distance from the housing and waste storage to the property line increases, observed concentrations of ammonia tend to decrease.
- 4) Most perimeter samples collected were less than 10% of the NR445 defined 24-hour ambient action concentrations (AAC), and less than 50% of the annual AAC.

The statements below are less conclusively supported, although they are likely to be true:

- 5) More apparent ammonia was observed around the poultry operation than either the dairies or swine operation, but whether this was a factor of the farm containing significantly more animal units than any of the other farms, or an intrinsic property of poultry husbandry is not clear.
- 6) Some on-farm locations in the dairy setback study, as well as a single very close property line location on the poultry farm exceeded the annual average ambient action concentration during the limited period of sampling conducted. This does not necessarily indicate a violation of the NR445 fence line standard has or will occur, but it does indicate the potential for on-farm concentrations to exceed this health based standard, with possible implications for both animal and worker health.

### **ACTIVE AMMONIA (NH<sub>3</sub>) AND HYDROGEN SULFIDE (H<sub>2</sub>S) SAMPLING**

The study data indicates that concentrations of ammonia and hydrogen sulfide tend to vary as much or more widely between visits to the same farm as they do between two different farms. This, combined with the design limitations preventing the collection of a representative and statistically significant set of samples, leads to few possible observations.

The following statements about hydrogen sulfide are supported by the data:

- 7) Hydrogen sulfide did not appear to be a significant issue around the participating poultry operation.
- 8) The few significantly elevated hydrogen sulfide readings and samples from this study were obtained relatively near liquid manure processing on dairies, either near sand channels or lagoons during agitation or downwind of post-digestion solids separation and biogas combustion.
- 9) Hydrogen sulfide on farms appears to be emitted in discrete plumes. This is supported by findings that samples closely spaced with those returning elevated results typically returned significantly lower results.
- 10) Results of this and other recent studies indicate that the role manure management choices have in generating emissions of this compound are significant and should not be ignored.

The following statement about ammonia is supported by the data:

- 11) In contrast to hydrogen sulfide, results from the ammonia samples show both a higher rate of detection, and generally higher concentrations downwind of farms. This implies that, relative to hydrogen sulfide, there are more processes that are broadly spread across the farm landscape leading to ammonia emissions.

In addition to the specific statements above, results of both the passive and active sampling conducted on these farms clearly demonstrated that concentrations of both compounds decrease rapidly as the distance to the source areas increases. Therefore setback distances to the property lines should be considered by farmers and regulators during the planning of new and expanding facilities.

### ***CONCLUSIONS***

From the results of this study, it can be seen that the farms in this study generally did not generate fence-line concentrations of concern at their property lines during this study. However, our results also clearly show that these farms do generate ammonia, and to a lesser extent hydrogen sulfide. Ammonia is an important component of fine particulate matter and haze; both are significant regional and national air quality issues. While they are not regulated by NR445, odors associated with hydrogen sulfide can be a significant local quality of life issue. Therefore, control and mitigation of these emissions is an important issue to consider when managing animals and their wastes.

This study yielded important insights into questions that may lead to additional areas of investigation. For example, the off-farm impacts of discrete concentrated hydrogen sulfide plumes associated with agitated liquid manure surfaces and post-digester processing of wastes has not been quantified or clarified. The NR445 ambient action concentration (AAC) for this compound is approximately 50 to 100 times the odor threshold, leading to potentially significant quality of life impacts well below the standard. Exploration and evaluation of management strategies which can reduce hydrogen sulfide emission is an important step to improving public perception of concentrated animal husbandry.

Additionally, several issues were not addressed at all in the current study, including:

- the effects of significantly different feeding regimes (for example, a high haylage/low grain diet for dairy cows)
- the combined effect of many small-to-medium sized CAFO farms in a small area
- the impact of swine and dairy CAFOs with more than 3000 animal units
- the effects of employing beneficial management practices on fence-line concentrations

Any additional future studies should focus on one or more of these other issues, to help round out our understanding of the impact these operations have on ambient air.

## **ACKNOWLEDGEMENTS**

We would like to extend our appreciation to the following for their support and dedication for funding, involvement and guidance for this project and the report you are reading.

Many thanks to all farmers who volunteered to participate in the study, whether or not our budget allowed their operation to be included; without the farmers' participation, no study would have been possible. Your willingness and interest in exploring these issues can only lead to a greater understanding of air impacts associated with agriculture, and to better management practices to reduce these impacts.

### **DNR Administration – Al Shea, John Melby, Sheri Stach and Bart Sponseller:**

The Wisconsin DNR regulates air quality under NR445 and these individuals supported the study with resources to accomplish this project.

### **DNR Staff – John Roth, David Panofsky and Jeffrey Voltz**

These individuals provided modeling support and results figures, study design advice, on-going moral support and report review.

### **Wisconsin Occupational Health Lab – LeRoy Dobson and Derek Popp:**

This lab provides analytical services, and these individuals provided sampling advice, the loan of equipment, and prompt results.

### **UW Platteville Farm – Randy Mentz**

Thanks for the loan of extra passive sampling devices, which made it possible to conduct the Dairy Setback and Swine sampling at the same time.

# TABLE OF CONTENTS

Executive Summary .....	iii
Background .....	iii
Key Findings .....	iv
Passive Ammonia (NH <sub>3</sub> ) Sampling .....	iv
Active NH <sub>3</sub> and (Hydrogen Sulfide) H <sub>2</sub> S Sampling .....	v
Conclusions .....	vi
Acknowledgements .....	vii
Table of Contents .....	viii
List of Appendices .....	ix
List of Figures .....	x
List of Tables .....	x
Introduction .....	1
Purpose .....	1
Project Objectives .....	1
Rationale and Project History .....	1
Regulatory Drivers .....	2
Parameters of Interest .....	2
Work Performed .....	3
Project Duration .....	3
Project Management .....	4
Project Team Bios .....	4
Methods .....	5
Study Design and Limitations .....	5
Study Design .....	5
Purpose: .....	5
Other Studies: .....	5
The Current Study: .....	6
Limitations: .....	7
Farm Selection Process .....	8
Laboratory Selection .....	9
Technology Selection Criteria and Rationale .....	10
Field Equipment .....	11
Jerome Real-time Hydrogen Sulfide Meter .....	11
Solar Powered Meteorological Station .....	12
Weather Shelters, Timers and other .....	13
Sampling Methods & Testing Protocols .....	14
Field Methods .....	14
Sample Chain of Custody .....	14
Data Analytical Methods .....	14
Data Presentation .....	14
Data Comparisons .....	15
Discrete Sample Data Management and Basic Calculations .....	16
Use of Raw LABORATORY Values .....	17
Data Quality Analysis, Blank Samples .....	18

Data Quality Analysis, Duplicate Samples .....	19
Meteorological Data Management.....	20
Non-Agricultural Background Sample Results .....	21
Results.....	22
Case Studies: Five Participating Farms .....	22
Overview.....	22
General Case Study Format .....	22
Case Study 1: Poultry .....	24
Background.....	24
Passive Sampling.....	26
Active Sampling.....	26
Case Study 1 Key Findings Summary Statements.....	27
Case Study 2: Dairy 4 .....	28
Background.....	28
Passive Sampling .....	30
Active Sampling.....	30
Case Study 2 Key Findings Summary Statements.....	31
Case Study 3: Dairy 2 .....	32
Background.....	32
Passive Sampling.....	34
Active Sampling.....	34
Case Study 3 Key Findings Summary Statement .....	35
Case Study 4: Dairy Setback.....	36
Background.....	36
Passive Sampling .....	38
Active Sampling.....	39
Case Study 4 Key Findings Summary Statements.....	40
Case Study 5: Swine .....	41
Background.....	41
Passive Sampling .....	43
Active Sampling.....	43
Case Study 5 Key Findings Summary Statements.....	44
Conclusions.....	45
General Comparisons.....	45
Comparison with NR445 Ambient Action Concentrations .....	48

## **LIST OF APPENDICES**

- Appendix A: Case Study 1: Poultry Results Figures
- Appendix B: Case Study 2: Dairy 4 Results Figures
- Appendix C: Case Study 3: Dairy 2 Results Figures
- Appendix D: Case Study 4: Dairy Setback Results Figures
- Appendix E: Case Study 5: Swine Results Figures

## LIST OF FIGURES

Figure M-1 Jerome Hydrogen Sulfide Meter.....	11
Figure M-2 Solar Powered Meteorological Station.....	12
Figure M-3 Sampling Equipment Weather Shelter.....	13
Figure L-1: Poultry Farm Layout.....	25
Figure L-2: Dairy 4 Farm Layout.....	29
Figure L-3: Dairy 2 Farm Layout.....	33
Figure L-4: Dairy Setback Farm Layout.....	37
Figure L-5: Swine Farm Layout.....	42
Figure C-1: Detection Rate vs. Animal Units.....	47
Figure C-2: Average Ammonia Concentration vs. Animal Units.....	47

## LIST OF TABLES

Table M-1 Blank Sample Results.....	19
Table M-2 Duplicate Sample Results.....	20
Table M-3 Non-Agricultural Background Sample Results.....	21
Table CS-1: Participating Farms.....	23
Table R-1: Passive Ammonia Sample Results, Poultry ( $\mu\text{g}/\text{m}^3$ ).....	26
Table R-2: Poultry Active Sampling Results ( $\mu\text{g}/\text{m}^3$ ).....	27
Table R-3: Passive Ammonia Sample Results, Dairy 4 ( $\mu\text{g}/\text{m}^3$ ).....	30
Table R-4: Active Sampling Results, Dairy 4 ( $\mu\text{g}/\text{m}^3$ ).....	31
Table R-5: Passive Ammonia Sample Results, Dairy 2 ( $\mu\text{g}/\text{m}^3$ ).....	34
Table R-6: Active Sampling Results, Dairy 2 ( $\mu\text{g}/\text{m}^3$ ).....	35
Table R-7: Passive Ammonia Sample Results, Dairy Setback ( $\mu\text{g}/\text{m}^3$ ).....	38
Table R-8: Active Sample Results, Dairy Setback ( $\mu\text{g}/\text{m}^3$ ).....	39
Table R-9: Passive Ammonia Sample Results, Swine ( $\mu\text{g}/\text{m}^3$ ).....	43
Table R-10: Active Sample Results, Swine ( $\mu\text{g}/\text{m}^3$ ).....	44
Table C-1: Farm Passive Sampling Results Comparison.....	46

# **INTRODUCTION**

## ***PURPOSE***

### **PROJECT OBJECTIVES**

This project is intended to evaluate fence-line concentrations of ammonia and hydrogen sulfide in an effort to:

- enhance understanding of the dynamics of animal agricultural air emissions
- provide information to help direct changes to NR445 and its applicability to agriculture

### **RATIONALE AND PROJECT HISTORY**

Agricultural practices in the past 30 years have led to increasing numbers of animals on fewer farms, which in turn have increased the amount of waste generated on each farm. Not only does this complicate waste handling for the farmer, but it also increases the chance that emission of odors and biogenic compounds may cause at least the perception of problems. Whether or not emissions of such compounds as hydrogen sulfide and ammonia from CAFOs are of legitimate regulatory or health concern is a current research topic nationally.

In 2004, Wisconsin DNR revised a state air rule governing the emission of hazardous chemicals of concern (NR 445). Among the chemicals regulated under this rule are several known to be associated with animal manure. At that time, however, not enough information was available to determine whether large animal operations would exceed regulatory limits associated with the rule. As such, an exemption to the application of NR445 for agricultural waste was put in place, until more information could be obtained. The exemption was extended again in 2008, and is set to expire on July 31, 2011.

Currently, Wisconsin DNR has limited on-the-ground knowledge related to ambient air concentrations and odors from livestock operations at the fence-line, though several academic papers have recently been published on the topic. Though the location of livestock operations and the air quality surrounding them have, in some cases, been regulated through local permits, the impact of beneficial management practices (BMPs) on ambient air concentrations and odor has not been directly considered.

This project is intended to view the air impacts of farms as a whole entity, rather than concentrating on specific portions of the operations (e.g., barns or manure lagoons), in an effort to evaluate concentrations where the general public could be exposed to the emissions. In this way it differs from other farm oriented air monitoring projects conducted in Wisconsin and around the country to date.

## **REGULATORY DRIVERS**

Several regulations at the state and local level are driving a need for scientific study and evaluation of ambient air concentrations. State hazardous air pollutant emissions are regulated under ch. NR 445, Wis. Adm. Code. This rule establishes ambient air standards for specific hazardous air pollutants, off the source's property. The acceptable ambient concentration standards for ammonia and hydrogen sulfide are 418 and 335 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ), respectively, both on a 24-hour average basis. In addition, ammonia has an annual ambient action concentration of  $100 \mu\text{g}/\text{m}^3$ .

NR 445, Wis. Adm. Code was updated in 2008 to extend an exemption period for livestock operations to July 31, 2011. This study was designed, in part, to provide information to support Department decisions on beneficial management practices for the control of hazardous air contaminant emissions.

Increasing attention is placed on the impact of CAFO emissions. Prior to this study, the Department had not quantified ambient air concentrations of hazardous air contaminants from any livestock operations at the fenceline to determine whether the pollutants might exceed the regulatory thresholds under NR 445, Wis. Adm. Code, Control of Hazardous Pollutants.

Wisconsin is experiencing increased conflicts between livestock operations and developing rural communities related to odor and water quality issues. A number of local governments are regulating the location and expansion of livestock operations through local zoning and issuing of conditional use permits. Until 2003, when Wisconsin passed the Livestock Siting Law, ATCP 51, Wis. Adm. Code, most zoning regulations were size neutral and did not address odors. Though not a state-wide requirement, ATCP 51 includes an odor standard for farms larger than 1000 animal units that limits the predicted odor impact on nearby residences. The issue of whether livestock operations are a threat to public health and welfare will continue, especially as the livestock industry transitions to larger size operations.

## **PARAMETERS OF INTEREST**

Hundreds of volatile compounds have been found associated with manures. Of these, over twenty compounds are listed in NR445. Choosing which parameters to include within this study was a process which, balanced

- the limited budget with the existence of ambient air testing methods,
- the perceived likelihood that any particular compound might actually be present in levels approaching those listed in NR445, and
- the probability that the presence of the compounds is actually associated with the agricultural operation.

Based on these factors, this study focuses on ammonia and hydrogen sulfide as the compounds most likely to be present at almost all farms. Several other compounds that are likely to be present (such as benzene and formaldehyde) were rejected because of their ubiquitous occurrence in the atmosphere, and thus the difficulty of associating their presence with the operation in question. While ammonia and hydrogen sulfide have other

sources, both natural and anthropogenic, their concentrations in the vicinity of farms will most likely be driven by the farm itself.

Ammonia is a by-product of the decay of urea, and is present around the urine of all animals. Ammonia is the most common basic (non-acid) gas present in the atmosphere, and as such is involved in the neutralization of acidic gases, such as sulfur and nitrogen oxides. The product of these atmospheric chemical reactions is aerosols which comprise a significant fraction of fine particulate matter (PM<sub>2.5</sub>). PM<sub>2.5</sub> is a major pollutant issue in Wisconsin and nationwide, causing regional haze and health related problems.

Additional environmental effects of ammonia include deposition to land and water, adding to excess nutrient loading which leads to algae blooms in water and contributing to the decline of native plant species on land through over-fertilization.

Nationwide, it is estimated that agriculture is responsible for 92% of ammonia emissions, through fertilizer applications and animal waste emissions. Wisconsin emission estimates for summer 2005 indicate that animal operations were responsible for about 88% of the agriculture related ammonia emissions. Control and reduction of these ammonia emissions therefore plays an important role in reducing regional PM<sub>2.5</sub> and haze issues.

Hydrogen sulfide is a product of the anaerobic decay of organic materials, which in the case of animal feeding operations is the manure. This gas has an extremely strong odor and can be perceived at extremely low concentrations, leading to quality of life issues, as well as being toxic at high concentrations. Based on work conducted directly around manure storage lagoons during the Conservation Innovation Grant (CIG study NRCS 68-3A75-5-157) conducted between 2006 and 2009, it was determined that hydrogen sulfide is not likely to be an NR445 issue at the property lines at most farms. As such, most sampling conducted during the current study is devoted to ammonia, with fewer hydrogen sulfide samples collected.

## **WORK PERFORMED**

### ***PROJECT DURATION***

The project planning commenced in February, 2010. Initially scheduled for completion in October, 2010, the monitoring portion of the project lost funding and was ended in early September, 2010. All monitoring was conducted between April 27 and September 10, 2010.

### **Project Action Plan and Timeline**

1. Initiation (February – April, 2010)

Upon initiation of the project, the search for participating farms began. The procedures and rationale for choosing farms is detailed in the methods section following.

2. Monitoring

Beginning in April 2010 and continuing into September, 2010 air monitoring was conducted around the test farms.

### 3. Data Analysis and Final Report Development

Data analysis and final report development commenced in September, 2010.

## ***PROJECT MANAGEMENT***

### **PROJECT TEAM BIOS**

**Bart Sponseller** is the Air Monitoring Section Chief in Madison, Wisconsin.

**David Grande** is the DNR lead worker on the project. Mr. Grande has a Bachelor's Degree in Chemistry from the University of Nebraska at Lincoln. He has worked in the air monitoring field for most of the past 25 years, including more than 15 years in his current position as a Toxic Air Monitoring Chemist. Notable projects include ammonia monitoring around a wastewater solids composting facility in western Wisconsin, and PCB monitoring during sediment remediation on the Fox River, as well as lead participation in the CIG Air Monitoring Study conducted with DATCP between 2005 and 2009.

## **METHODS**

### ***STUDY DESIGN AND LIMITATIONS***

#### **STUDY DESIGN:**

##### **Purpose:**

This study is driven by NR445, Wisconsin's air toxics rule, which regulates concentrations of hazardous air contaminants at the property line. The general purpose is to measure fence-line concentrations around a number of livestock operations for comparison with the ambient action concentrations defined in NR445, to determine how much of an issue these particular agricultural livestock facilities may present with respect to the existing regulation. No attempt is made to evaluate actual emissions from the farms, or to acquire data from which emission rates may be calculated.

##### **Other Studies:**

This project differs significantly from the CIG project DNR conducted with DATCP between 2006 and 2009, where concentrations around dairy manure lagoons were measured before and after different best management practices (BMPs) were installed, and from several studies underway on a national level, which are attempting to measure emissions from large farming operations.

One of these, conducted under the auspices of the US EPA (the National Air Emissions Monitoring Study NAEMS), is attempting to measure baseline emissions from barns and other area sources on farms, using a variety of real time instrumentation over the course of a 2-year study period. Concentrations for a number of parameters, as well as air flow measurements made at representative exhaust fans, are to be used to estimate air pollutant emissions. When the data becomes available, it is anticipated that the NAEMS will provide additional emissions information, supplementing existing emission factors used to estimate agricultural livestock emissions.

A second study performed in Wisconsin, sponsored by the USDA, attempted to measure whole farm emissions by using laser technology across transects downwind of the farm and extrapolating emissions from a combination of observed concentrations and meteorological information. In addition to requiring the use of specialized and delicate equipment, this type of test is extremely sensitive to ambient conditions, such that a sampling event covering 10 days may result in 4 or 5 days worth of usable data. While the data from this project is interesting, the extensive gaps within the data collected limit the utility of the results, since there is no information available on what was being emitted during missed periods.

## **The Current Study:**

The ideal sampling scenario for this type of work would be to conduct studies of greater than a year in duration around individual farms, with an array of continuous analyzers surrounding the subject farms. Use of continuous analyzers provides a means to capture peak values observed, as well as hourly, daily and annual averages. However, it would also require a significant investment of time and money, on the order of several hundred thousand dollars, that are not available to the Department at this time.

In an attempt to meet the Department's goal, a two-pronged approach to sampling was adopted. The primary sampling method employed is the passive method. An array of samplers was deployed around the property line at each farm in the study. These samplers were left in place for nominally a week (actual time varied from 6 – 10 days), after which they were exchanged for fresh samplers, and returned to the lab for processing and analysis. Each farm was sampled for 4 weekly periods. These passive samplers were for ammonia exclusively.

The study employed a passive method, whereby a sampling medium is exposed over a period of time by diffusion. These samplers are relatively inexpensive, and do not require a significant investment of time to deploy. However, they have the disadvantage of obtaining only an average concentration for their time of exposure, which needs to be at least a week to provide sufficient ammonia for analysis, so peak values and daily averages are not obtainable in this manner. In addition, it is not possible to obtain a calendar day concentration to make a direct comparison to the NR445 ambient action concentrations.

The second method employed was active sampling methods, where a small pump is used to draw a measured amount of air through an adsorbent medium to capture the ammonia. These methods are relatively inexpensive, but do require a significant amount of time. In addition, the method is limited to relatively short sampling periods (6-10 hours) limited by the life of the batteries used to power the pumps, and therefore do not capture daily averages, although peak values may be measured in theory.

Active sampling allows for determination of both ammonia and hydrogen sulfide. Samplers were deployed on the downwind side of the property, and run for periods ranging from 6 – 10 hours. Most of the farms had an ideal wind condition for this sampling (when downwind was to the property boundary closest to the animal housing or waste storage facilities), and thus these sampling trips were highly weather dependent. Up to 3 active sampling trips were conducted on each farm.

In addition to the separate methods for sample collection, use of a hand held hydrogen sulfide analyzer (Jerome Meter) was incorporated as well, to provide in the field real-time measurements. This analyzer is generally considered a survey instrument, providing backup data to compare to the concentrations obtained in the collected samples. Use of the Jerome Meter was generally limited to periods of active sampling.

## **LIMITATIONS:**

The Department's selection and use of these methods, rather than the more comprehensive means of deploying an array of continuous analyzers, was viewed as the best option available to obtain useable data given the limited project budget and time constraints. A significant limitation imposed by the sampling methods themselves is the inability to obtain a daily average to compare against the NR445 regulatory levels.

Another limitation of the study design is the relatively short time periods at each farm (about a month, all between late April and mid-September). Given the wide variability that can be expected to occur naturally at each farm during the course of a year (i.e., seasonality), these results do not guarantee representative measurements, although it is assumed that conditions in warmer temperatures will lead to higher concentrations than in winter. For ambient measurements, EPA typically requires a sampling frequency of once every three, six, or twelve days to ensure representativeness (120, 60, or 30 sampling events per year), or, in the case of passive style sampling, a program that extends across a full calendar year or more. Therefore, we are limited in our ability to compare measured concentrations against the NR445 annual concentration limits as well, and data representing the seasonal variations at any of the participating farms is not available.

An additional and perhaps more significant limitation to the study is the fact that a limited set of farms were approached for permission to monitor during this project, and that from these an even more limited set responded to the Department's request for permission to monitor. While these aspects are discussed further in the section following, the effect of them is to limit sampling to a very small set of operations which may not be representative of the full range of farms in the state.

A serious limitation arising from our farm selection process is that no very large operation (in excess of 3000 animals) within the geographic range of the study agreed to participate. Therefore, our data provides snapshots of what ammonia and hydrogen sulfide concentrations are around well-run, small to medium-sized CAFOs. Because of the limitations, this data should not be used to represent typical ambient conditions, nor should the results be used to extrapolate daily or annual average concentrations for the purposes of compliance with NR445.

In spite of these difficulties, this data set is unique in its scope. It does provide significant indications as to the generalized, broader impact of animal operations of the size included in the study with respect to ammonia and hydrogen sulfide concentrations at the fenceline. As long as care is taken with applying the data, some comparisons are possible between the different operations sampled, and some generalizations are possible from the data.

## ***FARM SELECTION PROCESS***

Farm selection for this project was constrained by budget and time available. These factors led to the desire to conduct measurements on farms within a 9-county area surrounding Dane and Dodge counties. Based on the assumption that larger operations would be more likely to create concentrations of concern relative to NR445, a list of all WPDS permitted livestock operations in Columbia, Dane, Dodge, Fond du Lac, Green, Jefferson, Ozaukee, Rock, Sauk and Washington counties, was obtained and reviewed. These farms typically have in excess of a 1000 animal units.

Each farm on this list was located using satellite mapping technology, and the general layout evaluated for ease of access to property lines. Following this basic determination, physical evaluation for monitoring suitability was conducted by exploring the area around each farm which was not immediately ruled out for lack of access. Significant topography or large woodlots around the farms fenceline were among the factors which were considered unsuitable for inclusion in the project. These features have significant impacts on local air movements, and can lead to non-representative data collection at the property line. Long travel times for monitoring staff were factored in as well.

This process led to a total of 22, mostly CAFO-sized, farms in Columbia, Dane, Dodge, Jefferson, Washington, Ozaukee, Fond du Lac, and Sauk counties which were then contacted via letter inviting participation in the project. Of the 22 farms, 17 were dairies, 2 poultry, 1 swine, 1 beef and 1 which has separate beef, swine and dairy facilities. Positive responses were obtained from 9 of these farms, including both poultry operations, the combination farm and 6 of the dairies. These farms provided more choices than our budget would allow monitoring for, so the search for additional farms was halted at that point to allow further evaluation of each of the responding farms.

As the budget allowed for only one poultry operation to be sampled, the choice of farm was obvious as both operations were of a similar size and one of the operations was significantly closer to Madison, the base of monitoring operations. Sampling began at that poultry farm while evaluation of the other farms was underway.

The layout of the combination farm placed significant distances between the different animals, which made it feasible to consider each of the different animal units as separate farms. However, the farm turned out to have a couple of separate beef units, which dispersed the animals too much to consider sampling around them, thereby leaving the project without a viable volunteer beef operation to monitor. After some deliberation, generally driven by budgetary and time constraints, the decision was made to eliminate the beef portion of the project rather than attempting to locate a suitable operation.

Similarly, the swine operation at the combination farm is relatively small with 449 animal units. In this case, however, several aspects of the operation made it suitable for sampling. Chief among these is the layout of the facility, which includes centralized housing and a relatively large storage lagoon, typical of much larger operations.

The combination farm's dairy operation was likewise on the small side for a Wisconsin CAFO (about 782 animal units), although it was not the smallest dairy which volunteered for the project. This farm offered a unique characteristic which made sampling around it very favorable. The area surrounding the dairy is separated into numerous small plots

separated by access lanes rather than large, continuous fields. This aspect of the farm, in combination with the recommendation made by a dairy farmer on the Department's Agricultural Waste BMP Advisory Group, led to sampling at different distances from the facility itself, which would provide information regarding concentrations at different setback distances, rather than simply at the property lines.

Therefore, the combination farm was sampled at both the swine and the dairy units. Because of the unique nature of the farm, with actual property boundaries up to 5 miles from the facility being sampled, a combination of actual and artificial property boundaries were used in deploying the samplers. The artificial property boundaries were set in such a way as to mimic the actual property lines a similarly sized operation might have. Figures depicting the property lines for purposes of the study are located in the Case Studies below as well as in the appendices.

The remaining dairies under consideration were numbered by the relative size of the operation based on the permitted level of animals, with the largest participating dairy designated Dairy 1, down to the smallest (Dairy 6). Attempts were made to visit each of these operations for a final evaluation, based on the layout of the operation, travel distance to the farm, size of the operation and odor characteristics. One farm (the largest based on permitted levels) did not respond to attempts to arrange a visit and was eventually dropped from consideration when budget cuts forced the project to end early, and a second farm (the largest actual farm, but second largest based on permits) dropped out after an evaluative visit.

Of the remaining four farms, each had characteristics making them desirable to sample. One of the farms is legally separated into the dairy only and the surrounding fields only, so that the actual property lines are very close to the housing and waste storage, thereby providing a potential worst case from the standpoint of setback distances. Another included a digester as well as very close property lines on three sides, while another had a public road running through the middle of the farm, thereby providing excellent access and a close boundary to the facility. The smallest farm, although less ideal from both size and access standpoints (only one boundary was close to the actual operation), feeds a ration with a high proportion of haylage that leaves the manure storage lagoon smelling sweet.

In the end, sampling was conducted on the 4<sup>th</sup> largest dairy (which had the best access), and an abbreviated sampling (2 weeks instead of 4) on the 3<sup>rd</sup> largest, before the project was terminated prematurely.

### ***LABORATORY SELECTION***

All samples collected for chemical analysis were submitted to the Wisconsin Occupational Health (WOHL) division of the State Laboratory of Hygiene located in Madison, Wisconsin. This lab is fully accredited by the American Industrial Hygiene Association for all aspects of industrial hygiene analysis, and has a long term working relationship with the DNR. In addition to providing sampling materials and analytical services, they provided the pumps used for the active air sampling.

### ***TECHNOLOGY SELECTION CRITERIA AND RATIONALE***

There are not specifically defined methods (e.g., US EPA Federal Reference Methods) required for the sampling performed in the course of this study, and as such, there is considerable latitude in the choices of equipment. In general, sampling equipment employed has been chosen because of its ready availability (equipment previously owned by the Department or borrowed from other institutions) and applicability to the sampling employed.

The exception to this is the passive sampling method employed. There are two main styles of passive sampling equipment suitable for use in this application, known by their primary manufacturers: Ogawa and Radiello. Both types of samplers provide similar results for ammonia. Prior to this study, DNR had not conducted passive sampling of this type. Because of this, the selection of either method employed involved the purchase of some equipment.

The Ogawa samplers have a slight advantage in terms of ease of use over the Radiello, but the Radiello has the potential to sample for both ammonia and hydrogen sulfide. Ogawa can only sample for ammonia. During consultation with WOHL personnel, however, it became apparent that the recommended analysis method for the hydrogen sulfide was one which the laboratory had tried in the past and discarded as being unreliable. Rather than attempting to develop an alternative analysis method for this parameter, the choice was made to go with the Ogawa passive samplers, allowing for passive sampling of ammonia only.

This choice was validated by the opportunity to expand upon the fence line only aspect of the study and include extra setbacks to help determine how quickly the ammonia dissipates after emission. This expansion was only possible within our budget constraints by the ability to borrow extra Ogawa samplers from UW Platteville, which would not have been possible with the Radiello samplers.

## FIELD EQUIPMENT

### Jerome Real-time Hydrogen Sulfide Meter

**Figure M-1**  
**Jerome Hydrogen Sulfide Meter**



Real time measurements of hydrogen sulfide are made using a Jerome Hydrogen Sulfide meter. This portable instrument provides near instantaneous measurements of hydrogen sulfide gas and is used in surveys around the property that are intended to help locate high concentration locations for samplers and to provide some information which can be used to help validate the time weighted average samples. The principle of operation involves measuring electrical potential across a gold foil, which changes as the quantity of hydrogen sulfide that the foil encounters changes. Display indicates hydrogen sulfide concentration in ppm, with a range from 0.001 – 50 ppm. This instrument was factory calibrated immediately prior to the projects inception. Typical use of the instrument would be during the days of active sampling, with up to three downwind surveys conducted on each of the days. While most data was collected at the property line, a limited amount was collected near significant emission sources as well.

## **Solar Powered Meteorological Station**

Meteorological information is collected using a portable solar powered met station. The met sensors are mounted on a 6 – 8 foot tripod, which is set up at a prominent point around the lagoons upon arrival at the site. Parameters include wind speed and direction, ambient temperature, relative humidity and solar radiation. Data is recorded on a fifteen-minute average basis.

**Figure M-2**  
**Solar Powered Meteorological Station**



### **Weather Shelters, Timers and other**

The sampling pumps employed in this study are intended for industrial hygiene sampling, the majority of which occurs indoors and is attended throughout. As such, they came without provisions for protection from weather. Samplers had been housed in plastic weather shelters constructed for this purpose. The picture below was taken during the CIG study, previously noted.

**Figure M-3  
Sampling Equipment Weather Shelter**



## ***SAMPLING METHODS & TESTING PROTOCOLS***

### **FIELD METHODS**

#### **Passive Samplers:**

Passive ammonia samples are collected using samplers designed by Ogawa. These samplers contain filter pads coated to react with ammonia and remove it from the atmosphere. They work through the principle of diffusion, whereby a predictable amount of air can be expected to pass over the filter pads in any given time unit.

#### **Active Samplers:**

Hydrogen sulfide and ammonia samples are collected using modified Occupational Safety and Health Organization (OSHA) methods. The basic methods involve sampling air by drawing it at a measured rate through adsorbent tubes, which are then submitted for analysis. Most samples are collected at a flow rate of about 0.5 liters per minute, for between 6 and 14 hours. As such, they represent time weighted average concentrations at each of the sampler locations.

Hydrogen sulfide is collected on charcoal tubes, desorbed using peroxide, which oxidizes the sulfide to sulfate, and then measured using ion chromatography. The adsorption onto the charcoal is a physical process, and can be reversed under adverse ambient conditions. These conditions can potentially include high humidity and heat.

Ammonia is collected onto carbon beads, which have been treated with sulfuric acid. The ammonia reacts with the sulfuric acid to form a chemical bond on the tube, which is then reversed in the lab. The resulting solution is then measured using ion chromatography. The chemical nature of the absorption makes these samples more stable to external conditions than the hydrogen sulfide samples.

### **SAMPLE CHAIN OF CUSTODY**

Sample records are maintained on a chain of custody form, which documents all pertinent field data necessary to determine sample validity and calculate air volume sampled. Following sample collection, all samples are sealed with end caps, placed in a sealed plastic bag with all other samples of the same type, and stored in a refrigerator until submission to the laboratory. Samples were generally submitted every other week, when a sufficient quantity permitting efficient use of lab resources had been collected.

### ***DATA ANALYTICAL METHODS***

#### **DATA PRESENTATION**

Meaningful representation of the data collected during this project proved to be challenging. Not only are the numeric concentration results important, but the spatial distribution of the samples and the wind conditions as well. Intercomparison between the different sampling episodes is essential. All of these elements are combined into a visual form using ArcMap software to plot the sample points, with the results presented both as proportional symbols associated with the points and as numeric values in a table. All

passive sampling locations were located using a global position system (GPS) unit to provide specific coordinates used in plotting the points.

Incorporating the wind rose plot directly into the figure enhances further data interpretation. A wind rose indicates the wind speed and direction during the sampling period. The color of the wind rose bars indicates the speed of the wind. The direction, in which the bars point, indicates the direction from where the wind was blowing. The length of the bar is measured against circular lines labeled with percentage values, which indicate what percentage of the time the wind was blowing from that direction.

The format of the sample locations numbers is designed to indicate on which farm the sampler is located. Note that sample location numbers with whole numbers are the passive sampler locations. Active sampling locations may include those, but will frequently include different locations between the passive samplers, in which case decimal values are used. For example: PF6 is the 6<sup>th</sup> passive sampler location set up on the Poultry Fenceline, and PF6.5 is an active sampling location about half way between PF6 and PF7.

The proportional symbols are scaled to the same values for each run within a single farm, so that sampling runs can be directly compared with each other visually. However, the differences found among the different farms are significant enough that each farm has its own scaling.

### **DATA COMPARISONS**

Direct quantitative comparisons between the different farms are not possible based on the gathered data, in part because of the limited number of sampling events at each farm. We did not collect a statistically significant quantity of samples from any single farm, much less from the whole spectrum of farms included in the project. This would have required sampling for at least a full year at each farm, which is beyond the means of the Department. We do not know whether we sampled during “typical” conditions at any particular farm. We were unable to assess potential seasonal differences due to the limited sampling period (i.e., 4 weeks per farm) This also led to the inability to comprehensively compare results among the farms.

Comparison of data between sampling visits and farms is desirable, even with these caveats, and as such an approach has been adopted wherein active sample concentrations observed on the downwind side of the farms are compiled for comparison between runs. These values are reported in tables and figures, with the maximum, minimum and average values shown for each individual active sampling run.

Each individual passive sample result is reported.

## **DISCRETE SAMPLE DATA MANAGEMENT AND BASIC CALCULATIONS**

All field samples collected for ammonia and hydrogen sulfide require a number of parameters to be recorded. The needs of passive and active samples are somewhat different, but both include unique identifying sample numbers, start and stop dates and times, and the exact location for field data. Active samples require beginning and ending flow rate values as well. In addition, the amount of ammonia or hydrogen sulfide collected and whether or not this amount represents a detect is required for the lab data.

All data collected for these samples is maintained in an Access database, set up with a number of built in calculations to facilitate data analysis. The basic concentration observed is calculated using the following equations:

$$\text{Elapsed Time (in minutes)} = (\text{Stop Date/Time}) - (\text{Start Date/Time})$$

### **For Passive Sampling:**

$$\text{Sample Concentration} = \alpha * [\text{Lab Result}] / [\text{Exposed Time}]$$

Where  $\alpha$  = conversion coefficient of concentration = 43.8 ppb min/ng @ 20°C

Lab Result is the reported lab value in  $\mu\text{g}/\text{sample}$

It should be noted that the conversion coefficient above is temperature dependent. All sample concentrations were calculated first using the 20°C value, and then using the average temperature of the run to determine the corrected values for comparison. The results of this evaluation indicated that all originally calculated values were within 10% of the more precise, corrected values. Because the values did not depart significantly, the simplified results using the generic conversion coefficient (43.8 ppb min/ $\mu\text{g}$  @ 20°C) have been reported and used in all subsequent evaluations.

### **For Active Sampling:**

$$\text{Average Sampling Rate (in Liters/Minute)} = ((\text{Start Rate}) + (\text{Stop Rate})) / 2$$

$$\text{Sample Volume (in m}^3\text{)} = ((\text{Elapsed time}) \times (\text{Average Sampling Rate})) / 1000$$

Note: The 1000 factor is to convert liters to cubic meters ( $\text{m}^3$ )

$$\text{Concentration (}\mu\text{g/m}^3\text{)} = (\text{Lab Result}) / (\text{Sample Volume})$$

Note: Lab Result is the reported lab value in  $\mu\text{g}/\text{sample}$

The resulting concentration values are used in further evaluation by incorporating them into site maps showing proportional symbols representing the results obtained at each location. These representations generate a visual aid to interpreting the results.

## **USE OF RAW LABORATORY VALUES**

A study of this nature involves detection of very small quantities of the target compounds. The laboratory doing the analysis may either run a series of tests designed to determine the Limit of Detection (LOD), which is the smallest quantity of the target compound which they can confidently state is indeed the compound of interest, or they may choose to pick a conservative value that they are sure of above this limit and only report values above this level.

WOHL uses a “reporting limit” for these tests, thereby avoiding the time and expense of specifically determining an actual LOD. The reporting limit is a value that the lab is confident is enough above the LOD that they have total confidence that what they are reporting is indeed the compound of interest, rather than an instrumental artifact.

In most cases, use of the reporting limit values is fine, because most of the samples in a particular set fall above the level, and those few which are below are relatively insignificant. During the course of this study, a significant number of samples returned analytical results which are below the laboratory reporting limit.

On one level, this poses no problem at all. The purpose of the study is to contrast the concentrations observed around the fence line with the ambient action concentrations listed for the compounds in NR445. A sample with results at the reporting limit for ammonia (5 µg for the passive samples), with a week long exposure time, represents a concentration of about 16.5 µg/m<sup>3</sup>, which is far below the NR445 listed action concentration of 418 µg/m<sup>3</sup>.

On another level, the presence of a significant quantity of values below the reporting limit causes problems, especially in the few cases where all samples collected around a facility return these values. In cases such as this, if only the reporting quantities are used to calculate concentrations, it then appears that the facility has no impact on local air conditions, which further implies there are no emissions from the facility. This situation does not provide a realistic picture of the effect the farm has on local ambient air conditions.

Because of the prevalence of non-reportable quantities detected in the samples from this study, combined with the consistently low values observed in blanks and good comparison of duplicate samples, the choice has been made to use raw values for reporting the passive sample concentrations. All concentrations calculated from raw values below the reporting limit are marked with an asterisk in the tables and figures.

A second effect of the large number of results below the reporting limit was the desire to obtain background samples from an area not directly impacted by agricultural operations for comparison. These samples were obtained at the Horicon air monitoring site, located on a peninsula in the Horicon Marsh, where a long term, regional sampling program for ammonia has been underway since the site was established in January, 2010. The purpose of collecting samples, instead of relying on the long term study, which are sampled using Radiello style samplers and analyzed at the Illinois Water Survey laboratory in Champaign, Illinois, was to ensure comparability of the background results with the farm samples.

It should be noted that the consistency and reliability of passive sampling results in this study which allow the use of raw laboratory analytical values is not true of the active sampling results. These samples showed a much higher tendency towards detectable blank values (especially for hydrogen sulfide), as well as a tendency towards more variability in the duplicate comparisons. As such, the decision was made to calculate these samples based on the laboratory reporting limits in the cases where results were below those values.

### **DATA QUALITY ANALYSIS, BLANK SAMPLES**

The collection of blank and duplicate samples for quality control purposes was an integral portion of the project. Blanks are samples prepared as though they were to be used for ambient sampling, except that they are not exposed to ambient air. They provide a measure of potential contamination encountered by the sampling media during the setup process, and thus are an indicator of potential problems.

Two types of blank samples were prepared as part of the passive sampling program; a preparation blank and a field blank. The preparation blank was prepared and packaged at the same time as the ambient samples, but it remained in the lab refrigerator in between. The field blanks accompanied the ambient samples to the field, where they were opened to the atmosphere for a short time (less than 1 minute) following the deployment of the ambient samples. This procedure was repeated during sample pickup. Active samples were accompanied by field blanks only.

The table below summarizes all blanks submitted during this project. In general, two blanks for passive samples were submitted for each sampling round. One blank for each parameter (hydrogen sulfide and ammonia) were submitted for each active sampling run. The preferred result for a blank is a non-detect. This table shows the number of blanks collected (approximately 6% of passive samples, 16.4% of hydrogen sulfide samples and 9.4% of active ammonia samples), how many of the blanks had detectable quantities of material on them and what percentage of the total that represents. In addition, the passive blank values show calculated air concentrations based on the time between preparation and packaging for the lab, for comparison with actual results obtained.

The maximum detected value in micrograms is shown, or, in the case of the passive samples, the measured value reported by the laboratory in  $\mu\text{g}$ . It is not particularly surprising that a significant percentage of the  $\text{H}_2\text{S}$  blanks returned detectable results, because the charcoal used as an absorbent contains a small amount of sulfur naturally.

The ammonia sampling tubes were generally clean, with the no values observed above the reporting limit of 7  $\mu\text{g}$ .

**Table M-1  
Blank Sample Results**

<b>Passive Samples</b>	<b>Total Blanks</b>	<b>Above Report Limit</b>	<b>% Above R. L.</b>	<b>Max (µg)</b>	<b>Avg (µg)</b>	<b>Max Calc (µg/m<sup>3</sup>)</b>	<b>Avg Calc (µg/m<sup>3</sup>)</b>
<b>Prep Blanks</b>	18	0	0.0%	0.81	0.27	2.1	0.7
<b>Field Blanks</b>	19	0	0.0%	1.6	0.79	5.0	2.4
<b>Active Samples</b>	<b>Total Blanks</b>	<b>Above Report Limit</b>	<b>% Above R. L.</b>	<b>Max (µg)</b>	<b>Avg (above R.L.)</b>		
<b>Ammonia</b>	12	0	0.0%				
<b>Hydrogen Sulfide</b>	10	8	80.0%	6.4	5.8		

**DATA QUALITY ANALYSIS, DUPLICATE SAMPLES**

Duplicate sampling is conducted by collecting two samples for the same parameter side by side for the purpose of comparing the results to determine an overall sampling precision. All passive sampler runs have at least one duplicate associated with them, but not all active sampling runs do. Ammonia duplicate samples were attempted during most runs, but because the preponderance of sampling conducted was for ammonia, few hydrogen sulfide duplicates were attempted, none of which was successful. A successful duplicate sample is obtained when both samples collected are deemed valid. Invalid samples may be caused by loss of sampling tubes, or pump & battery failures, among other reasons.

The pertinent quality parameter is the relative percent difference (RPD), which is the difference between the samples divided by the average of the results expressed as a percent. Ideally, this type of sampling should generate RPDs of less than 30%.

In cases where one or both samples return non-detects, the duplicates are considered to either qualitatively agree or disagree. Duplicate samples showing qualitative agreement are considered to have passed, but qualitative disagreement does not necessarily mean that the samples fail, as one sample can have a detectable quantity which is within 30% of the non-detect duplicate.

Results for successfully sampled duplicates are shown in the table below. The table shows the number of duplicate pairs analyzed, how many are in Qualitative Agreement (QA) or Disagreement (QD); how many pass or fail the numeric criteria (RPD < 30%), and then what the average, maximum and minimum RPDs are for each parameter. In addition, the percentage of duplicate pairs that are in each category (QA, QD, Pass or

Fail) is shown, as well as the average RPD for the active ammonia duplicates when the two samples, which failed, are excluded.

This analysis shows that when our duplicate sampling efforts were successful in the field (both samples submitted to the laboratory), the sample pairs passed quality assurance criteria 100% of the time for the passive ammonia samples and 81.8% of the time for the active ammonia samples. The overall RPDs of 6.5% and 28.9%, respectively, are within sampling criteria as well. With the two failing pairs excluded from the average RPD for the ammonia samples, this value drops to 8.9%.

The performance of the passive samplers in this analysis is better than that of the active samplers because of fewer points of failure. With the active samples, flow rate and the start and stop times are used to calculate sample volume, from which the lab results are converted into ambient concentrations. However, these values are only measured at the beginning and end of the sampling period, and there is no guarantee that the pumps performed equally well during the sample run. This inherent variability within the method probably gives rise to the larger discrepancies observed in the active samples. The passive sampling system is easier, as it is based on diffusion over the time the sampler was exposed to the atmosphere, so there is less inherent reason for variability in the method.

**Table M-2  
Duplicate Sample Results**

	Pairs	QA	QD	Pass	Fail	Avg RPD	Max RPD	Min RPD
<b>Passive</b>	18	4	2	18	0	6.5%	18.9%	0.0%
<b>%</b>		22.2%	11.1%	100%				
<b>NH3</b>	11	4	3	9	2	28.9%	141.6%	0.0%
		36.4%	27.3%	81.8%	18.2%	8.9%		

**METEOROLOGICAL DATA MANAGEMENT**

All meteorological parameters were collected on a data logger and downloaded to the central project database. The wind data is used to help decipher sampling results by enabling a determination of whether a particular sampling location was upwind or downwind of the different potential sources. Rather than averaging all wind data to generate a vector mean average wind speed and direction, each individual 15 minute average set of values is used to generate a wind rose using a freeware program developed by Lakes Environmental, known as WRPlot.

Each individual sample run, both the week long passive runs and the much shorter active sampling runs, has a unique wind rose containing all 15-minute data points from the inception of sampling to the collection of the final sampler. The wind roses generated from this data are included on the site map results representations to improve the effectiveness of the display.

## ***NON-AGRICULTURAL BACKGROUND SAMPLE RESULTS***

During the course of the study, the large number of low concentration samples obtained led to an interest in determining what background concentrations of ammonia are present away from agricultural livestock operations. A series of 3 samples were collected in late August, 2010, at the Horicon Air Monitoring Station located in the Horicon State Wildlife Refuge.

One of these samples was collected over a period of 2 weeks, to allow comparison with a separate sampling effort at the site, while the other two were collected for a week each during the same two week period. Data from these background samples is reported in the table below. It is important to note that none of the samples collected sufficient ammonia to be above the laboratory reporting level, so all data in the study is subject to greater uncertainty.

**Table M-3**  
**Non-Agricultural Background Sample Results**

<b>Date</b>	<b>Days</b>	<b>µg/sample</b>	<b>µg/m<sup>3</sup></b>
<b>08/17/2010</b>	14.4	2.5	4.0
<b>08/17/2010</b>	7.0	1.5	5.0
<b>08/24/2010</b>	7.4	1.7	5.3

It is not clear why the two week sample provides a result which is 20% or more below the corresponding weekly samples. This could be an artifact of the sampling method, but could equally well be an issue derived from dealing with values below the analytical reporting limit. In any case, the two individual weekly values provide consistent results, indicating that a concentration of around 5 µg/m<sup>3</sup> is a realistic background level in an area not significantly affected by agricultural operations. The values observed in our study are consistent with those collected as part of a long-term regional ammonia sampling effort conducted in part within Wisconsin, where values range from about 0.5 – 4.5 µg/m<sup>3</sup> over the course of the year.

For comparison purposes, an overall evaluation of all passive results obtained from the study was made with respect to the number of samples, the number of samples below reporting limits, and then further, to evaluate the observed concentrations when calculated with the measured values below the reporting limits in comparison with the background levels obtained from the Horicon site.

A total of 272 passive samples around farms were collected during the course of this study. Of these, 139 (51.1%) were below the laboratory reporting limits of 5 µg per sample, which translates to less than about 16 µg/m<sup>3</sup> for a week long sample. Using the raw measured values to calculate concentrations observed yields results which show that 4 of the samples (1.5%) were less than 6 µg/m<sup>3</sup>; 56 (20.6%) were between 6 and 10 µg/m<sup>3</sup>; and 79 (29.0%) were between 10 and 15 µg/m<sup>3</sup>. Therefore, even among the values below the reporting limit, most of the results were at least twice the observed background.

## **RESULTS**

### ***CASE STUDIES: FIVE PARTICIPATING FARMS***

#### **OVERVIEW**

The five farms used in this study were selected based on their size, animal type, and their layouts, which made them good candidates for air monitoring. These farms ranged in size from 450 animal units (swine) to over 12,100 animal units (poultry). The dairy farms in the study ranged from about 750 to 1500 animal units.

Each of the farms employed different manure management practices, which provides a representative mixture of the practices employed in Wisconsin.

#### **GENERAL CASE STUDY FORMAT**

Data from each study is examined in detail in the following sections. The basic format of the examination provides a general background explanation of the farm and what the testing was intended to measure, followed by a discussion of the results. Results are presented visually in graphics, most of which are contained within the appendices. This material is provided separately so that those who wish may refer to both documents at the same time.

Each of the discussion sections is divided into:

- a General Overview, which provides a description of the farm and an outline of the sampling that occurred on it;
- a section on Passive Sampling, wherein the results of most ammonia samples are discussed and
- a section on Active Sampling, which presents the results of limited sampling trips for ammonia and hydrogen sulfide.
- The final section for each study is a summary of key findings, where any conclusions that may be drawn from the data are presented.

Each set of results has a number of figures associated with it. These figures are aerial plots of each farm, with sampling locations and results associated with them combined. In addition, each figure includes a wind rose showing the winds present during the sampling period, and a table of the numeric results. The first figure in each appendix contains descriptors that demonstrate how to interpret it.

Separate figures for each passive and active sampling period have been generated, as well as a comparison figure documenting all four weeks of passive sampling. The passive sample figures show the same points reported in the case study tables, while the active samples are only summarized in the tables. All valid active samples are shown in the figures. These figures are combined into a separate Appendix file to save space in the report itself.

It should be noted that the majority of the discussion regarding ammonia and hydrogen sulfide results is based on the time integrated samples collected at the site, whether the samples were collected passively over a week, or actively over the course of 6 – 10 hours.

The limited readings collected on a real-time basis for hydrogen sulfide using the Jerome meter are only brought into the discussion when the measurements help clarify results of the ambient sampling. The real-time survey results are not comprehensively reported herein.

Following the case studies is a comparison section wherein the chemical data that can be compared is discussed. Not all of the results are readily comparable among the different facilities.

Table CS-1 below documents the farms which participated in the studies, with the case study name, animal units, dates of sampling, and how many rounds of passive and active sampling were conducted on each.

**Table CS-1: Participating Farms**

<b>Case Study</b>	<b>Animal Units</b>	<b>Start Date</b>	<b>End Date</b>	<b>Passive Sampling Rounds</b>	<b>Active Sampling Trips</b>
<b>Poultry</b>	10,655	April 27	May 25	4	3
<b>Dairy 2</b>	2,195	August 26	September 10	2	2
<b>Dairy 4</b>	1,875	June 1	June 30	4	3
<b>Dairy Setback</b>	782	July 6	August 5	4	3
<b>Swine</b>	449	July 6	August 10	4	2

## ***CASE STUDY 1: POULTRY***

### **BACKGROUND**

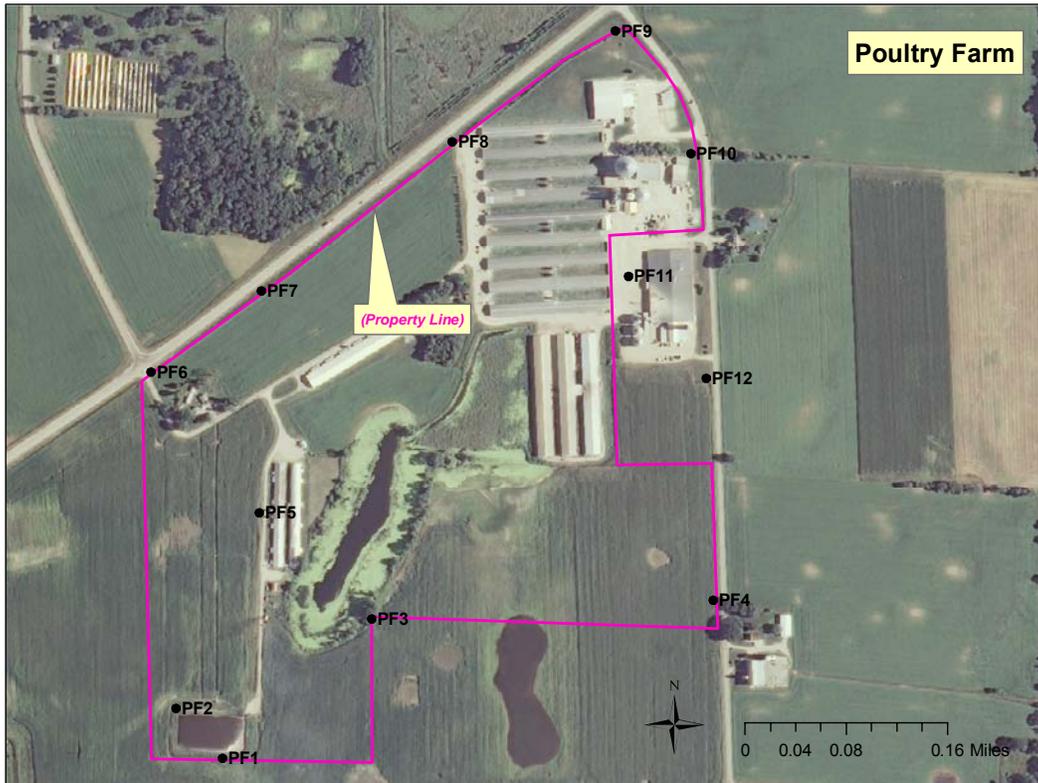
Large poultry operations are relatively scarce in Wisconsin, with 9 chicken, 1 duck and 2 turkey operations possessing WPDES permits. The farm chosen for the study is an egg laying operation consisting of 9 parallel barns for laying hens, 3 pullet barns and an egg processing facility. An average of about 914,000 laying hens and 303,000 pullets were on site during the weeks of testing. Animals were fed a ration of about 17.3% crude protein during this time.

Poultry manure is removed from the barns by conveyor belts and loaded onto manure spreaders which transport the manure to a composting facility consisting of 3 barns located next to the southern-most laying barn. The manure is dried and composted before being packaged for sale off site as a fertilizer. Eggs are transported to the processing facility using a rod conveyor. Wash water used in the processing is hauled to a small waste lagoon occupying about an acre at the southern end of the property.

The figure on the following page shows an aerial view of the farm, with passive sampling locations marked. Significant features in the figure include the laying barns, oriented east to west near the north east portion of the property, the three manure processing barns located just south of the laying barns, and the pullet barns, one of which is directly west of the southern most laying barn, with the other two parallel to each other somewhat to the west and south of the first. The facility to the east of the laying barns is a pet food manufacturer with no known ammonia or hydrogen sulfide emissions.

Note that not all sampling locations are on the property lines. In the case of PF2 and PF5, the actual western property boundary was in the middle of an active corn field and generally not practical for monitoring purposes. In the case of PF11, the actual boundary occurs in the middle of a wide driveway between the laying barns and the neighboring facility, and PF12 was accidentally placed on the neighboring property after misreading the parcel map and assuming that the southern driveway marked the extent of the property.

Figure L-1: Poultry Farm Layout



## PASSIVE SAMPLING

Passive sampling on the poultry farm began on April 27, 2010 and continued through May 25, 2010. Each passive sampler was exposed for a week. During this time, a total of 60 samples were collected, including 48 ambient samples, 4 duplicates, 4 field blanks and 4 preparation blanks. There were no issues encountered which prevented or invalidated any of these samples.

Results of the ambient samples are documented in the table below. Concentrations are in micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). Note that these concentrations represent weekly average values. Asterisks denote values calculated from results below the lab reporting limit.

**Table R-1: Passive Ammonia Sample Results, Poultry ( $\mu\text{g}/\text{m}^3$ )**

Location	04/27/2010	05/04/2010	05/12/2010	05/18/2010
PF1	14.0*	24.7	29.3	25.2
PF2	39.2	19.7	23.5	86.6
PF3	13.4*	13.5*	27.0	17.4
PF4	14.7*	15.3	8.1*	11.3*
PF5	36.2	41.2	88.6	132.1
PF6	13.5*	25.9	15.8*	23.3
PF7	15.4*	22.4	22.7	42.1
PF8	82.2	70.7	77.1	136.0
PF9	75.6	12.7*	11.6*	18.1
PF10	59.3	29.4	21.6	16.9
PF11	178.6	123.6	115.6	109.7
PF12	36.4	41.2	35.8	35.6

Three sampling sites returned results of greater than  $100 \mu\text{g}/\text{m}^3$  at least once during the study period: PF5, across the lane from the pullet barns; PF8, near the north-west end of the layer barns; and PF11 located between the layer barns and the neighboring facility. PF11 was consistently above  $100 \mu\text{g}/\text{m}^3$  during the sampling, which, given its proximity to the laying barns, the composting barns and the loading facilities for composted manure, is not surprising. This particular location is not one a member of the general public would typically access, as it is inside a gated area. The location was included in the study because it is technically on a neighboring parcel.

## ACTIVE SAMPLING

The orientation of this farm makes for the best sampling to be conducted during periods of southerly winds. Active sampling for ammonia and hydrogen sulfide was conducted three times during the project, on May 4<sup>th</sup>, 24<sup>th</sup> and 25<sup>th</sup>. Sampling was conducted solely on the downwind property line. On May 4<sup>th</sup> and 24<sup>th</sup>, winds were mostly out of the south, while on the 25<sup>th</sup> the winds contained a strong westerly component.

Table R-2 on the following page summarizes all valid results from the active sampling. Values shown include averages, maxima and minima, as well as the number of detects and samples, with the corresponding detection rate. Summation calculations are

evaluated at the laboratory reporting limit, and values with a “<” symbol represent results below this limit. Note that differences in these “<” results is derived from the volume of air sampled. Ammonia results from each sampling episode are reported separately. No hydrogen sulfide was detected in any of the active samples collected around this farm, so results from all episodes are reported on a single line.

It should be noted that samples from the first run at this location have generally higher detection limits than those of the remainder of the project. At that point, actual conditions required to obtain good samples were still being determined, and lower sampling rates were employed. Subsequent runs on this and the other farms employed higher sampling rates, which lead to lower detection limits.

**Table R-2: Poultry Active Sampling Results ( $\mu\text{g}/\text{m}^3$ )**

Ammonia	Average	Max	Min	Detects	Samples	Detection Rate
05/04/2010	70.1	105.6	<48	6	10	60%
05/24/2010	103.5	632.0	<14	3	9	33%
05/25/2010	54.2	164.0	12.6	7	10	70%
H2S	<19	<40	<8	0	9	0%

Ammonia samples with results above  $100 \mu\text{g}/\text{m}^3$  were observed during each sampling episode, with a total of four separate samples in this category. During the first run, location PF10 showed the highest value, while in the second and third runs, the highest location was active location PF8.2 which was situated at the nearest approach of the fenceline to an exhaust fan on a laying barn.

Note that the maximum result obtained on 5/24 exceeds the 24 hour NR445 ambient action concentration for ammonia. This sample is the highest observed at any of the farms during this study. It should be noted, however, that the sample as collected does not correspond directly to a 24 hour average value because sampling occurred for about 6 hours, and that monitoring is not regarded as a method for compliance with the standards in any case.

**CASE STUDY 1 KEY FINDINGS SUMMARY STATEMENTS**

Results from this case study indicate that the area around PF11, located in between the pet food factory and the poultry barns, is a candidate to potentially exceed the annual average ambient action concentration for ammonia ( $100 \mu\text{g}/\text{m}^3$ ), as every weekly sample collected in this area exceeded this value.

While the only property line sample in this study to exceed the ammonia daily ambient action concentration ( $418 \mu\text{g}/\text{m}^3$ ) was obtained at this farm, it should be noted that this merely indicates the possibility that the NR445 ambient action concentration could be exceeded at this facility, not that it has been. The sample in question was of about 6 hours in duration, and thus not directly comparable to the standard.

The low hydrogen sulfide results were corroborated by the instantaneous Jerome meter findings, which showed a very slight elevation above background all along the downwind side of the property. No particular hot-spots for this compound were found.

## ***CASE STUDY 2: DAIRY 4***

### **BACKGROUND**

Dairy 4 was the fourth largest of the dairies, which originally chose to volunteer for the study, with a permitted level of 1270 animal units at the inception of the project. Their permit was renewed on July 1, 2010, for a current level of 1817 animal units.

This operation is somewhat unique for several reasons. First, from a monitoring standpoint, the farm is ideal, with close public road access on all four sides of the dairy barns. While the family, which owns and operates the dairy, owns significantly more land to the south, north and west, the presence of a public road through the middle of the operation makes NR445 property limits applicable at this point. All adult cows, milking and dry, are housed in the barns near the center of the figure on the following page, while steers and heifers are housed south of the road near the eastern edge of the figure.

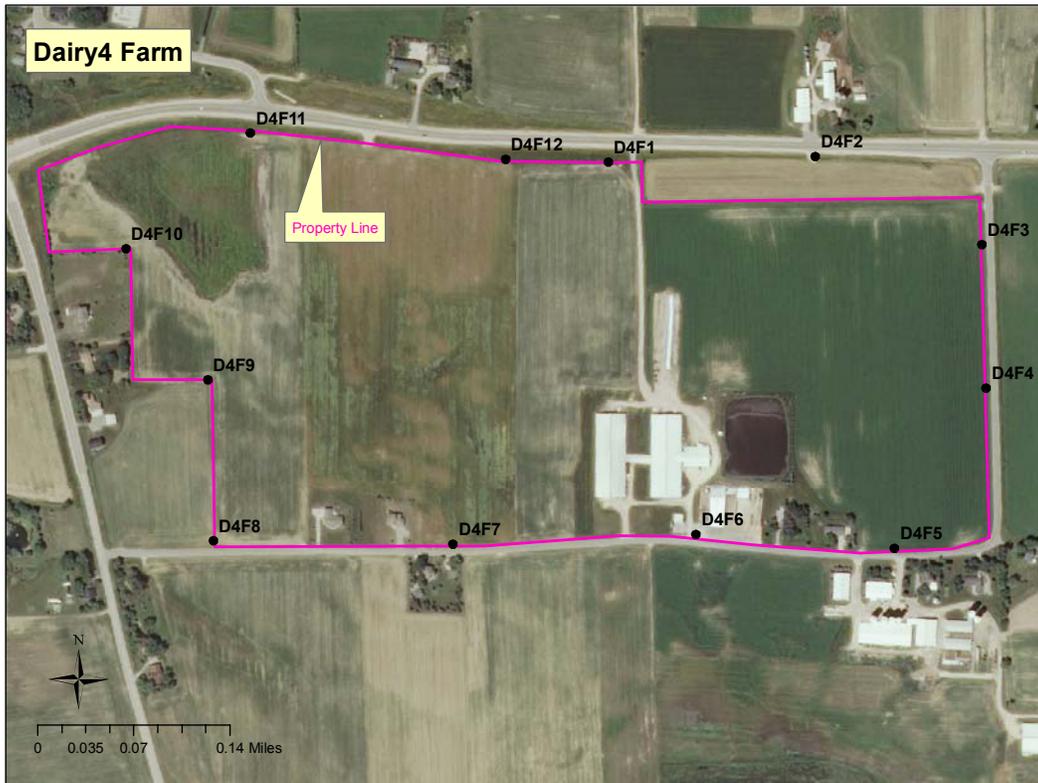
The dairy consists of 2 barns. The western most barn uses rubber mattresses, bedded with rice or oat hulls for bedding and rubber flooring. This barn has a slatted floor and 3.3 million gallon under-floor manure storage. The eastern barn uses sand bedding with a flush system to remove manure and soiled bedding. The southern barn flushes (the barn that is in the figure on the following page) while the northern part of the east barn uses mechanical scraping to remove the manure and sand bedding. (These features are not present in the figure on the following page).

All barn flush water is directed to a dual lane sand channel located to the west of the under-floor storage barn, which separates the sand from the manure. Sand is stacked and reused after it has been cleaned. After which the water and manure enter a 4.7 million gallon concrete storage lagoon to the northwest of the sand channel. (These features are not present in the figure on the following page). Water from the west lagoon is pumped to another 4.7 million gallon east lagoon, from which the barn flush water is drawn. Manure is hauled once per year in the fall. The manure of the heifers and steers on the south side of the road is hauled every six months. All manure is applied according to our NMP plan.

During the study, there were 850 milking and dry cows on site, as well as 1050 young stock and steers. Rations are generally 50% hay and 50% corn silage for the forages, and high moisture shelled corn mixed with dry corn. Wet distiller's grain is in the mix for the milking cows. Dry cows are fed all forages with low potassium, straw or marsh grass. Rations ranged from about 13 – 18% crude protein, based on the state of the cow (dry, production, heifer, etc). Nitrogen content varied from 2.1 – 2.9%, and sulfur content varied from 0.2 – 0.29%. Under this feed regime, a daily average production of 90 pounds milk per cow is achieved.

The figure on the following page shows an aerial view of the farm, with passive sampling locations marked. Note that location D4F2 is not actually on the property line, but is mistakenly on a neighboring parcel. Also note that distances from the heart of the operation to the property line vary significantly, depending on the direction.

Figure L-2: Dairy 4 Farm Layout



## PASSIVE SAMPLING

Passive sampling began on June 1, 2010 and continued through June 30, 2010. Each sampler was exposed for a week. During this time, a total of 63 samples was collected, including 48 ambient samples, 7 duplicates, 4 field blanks and 4 preparation blanks. One sample was invalidated, when the sampler was found on the ground at the time of collection.

Results of the ambient samples are documented in the table below. Concentrations are in micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). Asterisks denote values calculated from results below the lab reporting limit. Note that the empty place in the table indicates the above mentioned invalid sample.

**Table R-3: Passive Ammonia Sample Results, Dairy 4 ( $\mu\text{g}/\text{m}^3$ )**

Location	06/01/2010	06/09/2010	06/17/2010	06/23/2010
D4F1	23.9	12.1*	19.8*	17.8
D4F2	21.1	11.9*	23.4	17.5
D4F3	21.3	10.9*	20.2	12.6*
D4F4	22.7	13.8*	19.4*	17.8
D4F5	31.6	31.7	34.5	33.0
D4F6	57.5	77.9	43.6	46.3
D4F7	16.4	19.6	11.1*	20.2
D4F8	10.4*	11.5*		7.9*
D4F9	12.7*	11.7*	10.7*	8.9*
D4F10	10.1*	11.2*	9.9*	7.9*
D4F11	15.3	8.9*	11.9*	7.9*
D4F12	21.1	11.8*	21.4	15.2*

No weekly average concentrations exceeded  $100 \mu\text{g}/\text{m}^3$  at this facility during the study. The highest observed values were obtained from location D4F6 each week. This site was located at the junction of the driveway to the milking parlors and barns and the public road, and was by far the site closest to the operation.

## ACTIVE SAMPLING

Theoretically, the orientation of this farm allows sampling with winds from any direction, although northerly winds (i.e., winds from the north) provide samples with the least distance to the barns and waste handling systems. Active sampling for ammonia and hydrogen sulfide was conducted three times during the project, on June 9<sup>th</sup>, 17<sup>th</sup> and 24<sup>th</sup>. Winds were significantly different during each sampling episode, and therefore, entirely different sampling locations were used during each. Active sampling was conducted solely on the downwind property line.

Table R-4 on the following page summarizes all valid results from the active sampling. Values shown include averages, maxima and minima, as well as the number of detects and samples, with the corresponding detection rate. Summation calculations are evaluated at the laboratory reporting limit, and values with a "<" symbol represent results

below this limit. Note that differences in these “<” results is derived from the volume of air sampled. Ammonia results are reported separately for each sampling episode. Hydrogen sulfide results are combined for the first two episodes, and separated for the final sampling run.

**Table R-4: Active Sampling Results, Dairy 4 ( $\mu\text{g}/\text{m}^3$ )**

<b>Ammonia</b>	<b>Average</b>	<b>Max</b>	<b>Min</b>	<b>Detects</b>	<b>Samples</b>	<b>Detection Rate</b>
<b>06/09/2010</b>	<14	<32	<10	1	9	11%
<b>06/17/2010</b>	<13	27.7	<10	2	9	22%
<b>06/24/2010</b>	47.6	113.5	<9	8	9	89%
<b>Hydrogen Sulfide</b>						
<b>6/9 &amp; 6/17</b>	<6	<7	5.5	1	4	25%
<b>06/24/2010</b>	<15	25.6	<5	2	4	50%

On June 9<sup>th</sup>, winds were from the west-southwest, and sampling was set-up along the roadway to the east. On June 17<sup>th</sup>, winds were southerly and sampling was set-up along the northern property boundary. On June 24<sup>th</sup>, winds were from the northwest, with samplers set-up along the southern roadway. The distance to the barns and lagoons was a half or less on June 24<sup>th</sup> relative to the other two sampling days.

The ammonia results we see on these days demonstrate the effect of set-back distances, with very few detectable quantities obtained on the first two sampling days, while on the final sampling day, a much higher rate of detection, as well as higher overall maximum concentrations of ammonia were observed.

Hydrogen sulfide results are similarly affected by proximity to the barns and lagoons, with the highest results and detection rate obtained on the third sampling day. Note that from the first two sampling days, the sample with a reportable quantity of hydrogen sulfide collected is actually the lowest result. This is a factor of more air volume being collected than with the other samples in these runs.

The hydrogen sulfide results were supported by Jerome surveys. Little to no H<sub>2</sub>S was observed along the northern and eastern boundaries of the farm, but a much stronger signal was detected along the southern edge with winds from the north. On the final active sampling day, source areas close to the road including the sand channel outfall and the slatted floor barn were surveyed to estimate strength of the plume at the source. Values in excess of 1000 ppb (1500  $\mu\text{g}/\text{m}^3$ ) were observed above the sand channel outfall, while the highest instantaneous values along the nearest downwind road were less than 10% of this value. Values observed near the barn were below 50 ppb.

### **CASE STUDY 2 KEY FINDINGS SUMMARY STATEMENTS**

By allowing ready access for monitoring on multiple sides at different distances from the source areas, this location provided a clear illustration of the effect setbacks can have. Samples collected along the northern boundary were about 6 times as far to the nearest barn as the samples collected along the southern boundary, and showed a much lower rate of detection and overall concentration of ammonia and hydrogen sulfide. In addition, the sand channel was confirmed as a significant source of H<sub>2</sub>S.

## ***CASE STUDY 3: DAIRY 2***

### **BACKGROUND**

Dairy 2 was the second largest of the dairies which remained among the volunteer farms by the end of the study, with a permitted level of about 2200 animal units at the inception of the project. This farm includes a number of satellite operations away from the main site. The main location, where the study occurred, includes the dairy, and feed mixing operations for all operations. This site housed 1450 milking cows and 150 prefresh cows and heifers. The milking animals on this site were fed a ration of 17% crude protein and had a milk production average of 78 lb per cow during the summer month of this study.

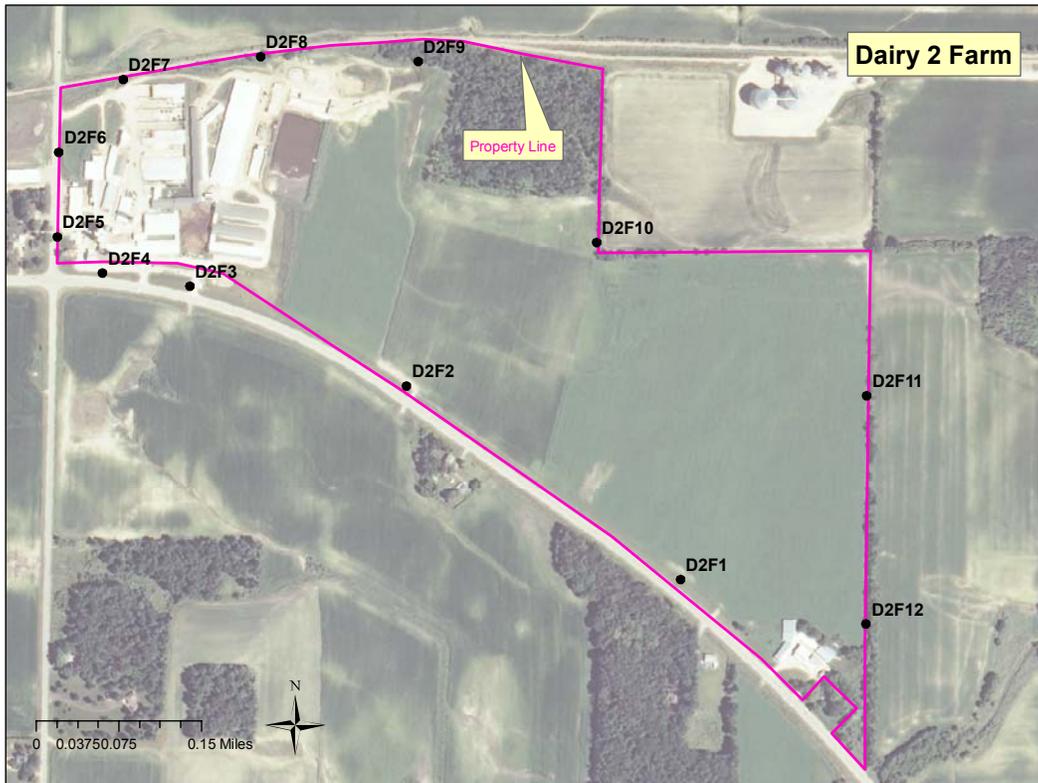
The dairy consists of five barns arrayed around a concrete waste storage that is 160 ft by 230 ft, as well as two additional barns extending in a line to the north. A portion of this barn area consists of pit under barn, 110 ft by 270 ft. To the east of these two barns is a lagoon that is 200 ft by 400 ft. The majority of the barns are bedded with separated solids on a mattress system and the rest of the barns are bedded deep bed with separated solids, which includes the prefresh and calving area on the west side of the site. All the barns, except the prefresh ones, are scraped three times a day by a skid steer or alley scraper at milking time.

All barn and dairy center waste is directed to an in-ground mesophilic manure digester, which fuels a generator. These features are at the northeastern end of the facility. Digestate post digestion and separation process is sent to the outside concrete waste storage which serves as the first stage storage. The existing lagoon east of the barns serves as second stage storage following all processes. A new, larger, storage lagoon, currently under construction, will be 350 ft by 380 ft and will serve as third stage storage.

It should be noted that the meteorological station (co-located with D2F1) was inadvertently situated in a less than ideal position during this case study (note the density of the wood lot in the figure). This fact came to light during the first active sampling run, during which there was a strong southerly wind. It was noted that the wind vane was responding erratically, and the wind speed indicators barely moving in spite of a strong wind. Information available on the web from the Dane County airport located about 10 miles away was used in place of the on-site data. While it appears that D2F2 would have been a better location for the weather station, locating it here was not possible because of construction activity in that area.

The figure on the following page shows an aerial view of the farm, with passive sampling locations marked. Note that several locations are not actually on the property line. These include locations D2F9, which is set just inside the property line on the inside of a thin wood lot; and D2F3 and D2F4 which are located just off the property on the highway right-of-way.

Figure L-3: Dairy 2 Farm Layout



## PASSIVE SAMPLING

Passive sampling began on August 26, 2010 and continued through September 10, 2010. Each sampler was exposed for a week. During this time, a total of 30 samples were collected, including 24 ambient samples, 2 duplicates, 2 field blanks and 2 preparation blanks.

Results of the ambient samples are documented in the table below. Concentrations are in micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). Asterisks denote values calculated from results below lab reporting limit.

**Table R-5: Passive Ammonia Sample Results, Dairy 2 ( $\mu\text{g}/\text{m}^3$ )**

<b>Location</b>	<b>08/26/2010</b>	<b>09/03/2010</b>
<b>D2F1</b>	13.9*	7.6*
<b>D2F2</b>	68.1	11.4*
<b>D2F3</b>	14.2*	53.5
<b>D2F4</b>	12.5*	46.8
<b>D2F5</b>	10.5*	22.1
<b>D2F6</b>	11.4*	27.4
<b>D2F7</b>	79.6	25.8
<b>D2F8</b>	256.1	50.2
<b>D2F9</b>	24.2	14.7*
<b>D2F10</b>	22.9	9.0*
<b>D2F11</b>	21.2	7.0*
<b>D2F12</b>	23.8	13.3*

Much of this farm is quite compact, with boundaries located within a tenth of a mile from the center of the operation, and barns extending nearly to the boundaries. Samplers D2F3 through D2F9 were located along these close boundaries, while the remaining samplers were most distant along the southern and eastern edges. The highest and only value to exceed  $100 \mu\text{g}/\text{m}^3$  was observed at D2F8, located closely to the north of the barns, generator building and digester.

It should be noted that the result from the first week at location D2F2 ( $68.1 \mu\text{g}/\text{m}^3$ ) is somewhat inexplicable. Given that the winds that week were almost exclusively from the south east, this value most likely does not represent an impact of the facility being sampled. Similarly, the results from D2F9 – D2F12 may indicate another ammonia source in the neighborhood.

## ACTIVE SAMPLING

Theoretically, the orientation of this farm allows sampling with winds from most directions, although westerly and north-westerly winds are undesirable given the long stretch to the eastern property lines. Active sampling for ammonia and hydrogen sulfide was conducted twice during the project, on August 31<sup>st</sup> and September 9<sup>th</sup>. Winds were significantly different during each sampling episode, and some different sampling

locations were used during each. Active sampling was conducted solely on the downwind property line.

Table R-6 on the following page summarizes all valid results from the active sampling. Values shown include averages, maxima and minima, as well as the number of detects and samples, with the corresponding detection rate. Summation calculations are evaluated at the laboratory reporting limit, and values with a “<” symbol represent results below this limit. Note that differences in these “<” results is derived from the volume of air sampled. Both ammonia and hydrogen sulfide results are reported separately for each sampling episode.

**Table R-6: Active Sampling Results, Dairy 2 ( $\mu\text{g}/\text{m}^3$ )**

<b>Ammonia</b>	<b>Average</b>	<b>Max</b>	<b>Min</b>	<b>Detects</b>	<b>Samples</b>	<b>Detection Rate</b>
<b>08/31/2010</b>	76.2	254.8	<9	4	6	67%
<b>09/09/2010</b>	44.0	89.7	<15	3	6	50%
<b>Hydrogen Sulfide</b>						
<b>08/31/2010</b>	40.6	174.4	<6	3	6	50%
<b>09/09/2010</b>	<11	<18	<8	0	6	0%

Winds on 8/31 were from the southeast, which provided the minimum distance from the generator and some of the barns, while winds on September 9<sup>th</sup> were generally north-easterly. Note that the maximum ammonia value observed on 8/31/2010 was obtained at the same location and is about the same magnitude as the passive sample from that week (D2F8, 256.1  $\mu\text{g}/\text{m}^3$  passive versus 254.8  $\mu\text{g}/\text{m}^3$  active).

In addition, notice the maximum hydrogen sulfide value obtained on 8/31. This value (174.4  $\mu\text{g}/\text{m}^3$ ) is the highest observed during this study. Jerome surveys were conducted which traced the origin of the high concentration at this location to the generator/seperator building where the biogas evolved from the waste in the digester is burned to generate electricity and the liquids have the solids separated for use as bedding. In this case, the generator/seperator building is behaving as a point source for hydrogen sulfide.

### **CASE STUDY 3 KEY FINDINGS SUMMARY STATEMENT**

Although some high values were observed during this case study, both for ammonia and hydrogen sulfide, there were no results observed above the 24 hour ambient action concentrations defined in NR445. The highest ammonia concentration site averages above 100  $\mu\text{g}/\text{m}^3$  (the annual average action concentration) during the two weeks of the study, and this indicates the potential for concentrations above this level to be generated on an annual basis. It should be noted, however, that two weeks worth of data is not sufficient to determine whether or not this level is likely to be exceeded.

A pertinent conclusion to draw from this case study is that manure digesters, solids separators and generator sets may serve as point sources of hydrogen sulfide. Relatively high concentrations of this gas may leave the property and become an issue with neighbors.

## ***CASE STUDY 4: DAIRY SETBACK***

### **BACKGROUND**

The Dairy Setback project occurred on the smallest permitted farm among the volunteers. This farm is a research facility with a variety of feeding and cropping regimes, such that the dairy barn is surrounded by a number of small field plots separated by access lanes. This arrangement allowed for locating samplers at a variety of different distances from the barn and waste storage lagoon, thereby allowing exploration of the effect distance has on dispersion.

A second variance between this case study and the overall project design parameters resulted from the very large area the overall farm covers. The NR445 relevant boundaries of the farm are a mile from east to west, and so the eastern and western property boundaries were not used. While the northern and southern study boundaries were the NR445 relevant roads, the eastern and western study boundaries were inside of the actual boundaries. The overall area enclosed by the study boundaries is about 160 – 180 acres.

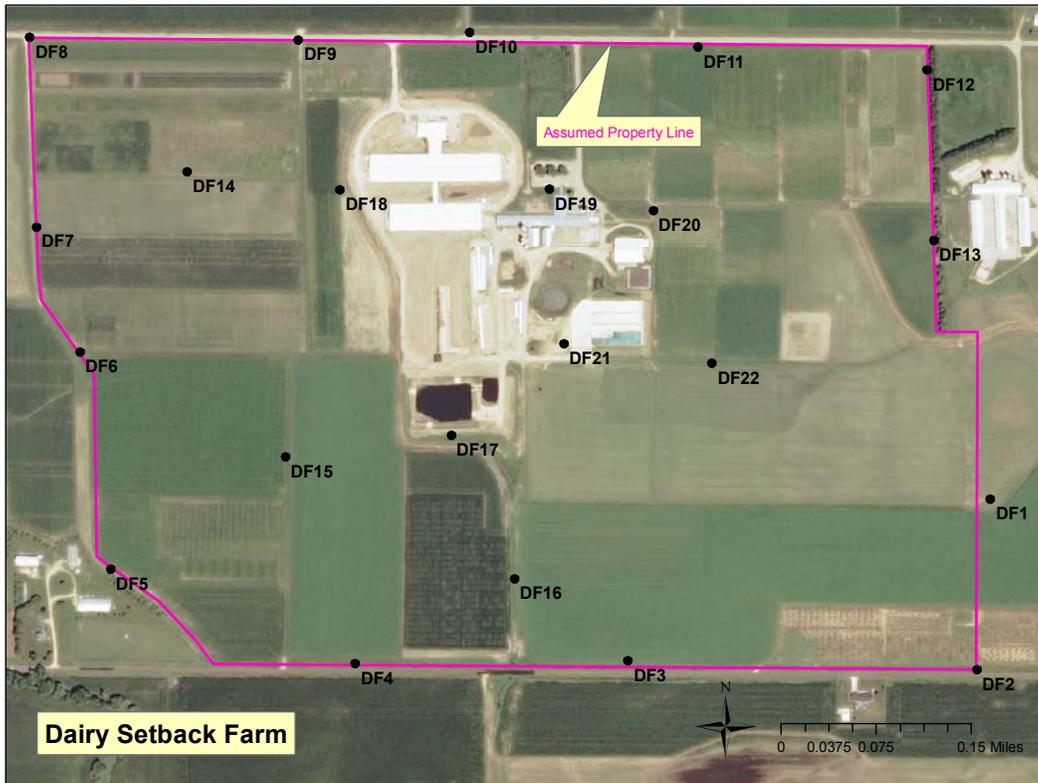
The dairy consists of 2 parallel barns using sand bedding. Each barn is mechanically scraped to a center flush alley, from which wastes flow to a sand channel and then to a 2-stage lagoon, with the smaller first stage providing extra settling space. Flush water is recirculated from the second lagoon. The facility houses about 530 milking and dry cows, and 25 heifers. Adjacent to the barns are pastures where some rotational grazing occurs. Near the barns to the east are calf hutches housing about 60 calves.

Animal diets and their relation to production are one of the main topics of research at this facility, so provisions are in place to allow feeding different rations to different groups of animals.

The lagoon on this farm was agitated and pumped during the study period. Agitation occurred on July 16, 19, 20 21, 26, 27, 29, 30 and 31, and on August 2 – 6. Manure was applied on land several miles away.

The figure on the following page shows an aerial view of the farm, with passive sampling locations marked. The study boundary is outlined in pink and referred to as the “Assumed Property Line”. Only locations DF2, DF3 & DF4 along the southern edge and DF8, DF9, DF10 & DF11 along the northern road are actually on NR445 relevant boundaries. Locations DF5, DF6 & DF7 define the western study boundary, and DF12, DF13 & DF1 the eastern boundary. Locations DF14, DF15, DF16 & DF22 are about halfway from the center of the operation to the assigned boundaries, while the remaining locations, DF17, DF18, DF19, DF20 and DF21 approximate the outer edge of the active facility.

Figure L-4: Dairy Setback Farm Layout



## PASSIVE SAMPLING

Passive sampling began on July 6, 2010 and continued through August 5, 2010. Samplers were exposed for a week. During this time, a total of 99 samples were collected, including 88 ambient samples, 4 duplicates, 4 field blanks and 3 preparation blanks. One sample was invalidated when it was found on the ground at the time of collection.

Results of the ambient samples are documented in the table below. Concentrations are in micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). Asterisks denote values calculated from results below lab reporting limit. Note that the empty place in the table indicates the above mentioned invalid sample. Locations DF1 through DF13 approximate typical property boundary samples, while the remainder represent on farm locations.

**Table R-7: Passive Ammonia Sample Results, Dairy Setback ( $\mu\text{g}/\text{m}^3$ )**

Location	07/06/2010	07/13/2010	07/20/2010	07/27/2010
DF1	24.6	13.5*	13.7*	19.5
DF2	12.0*	9.7*	8.3*	9.0*
DF3	15.3*	9.1*	12.1*	14.0
DF4	11.0*	10.8*	9.6*	11.1*
DF5	12.3*	10.4*	9.9*	11.7*
DF6	11.3*	10.1*	10.2*	11.1*
DF7	11.0*	13.8*	10.2*	13.0*
DF8	11.0*	11.8*	11.2*	14.3
DF9	11.0*	17.1	11.2*	11.4*
DF10	23.7	23.2	25.5	20.9
DF11	19.4	22.2	14.0*	17.2
DF12	18.0	16.1*	12.1*	14.8
DF13	20.4	15.5*	12.8*	17.0
DF14	12.0*	12.5*	13.4*	15.1
DF15		10.4*	12.4*	5.0*
DF16	18.4	10.1*	14.7*	17.0
DF17	273.6	209.4	168.9	204.2
DF18	30.4	27.7	29.3	29.2
DF19	110.2	111.4	95.6	108.7
DF20	73.5	64.2	63.7	58.3
DF21	83.8	84.4	54.2	71.6
D422	47.0	26.0	21.4	31.8

Note that most samples collected at the outer boundaries of this case study are below the laboratory reporting limit, while only those within the inner circle are consistently higher. The highest results from each run are from DF17, which was located close to the manure lagoon.

The second highest concentration site, DF19, was located between the calf area, the pastures and the barns. Average concentrations in both these areas exceed  $100 \mu\text{g}/\text{m}^3$  during the study.

Note that in spite of these relatively high values observed within the confines of the farm, concentrations are reduced by a factor of 5 to 10 times at the nearest fencelines.

## ACTIVE SAMPLING

Unlike the remainder of the case studies, active sampling on this farm was conducted at various setbacks from the main emission points, as well as upwind samples. Both ammonia and hydrogen sulfide samples were collected at most sampling points, with the exception of samples collected immediately downwind of the barns, which were for ammonia only.

Best conditions for active sampling on this farm are with southerly or northerly winds. Two of the three sampling trips were conducted during southerly winds, but the final run was made during northwesterly winds, requiring a slightly different, and less favorable, set of locations. Samples were collected on July 14<sup>th</sup>, July 30<sup>th</sup> and August 5<sup>th</sup>.

Table R-8 below summarizes all valid results from the active sampling. Because sampling was not simply conducted at the downwind property line, summation of the samples is based on relative location, rather than the sampling episode. Thus samples downwind of the barns are grouped, as well as those downwind of the sand channel, etc.

Values shown include averages, maxima and minima, as well as the number of detects and samples, with the corresponding detection rate. Summation calculations are evaluated at the laboratory reporting limit, and values with a “<” symbol represent results below this limit. Note that differences in these “<” results is derived from the volume of air sampled. Both ammonia and hydrogen sulfide results are reported separately for each sampling episode.

**Table R-8: Active Sample Results, Dairy Setback ( $\mu\text{g}/\text{m}^3$ )**

<b>Ammonia</b>	<b>Average</b>	<b>Max</b>	<b>Min</b>	<b>Detects</b>	<b>Samples</b>	<b>Detection Rate</b>
<b>Upwind</b>	<8.5	<9	<8	0	3	0%
<b>DW Barns</b>	114.7	180.9	52.9	6	6	100%
<b>DW Sand Channel</b>	162.3	329.2	77.7	3	3	100%
<b>DW Lagoon</b>	380.4	662.8	68.4	3	3	100%
<b>DW Property Line</b>	35.0	72.9	<9	4	6	67%
<b>Hydrogen Sulfide</b>						
<b>Upwind</b>	<5.5	<6	<5	0	3	0%
<b>DW Sand Channel</b>	37.2	55.6	17.3	3	3	100%
<b>DW Lagoon</b>	55.5	117.4	16.3	3	3	100%
<b>DW Property Line</b>	<6	<7	<5	0	3	0%

Note that the results of these samples supports the passive sampling, with areas within the farm boundaries close to the source areas (barns, sand channel and waste lagoon) showing concentrations above the NR445 annual average ambient action concentration of  $100 \mu\text{g}/\text{m}^3$ , and those on the property boundaries showing much reduced concentrations. One active sample in this case study exceeded daily ambient action concentration of  $418 \mu\text{g}/\text{m}^3$ , directly downwind of the waste lagoon.

The hydrogen sulfide results demonstrate a similar pattern, although at a lower overall magnitude.

## **CASE STUDY 4 KEY FINDINGS SUMMARY STATEMENTS**

Data from this portion of the study will be useful for comparison with standard pollution modeling used to estimate the impact of these types of facilities on local ambient air. Modeling impact is currently the prime way to determine compliance with NR445, but there are many questions regarding the accuracy and applicability of source modeling when applied to the types of air emission sources encountered at farms.

Air pollution models were designed with factories in mind, where generally consistent process emissions are channeled through defined ducts and exit the building from smoke stacks of known heights at consistent rates. Modeling then becomes an exercise of determining the dispersal of a known amount of pollutant entering the atmosphere at a defined point.

Agricultural emissions, however, are derived from variable processes (for instance, the rate of conversion of urea in urine to ammonia is not only temperature dependent, but also depends on how much urea remains in the urine (how old it is)), which generally occur in open sided and naturally ventilated buildings from which emissions can leave in any number of directions. On top of this, ammonia and hydrogen sulfide are quite biologically active and may react quickly once released to the atmosphere.

These factors combine to make modeling of agricultural emissions a difficult process. The results of this case study will be useful to help evaluate the relevant pollution models by providing a number of setback points to demonstrate how quickly ammonia concentrations decrease after being released from the animals and waste.

Overall, our results indicate that NR445 annual ambient action concentrations for ammonia could be exceeded within the property boundaries of this farm. Because NR445 regulates concentrations at the property lines, and is not enforceable inside private property.

## ***CASE STUDY 5: SWINE***

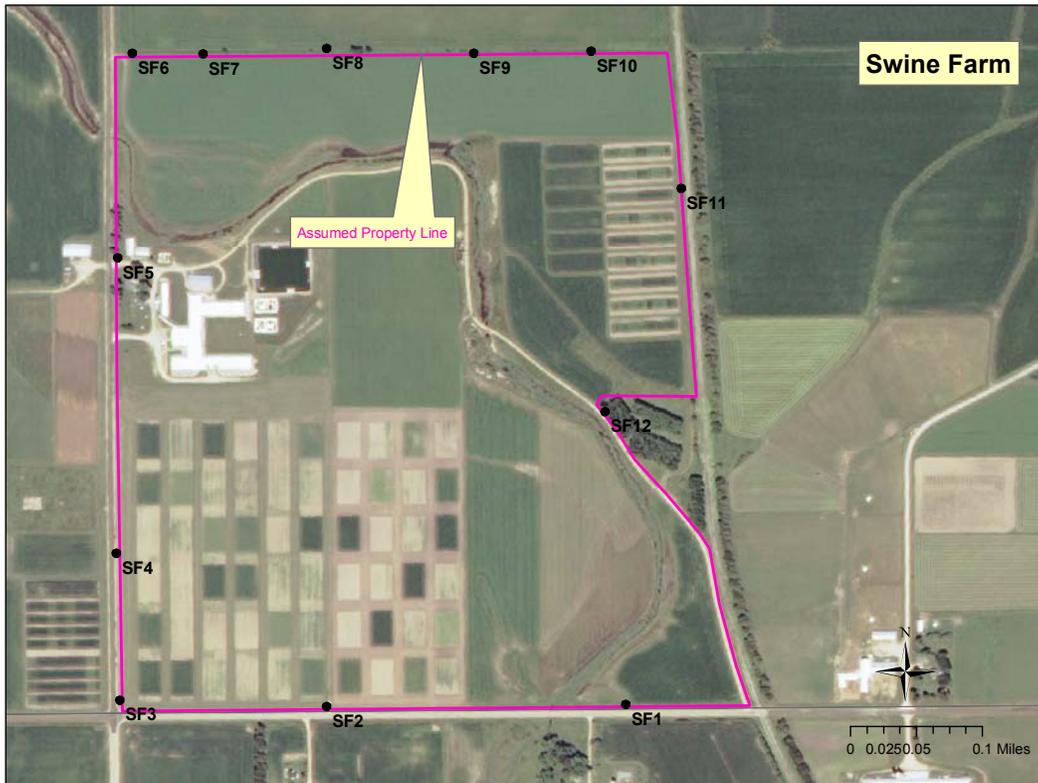
### **BACKGROUND**

The swine case study occurred on the same farm as the dairy setback, although the swine farm is about 3 miles to the west of the dairy. The swine facility, though housing a relatively small number of animals, is constructed and operated along the lines of a much larger facility. Animals are fully confined, and wastes are stored in a large lagoon.

The swine facility consists of a slatted floor barn which is flushed to the storage lagoon. Animals are housed in a number of small rooms inside the barn, which allows careful control of feeding regimes. Several retired housing buildings and lagoons are present on site as well. A total of about 240 sows, 16 boars, 450 pigs up to 55 pounds, and 750 pigs from 55 pounds to market weight are housed on the facility, for a total of about 449 animal units. It should be noted that a facility of this size by itself would not require a WPDES permit.

The figure on the following page shows an aerial view of the farm, with passive sampling locations marked. While the swine facility is part of the same research farm as the dairy setback case study and the property continues both to the east and west, most samplers were located along NR445 relevant property lines. The western and southern study boundaries are public roads, the northern study boundary is the actual property boundary, and the eastern study boundary is a railroad corridor, thus NR445 relevant. The study boundary is outlined in pink and referred to as the “Assumed Property Line”. A single sampler, located at SF12 is located inside of these boundaries. This location was chosen to be towards the facility in a small woodlot, rather than away from it.

Figure L-5: Swine Farm Layout



## PASSIVE SAMPLING

Passive sampling began on July 6, 2010 and continued through August 10, 2010. Samplers were exposed for a week. During this time, a total of 60 samples were collected, including 48 ambient samples, 4 duplicates, 4 field blanks and 4 preparation blanks.

Results of the passive samples are documented in the table below. Concentrations are in micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). Asterisks denote values calculated from results below lab reporting limit. Note that nearly all passive samples obtained during this case study returned results below the laboratory reporting limit.

**Table R-9: Passive Ammonia Sample Results, Swine ( $\mu\text{g}/\text{m}^3$ )**

<b>Location</b>	<b>07/06/2010</b>	<b>07/16/2010</b>	<b>07/23/2010</b>	<b>07/30/2010</b>
<b>SF1</b>	7.8*	6.9*	6.9*	9.1*
<b>SF2</b>	7.4*	8.3*	8.9*	10.6
<b>SF3</b>	6.2*	7.9*	6.9*	9.3*
<b>SF4</b>	6.5*	7.9*	6.9*	8.2*
<b>SF5</b>	11.1*	9.9*	10.5*	12.5
<b>SF6</b>	6.5*	7.3*	7.9*	11.2
<b>SF7</b>	7.6*	6.3*	7.6*	10.1*
<b>SF8</b>	6.0*	7.6*	14.1*	9.9*
<b>SF9</b>	5.8*	7.9*	6.9*	9.7*
<b>SF10</b>	5.8*	7.6*	6.9*	10.4*
<b>SF11</b>	6.0*	7.6*	5.9*	8.7*
<b>SF12</b>	6.3*	7.9*	7.2*	7.4*

The low results associated with this case study were surprising, and inspired the need to obtain the non-agricultural background samples reported in the Methods section previously. Only a handful of the swine samples show concentrations in excess of two times the background concentrations observed at the Horicon Air Monitoring Station, which clearly indicates this operation has a relatively small impact on the ammonia concentrations in the atmosphere.

## ACTIVE SAMPLING

The orientation of this farm makes for the best sampling to be conducted during periods of easterly winds. Active sampling for ammonia and hydrogen sulfide was conducted twice during the project, on July 13<sup>th</sup> and August 10<sup>th</sup>. Sampling was conducted solely on the downwind property line.

Table R-10 on the following page summarizes all valid results from the active sampling. Values shown include averages, maxima and minima, as well as the number of detects and samples, with the corresponding detection rate. Summation calculations are evaluated at the laboratory reporting limit, and values with a "<" symbol represent results below this limit. Note that differences in these "<" results is derived from the volume of air sampled.

Little variation was seen in the results between the two sampling episodes, so results from both are combined.

**Table R-10: Active Sample Results, Swine ( $\mu\text{g}/\text{m}^3$ )**

	<b>Average</b>	<b>Max</b>	<b>Min</b>	<b>Detects</b>	<b>Samples</b>	<b>Detection Rate</b>
<b>Ammonia</b>	12.7	21.7	<8	11	15	73%
<b>Hydrogen Sulfide</b>	<8	<11	<5	1	7	14%

While the active samples show a greater rate of detection than the passive samples, the actual concentrations observed are not significantly higher. In large part, the greater rate of detection is related in part to being able to choose downwind sampling locations for the active sampling, combined with significantly variable winds tending towards the most distant locations for the passive sampling effort.

Jerome meter surveys for hydrogen sulfide yielded results well below the laboratory reporting limits, confirming the active sample results.

#### **CASE STUDY 5 KEY FINDINGS SUMMARY STATEMENTS**

Very low concentration results were obtained at this farm. Whether these low results are derived from the farm being very well managed, a relatively small operation, or some other factors or combination thereof is not known. Whether this operation is truly representative of swine farms even of this size is also not known.

The low results and questions about representativeness of the farm limit conclusions one can draw from this case study.

## CONCLUSIONS

### *GENERAL COMPARISONS*

Based on the quality assurance samples and general comparisons between the active and passive sampling, it appears that the data collected in this project is generally reflective of the conditions around the farms studied. The comparison between the results obtained around the farms, with those from the non-agricultural background location leads to a safe and obvious conclusion: animal agriculture operations tend to increase local ammonia concentrations above background.

The magnitude of the increase was the real point of this study, and here results diverge among the different farms, ranging from the swine operation with very few detected values throughout the study, to the poultry operation which had far more samples with reportable quantities than otherwise. The dairies are generally in between the two extremes with respect to ammonia concentrations, although some significant hydrogen sulfide concentrations were observed, and the single highest passive ammonia value was obtained around a dairy as well.

Evaluating these differences and attempting to find commonality to allow comparisons is the purpose of this section.

The samplers were located around the perimeter of the facility, so that at any given time, some would be upwind and others would be downwind of the barns and waste handling areas. During the course of the week that the samplers were in the field, winds would shift to different directions, frequently covering most of the cardinal directions. An examination of the rate of detection, that is, the percentage of samples returning results which are greater than the laboratory reporting limits, provides an important evaluative factor.

Several different potential reasons for a higher detection rate exist, including a source strength is strong enough to generate concentrations above background even with little wind from a particular direction; a distribution of winds which include most directions; and emitting facilities which are close to the perimeter. While examination of each individual run results figure in the Appendices provides a wealth of information documenting various sources within each farm, aggregating the results can provide significant information as well.

A direct comparison between these farms is not realistic, as there are different animals, including different aged animals, involved, farms of different sizes, and significant differences in the layout of the farms. The use of animal units to normalize farms of different animal types is standard which allows some comparison. In addition, the results of the study allow comparison along the lines of detection rate and frequency distribution of different concentration ranges.

Table C-1 on the following page combines these factors and others for the complete dataset from each farm for direct comparison. It should be noted that for the purposes of this table, the Dairy Setback (DairyS) results are compiled from the perimeter samples

only to avoid biasing the comparisons. It is also important to note that the Dairy2 dataset includes half the number of samples collected with the others.

The top portion of the table includes the animal units associated with each farm, the number of samples which returned results above the laboratory reporting limit, and the percentage of total samples that number represents.

The second portion of the table tabulates the number of samples with results in different concentration ranges. This portion enhances the evaluation of results beyond the mere fact of detection by providing a magnitude of the results observed around each facility.

The next portion of the table provides an average, maximum and minimum derived from the entire dataset, including values calculated from lab results both above and below the reporting limit. The final portion of the table compares the average to the non-agricultural background samples obtained at the Horicon Air Monitoring Station.

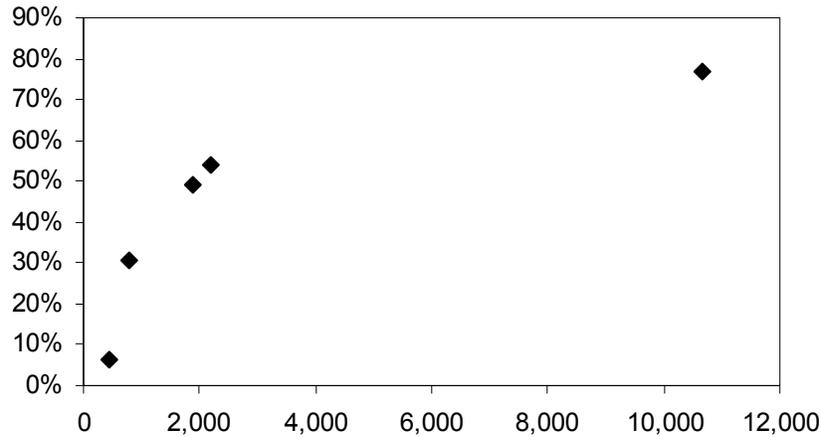
**Table C-1: Farm Passive Sampling Results Comparison**

<b>Farm</b>	<b>Poultry</b>	<b>Dairy2</b>	<b>Dairy4</b>	<b>DairyS</b>	<b>Swine</b>
<b>Animal Units</b>	10,655	2195	1875	782	449
<b>Detects</b>	37	13	23	16	3
<b>Detection Rate</b>	77.1%	54.2%	48.9%	30.8%	6.3%
<b>Samples &gt;20 µg/m<sup>3</sup></b>	11	7	9	7	0
<b>Samples &gt;30 µg/m<sup>3</sup></b>	7	1	6	0	0
<b>Samples &gt;50 µg/m<sup>3</sup></b>	2	3	1	0	0
<b>Samples &gt;75 µg/m<sup>3</sup></b>	4	1	1	0	0
<b>Samples &gt;100 µg/m<sup>3</sup></b>	6	1	0	0	0
<b>Average All</b>	44.8	35.3	19.9	14.0	8.1
<b>Maximum</b>	178.6	256.1	77.9	25.5	14.1
<b>Minimum</b>	8.1	7.0	7.9	8.3	5.8
<b>Rel to Background</b>	9.0	7.1	4.0	2.8	1.6

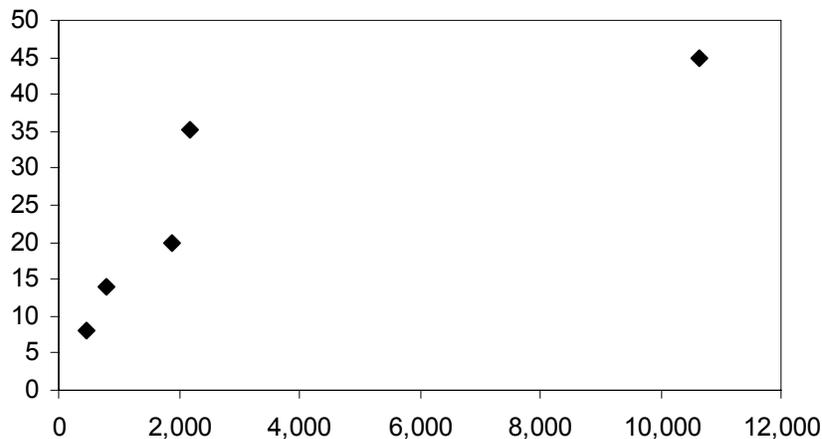
As can be seen in the table, in general the more animal units present, the greater the detection rate and the higher the concentrations observed. Location of emission sources relative to sampling location also matters. These relationships are shown in the figures on the following page. The first figure shows the detection rate plotted against animal units, while the second shows the average ammonia concentration. Note that in both cases, the left-most symbol represents the swine farm, the furthest right the poultry operation, and the middle three the dairy farms.

The plot of detection rate demonstrates a nice curve, with the three dairies showing an almost linear relationship to each other when viewed in this manner. There is not sufficient data in the study to use this relationship to predict how frequently there will be detectable ammonia around different farms.

**Figure C-1: Detection Rate vs. Animal Units**



**Figure C-2: Average Ammonia Concentration vs. Animal Units**



There is not enough data to predict the magnitude of the concentrations observed, especially given that the data in figure C-2 do not show as much of a relationship as appears to exist in figure C-1. In reality, a large number of variables affect ammonia concentrations, but the data obtained in this study does indicate that the more animals present, the higher the likelihood that detectable quantities of ammonia will be present in the atmosphere.

Hydrogen sulfide, on the other hand, was more associated with particular manure handling practices on dairies than the poultry and swine farms in our study. Each of the dairies in the study manage their wastes using techniques which the CIG study conducted with DATCP has shown to be significant sources of hydrogen sulfide: sand channels, biogas generators and solids separation systems.

One hydrogen sulfide sample result in excess of 50% of the 24-hour AAC ( $335 \mu\text{g}/\text{m}^3$ ) was observed, but 80% of the samples were below the detection limits or otherwise less

than 5% of the AAC. Samples collected relatively near to ones showing elevated concentrations tended to be much lower. The implication of this is that generation of hydrogen sulfide is a result of processes which evolve discrete plumes.

It would be both interesting and perhaps important to evaluate a dairy which manages its waste without the use of these components for comparing hydrogen sulfide results.

### ***COMPARISON WITH NR445 AMBIENT ACTION CONCENTRATIONS***

This project was primarily driven by NR445 considerations. One of the main questions which started the project was how likely is it that a typical farming operation would trigger the limits associated with this rule. While results from the project are not directly comparable to the ambient action concentrations, they can be viewed as indicative.

Approximately 31% of active ammonia samples returned results in excess of 10% of the 24-hour AAC, although only 3% were in excess of 75% of this level. Of these samples, 3 were collected near the lagoon and sand channel of the Dairy Setback study, which suggests the possibility that a farm with minimal setback for its waste storage lagoon could possibly exceed the NR445 level for ammonia.

The fourth sample actually exceeded the 24-hour AAC. It was collected over about 6 hours at the Poultry Fenceline, less than 15 yards directly downwind of a barn exhaust fan. Because of the far less than 24 hour time frame of the sample, this result does not necessarily represent an exceedance of the AAC, although it does suggest that it is possible.

The highest active sample for hydrogen sulfide was collected downwind of the building containing a digester, solids separator, and biogas generator on Farm Dairy 2. This sample was slightly greater than half of the NR445 AAC for hydrogen sulfide (336  $\mu\text{g}/\text{m}^3$ ). Whether a farm with a similar system could exceed the AAC for this compound can not be determined from this dataset.

More significantly, there are indications from the Poultry operation, the Dairy Setback and Dairy 2 that on farm concentrations may frequently exceed the annual AAC for ammonia (100  $\mu\text{g}/\text{m}^3$ ). While in the case of the Poultry farm and Dairy 2, the locations where these values were observed are technically on or near the property lines, in both cases they are not places where the public would typically go.

The results of this study show conclusively that large animal operations are sources for ammonia. Ammonia is part of significant national, regional and local air pollution issues including PM2.5, regional haze and nitrogen deposition. Improving management practices to minimize emissions from agriculture, which is estimated to provide in excess of 90% of ammonia to the atmosphere, is an important and worthy goal.