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Progress in Estimating Setback Distances for Livestock Facilities

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Summary and Implications

The University of Minnesota has introduced a tool used by county planners and livestock producers for developing a science-based estimate of setback distances between a livestock facility and neighbors. This paper provides an overview of the tool and an example illustrating the process for estimating setback distances. Minnesota's development efforts have resulted in the first scientifically based tool being used in the United States for public policy decisions for location of livestock facilities. More recently, University of Nebraska faculty have initiated a cooperative development effort with the Minnesota team to develop a Nebraska Odor Footprint tool which will perform a similar estimate of setback but with several unique options. This tool will consider wind direction, terrain, and Nebraska weather conditions in estimating directionally varying setbacks. It should assist producers gain approval for construction of new and expanded livestock facilities in Nebraska.

Background

Rural communities are struggling to balance odor issues with the presence and growth of the livestock industry. Currently the type of animal facility, odor control measures, prevailing wind direction, atmospheric conditions, and a community's tolerance to some degree of odor are largely ignored in the planning process because scientific tools that incorporate this information are lacking. Without such tools, decisions on setback distances and acceptable type and size of facilities are influenced by a range of arguments, often emotional in nature. In addition, livestock producers are without tools for evaulating a new facility's impact on a rural community relative to alternative sites, facility animal capacity, and odor control measures.

The role of state and federal agencies relative to livestock air quality issues is likely to increase. For example, Colorado now mandates covers on all manure storage and lagoons. New Iowa legislation will establish thresholds for odor, hydrogen sulfide, and ammonia. Minnesota has a maximum ambient hydrogen sulfide level of 30 ppb (three times lower than the Nebraska standard). United States EPA is reviewing potential regulation of ammonia and dust emission from livestock sources.

Scientifically Based Setback Tools

Recently, several tools have been developed with which to make scienfically based estimates of separation distances needed to minimize odor complaints. Ontario's Minimum Distance Setback Distance guideline has been used since the 1970's for siting of livestock facilities and residences in rural communities. The guidelines is a cross between science-based rules and personal experience. Europeans have developed several models including

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an Austrian model which determines recommended setback distances for animal housing only. Two European models, including the Austrian model, were the foundation for a Purdue model that was applied to both buildings and outdoor manure storages. Most recently, OFFSET, a tool developed in Minnesota to assess odor movement from livestock facilities, is being applied as a community odor planning tool in three Minnesota counties. Cooperative efforts between the UNL and the University of Minnesota have the potential to improve this odor modeling tool and adapt the OFFSET concept to Nebraska. Critical limitations for use of OFFSET in Nebraska include differences in weather conditions, lack of emissions data for anaerobic lagoons and open feedlots, and its current prediction of odor emissions without regard for wind direction. In addition, the Minnesota model does not handle odors from area sources well (e.g. open feedlots, large buildings, or large manure storages or lagoons).

Table 1. Odor emission number for animal housing with average management level.

Species	Animal Type	Housing Type	Odor Emission Number (Rate)
Cattle	Beef/Dairy	Dirt/concrete lot	4
	Dairy	Free stall. Scrape.	6
		Free Stall. Deep pit	6
		Loose housing, scrape	6
		Tie stall, scrape	2
Swine	Gestation	Deep pit, natural or mechanical	50
		Pull plug, natural or mechanical	30
	Farrowing	Pull plug, natural or mechanical	14
	Nursery	Deep pit, natural or mechanical	42
		Pull plug, natural or mechanical	42
	Finishing	Deep pit, natural or mechanical	34
		Pull plug, natural or mechanical	20
		Hoop barn, deep bedded, scrape	4
		Cargil (open front), scrape	11
		Loose housing, scrape	11
		Open concrete lot; scrape	11
Poultry	Broiler	Litter	1
	Turkey	Litter	2

Table 2. Odor emission number for liquid or solid manure storage.

Storage Type	Odor Emission Number (Rate)
Earthen basin, single or multiple cells*	13
Steel or concrete tank, above or below ground	28
Crusted stockpile	2

*Earthen basins are designed for manure storage without any treatment. Treatment lagoons may have less odor.

Table 3. Odor control factors.

Odor Control Technology		Odor Control Factor
Biofilter on 100% of building exhaust fans		0.1
Geotextile cover (> = 2.4 mm)		0.5
Straw or natural crust on manure	2" thick	0.5
	4" thick	0.4
	6" thick	0.3
	8" thick	0.2
Impermeable cover		0.1
Oil sprinkling		0.5

Minnesota OFFSET Tool[2]

Recognizing the increasing number of nuisance-related conflicts between the livestock industry and rural neighbors, the Minnesota State Legislature funded an effort to develop the "Odor From Feedlots Setback Estimation Tool" (OFFSET). The University of Minnesota Biosystems and Agricultural Engineering Department under the guidance of a stakeholder advisory committee has initiated three major activities contributing to the implementation of

OFFSET:

1. Collection of a large data base of odor emission rates from a wide range of animal housing and manure storage systems. This data base is the foundation for selection of an appropriate odor emission factor that is used to define the magnitude of an odor source. Odor emissions factors have been published for common cattle, swine, and poultry housing types (Table 1) and manure storage options including earthen basins, formed manure storage tanks, and crusted manure stockpiles (Table 2). In addition, the Minnesota model recognizes the odor control benefits of different technologies (Table 3)
2. Adaption of an air dispersion computer model, INPUFF-2, to predict downwind concentrations of odors based upon meteorology and odor emission factors. This model has facilitated the recommendation of separation distances based upon total odor emissions and annoyance free levels (Figure 1).
3. Validation of this tool in repeated experiments with 20 individual farm sites.

This tool has two primary applications in Minnesota at this time. It is being used by producers prior to the construction of a new facility or expansion of an existing facility to forecast potential impacts of the planned development on neighbors and identify appropriate setback distances. The tool also allows producers to evaluate alternative odor control practices for their ability to reduce setback requirements and encourages a better fit for a

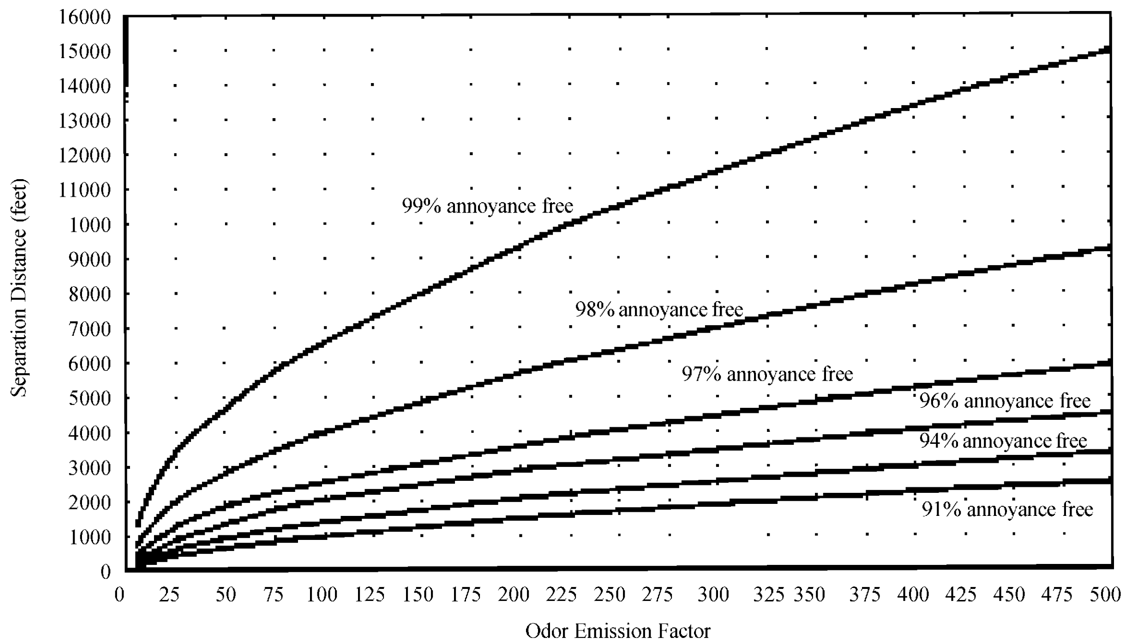

Figure 1. Estimated setback distances from animal operations at different odor annoyance-free requirements of surrounding community leeward of the prevailing wind from animal operations.

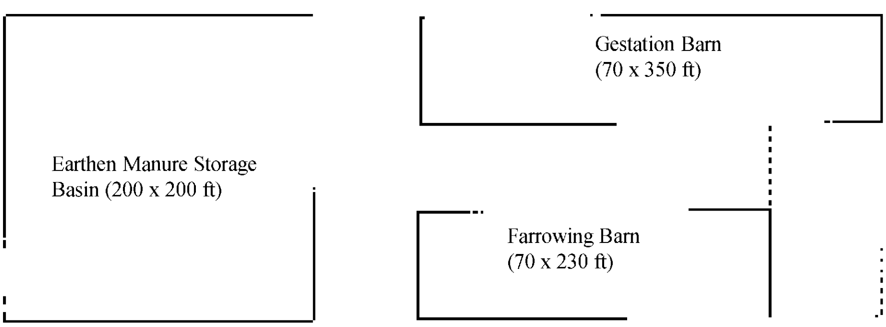

Figure 2. Layout of facilities for sample problem and other required information for using OFFSET to evaluate recommended setback distances.

proposed facility within a community. The tool is being pilot tested by three Minnesota counties for the purpose of county zoning review of proposed facilities and the appropriate setback required for that facility.

Sample Application of OFFSET

A farmer proposes a 1,200-head sow gestation and farrowing operation with mechanical ventilation and pull-plug gutters and a single-stage earthen basin (Figure 2). The county has established setbacks equal to the 97% annoyance-free curve at the nearest community. Currently, the nearest neighbor is 0.5 miles (2,640 feet) from the farm. Does this farm meet the county guidelines?

Step 1. There are three odor sources at the site, i.e. two buildings and one basin. The three source names are listed in Column A of Table 4 along with the odor emission numbers for each source from Tables 1 and 2.

Step 2. The dimensions of the gestation building and farrowing building are 70 x 350 ft. and 70 x 230 ft., respectively. The areas are 24,500 ft^2 and 16,100 ft^2, respectively for these two buildings (Area = Width x Length). The dimensions of the basin are 200 x 200 ft (40,000 ft^2 of surface area). These areas are entered in Column C of Table 4.

Step 3. There is no odor control technology for this site, so 1 is entered in Column D of Table 4 for each source.

Step 4. The odor emission factor (Column E) for each source is found by multiplying the above three numbers and dividing by 10,000.

Step 5. The three odor emission factors in Column E are summed to determine the Total Odor Emission Factor (TOEF) for the site. In this case the TOEF is 148.

Step 6. In Figure 1, locate 148 on the x-axis. Then move vertically to the 97% "odor annoyance-free" curve. Moving horizontally to the vertical axis shows the minimum setback distance to achieve 97% annoyance-free is approximately 3,000 ft. If neighbors live within 3,000 feet of the proposed site for this facility, this site may

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be determined to be unacceptable and would not meet county zoning standards. Therefore, this farm does not comply with the county guidelines because the community will experience annoying odors greater than the allowable 3% per month (22 hours per month from April through October).

To comply with county regulations, the farmer must reduce odor emissions from his animal production site or consider alternative sites. The question then becomes how much odor emission reduction is necessary to meet the 97% annoyance-free standard. The farmer contemplates the addition of a biofilter on the two buildings (odor control factor of 0.1 from Table 3) and a geotextile cover on the manure storage (odor control factor of 0.5 from Table 3). Table 5 indicates the changes in odor emissions with these two modifications. Note that Columns A, B, and C did not change between Table 4 and Table 5.

With a new Odor Emission Total estimated, go to Figure 1 and find 30.5 on the horizontal scale. For this TOEF the 97% annoyance-free level is achieved within 1,700 feet. Only the 99% annoyance-free curve is not reached by a 0.5 mile distance to the nearest neighbor. The odor control technologies used in this example are presently available. Although not common, they can be seen on demonstration farms. Additional cost to the producer to implement these odor control measures should be weighed against the expenses incurred in trying to find an alternative site.

Strengths and Weaknesses of OFFSET

The Minnesota OFFSET tool for estimating neighbor exposure to odor is a major advancement in the application of science-based tools to this issue. It provides a simple mechanism by which producers and county planners can make reasonable judgements as to the degree of impact a facility may have on the community. The University of Minnesota faculty who developed this tool are to be commended for

Table 4. Summary table for calculating the total odor emission factor for a 1,200-sow unit with no odor control practices.*

Column A Odor Source	Column B Odor Emission Number	Column C Area (sq. ft)	Column D Odor Control Factor	Column E Odor Emission Factor (B x C X D/10,000)
Gestation Barn	**30 OU/ft^2**	**24,500**	**1**	**73.7**
Farrowing Barn	**14 OU/ft^2**	**16,100**	**1**	**22.5**
Manure Storage	**13 OU/ft^2**	**40,000**	**1**	**52.0**
Total Odor Emission Factor (sum of Column E)				**148.0**
Setback Distance from Figure 1 for **97%** Annoyance Free Curve				**3,000 feet**

*Text in bold is entered by producer and is specific to individual operations.

Table 5. Summary table for calculating the total odor emission factor for a 1,200-sow unit with some odor control practices.*

Column A Odor Number	Column B Odor Emission (sq. ft)	Column C Area Factor	Column D Odor Control (B x C X D/10,000)	Column E Odor Emission Factor
Gestation Barn	**30 OU/ft^2**	**24,500**	**0.1**	**7.4**
Farrowing Barn	**14 OU/ft^2**	**16,100**	**0.1**	**2.3**
Manure Storage	**13 OU/ft^2**	**40,000**	**0.4**	**26.0**
Total Odor Emission Factor (sum of Column E)				**35.7**
Setback Distance from Figure 1 for **97%** Annoyance Free Curve				**1,700 feet**

*Text in bold is entered by producer and is specific to individual operations.

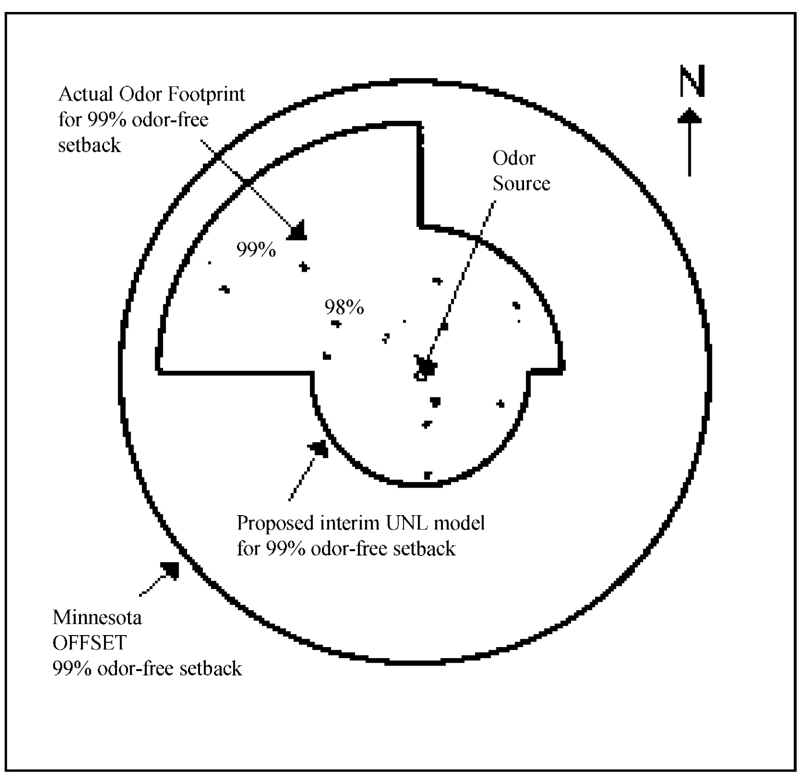

Figure 3. Predicted odor-free exposure frequencies for a livestock facility based upon the Nebraska Odor Footprint tool, a proposed interim tool, and the Minnesota OFFSET model.

Wind Rose for St. Paul, MN (Apr. 15 - Oct 14, 1984-1992)

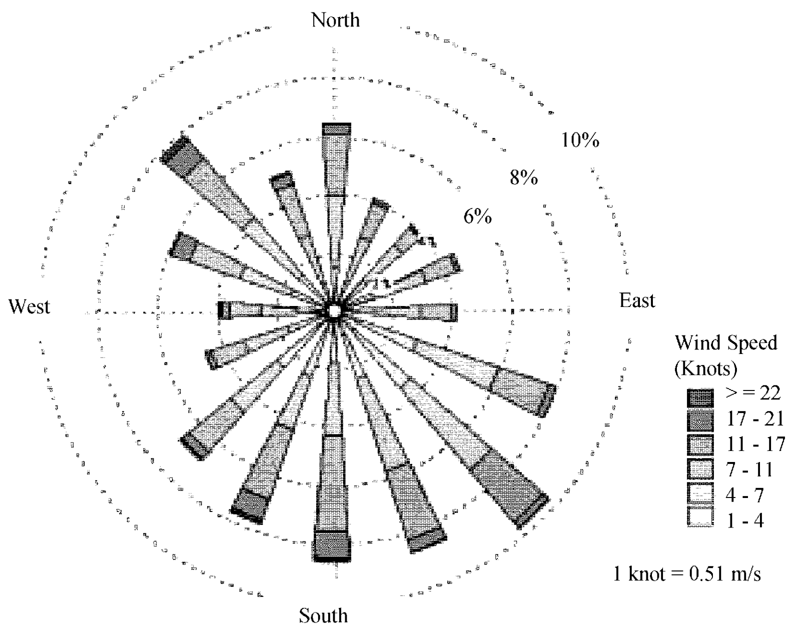

Figure 4. Wind rose used to compare Minnesota OFFSET and Nebraska Odor Footprint model (see Figure 3 illustration).

leading this effort to utilize science in assisting with a highly controversial issue.

However, the model has several limitations if it were to be applied outside Minnesota. They include:

1. The emission factors were estimated for animal housing and manure storage facilities common to Minneota. These emission factors may not always be applicable to other states or include facilities common in other states. For example, application of OFFSET to Nebraska would require development of emission factors for open beef feedlots, anaerobic lagoons, and runoff holding ponds.
2. The tool that predicts "annoyance-free" setback distances is based upon Minnesota meteorology. Differences in wind speed, temperature, and solar radiation characteristics affect the stability or instability of air and the distance required to dilute odorous air to below nuisance levels. Minnesota weather conditions are likely to predict a more conservative value for setback for most Nebraska conditions. Regionally specific weather data will need to be used for reproducing Figure 1 for locations outside Minnesota.

Two additional potential shortfalls of the current OFFSET tool need to be evaluated in the development of future models and tools. Those concerns include:

1. The predicted setback distance by OFFSET is for prevailing wind conditions. However, this setback distance is currently applied in all directions from a livestock facility. This leads to an over-estimate of the necessary setback in directions other than prevailing wind direction.
2. The current model assumes that all odor from a livestock facility originates from a single point. In reality, many livestock facilities, including beef cattle feedlots, should be considered as an area source of odor. Tools which model a livestock facility as an area source will be critical for correctly predicting setback distances from feedlots, anaerobic lagoons, and larger confinement barns.

The Proposed Nebraska Odor Footprint Tool

UNL has been working with Minnesota to rectify these shortcomings and, through the use of a new model, we hope to be able to improve the ability to estimate the frequency of exposure to annoying levels of odor while using NE conditions (Figure 3 and 4). We currently are focussing on:

- field evaluation of odor emission rates for anaerobic lagoons and feedlots, and validation in Nebraska of Minnesota emission rates for other facilities,
- integration of Nebraska weather data into the improved model, and
- development of a planning device (the Footprint tool) for Nebraska industry and community use.

Currently we are equipping a portable wind tunnel (emissions rate chamber) with appropriate gas sampling equipment and we will measure preliminary odor emission rates during the fall of 2002 to test the equipment and procedures. A second period of data collection will occur over a six-month period (March through August 2003) on emissions from 10 single-stage anaerobic lagoons in Nebraska. Samples will be collected at each lagoon on three occasions (early spring, early summer, and late summer). Within the limits of the ten lagoons to be sampled, we will identify a range of lagoon designs (different loading rates and conditions such as purple vs. non-purple). Odor samples will be shipped overnight to the University of Minnesota olfactometry lab for intensity measurement.

Odor emission rates will be expressed as odor units per square foot per hour and grouped to account for seasonal effects and lagoon design. Existing weather data (Nebraska) and the Minnesota emission rate data set will be integrated with the lagoon odor emission rates to produce the initial Nebraska Odor Footprint tool. An advisory committee will be established to review project procedures and

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results, to provide guidance on Nebraska Odor Footprint tool development and application, and to develop consensus on issues that may be controversial. Representatives of producer associations, Farm Bureau, Nebraska Association of County Officials, Nebraska Department of Environmental Quality (air quality division), and other organizations would potentially fulfill this role.

The Nebraska Odor Footprint tool will be refined with a user-friendly interface having specific outputs for producers and for planners. With the completion of this tool, an educational program targeted at producers and county public policy and planning officials will be delivered. All of these activities are dependent upon access to sufficient labor and financial resources. UNL and the Nebraska Pork Producers Association have provided some resources to move the Nebraska Odor Footprint tool forward.

It is hoped that the Nebraska Odor Footprint tool will assist producers in gaining approval for construction of new and expanded livestock facilities in Nebraska. A successful project will provide them with an ability to determine the intensity and frequency/infrequency of neighbor exposure to their odor footprint, based upon the size and type of housing, manure storage and odor control technologies they plan to use. It will also allow producers to compare neighborhood impact of alternative sites for new facilities. In addition, it will give county officials a way to understand the likelihood, magnitude and impacted area of odors for a proposed facility.

With this they can then make more informed and better decisions on new and expanded facilities. Finally, producers and community leaders will have a common basis with which to evaluate alternative technology options (odor control, housing type, and manure storage type) for reducing odor emissions and the anticipated odor footprints with these options.

Weather conditions leading to higher odors in the neighborhood of a facility will be analyzed in the Odor Footprint tool. Odor episodes classified based on the time of the day or season of the year will enable producers to identify the situations when such episodes can potentially occur. Odor control technologies implemented only during these occurrence periods will help the producer minimize odors in the neighborhood more economically.

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[2]The authors would like to recognize that significant information about the OFFSET model for this paper was adapted from University of Minnesota publications authored by Larry Jacobson, David Schmidt, Kevin Janni, and Susan Wood. Permission was granted by Larry Jacobsen.