SDOFT
South Dakota Odor Footprint Tool

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Introduction

Livestock and poultry producers continually face economical and time restraint challenges. They seek a life style that does not demand 10 to 16 hours labor each day. As a result producers have expanded and concentrated their operations in recent years to make the operation more affordable and bring in additional labor to share the work load. But this expansion has also resulted in a community that is concerned about emissions of air pollutants, especially odorants. Because of this concern, there has been an increase in complaints towards animal production facilities.

Figure 1. Prediction of odor problems is important as rural and non-rural areas converge.

To address these concerns between production facilities and community residences, local regulators establish minimum setback (separation) distances through local zoning and/or state regulatory procedures. Unfortunately, very few of these setback requirements have a scientific basis because the science did not exist and decisions by local officials were based on emotions.

To provide the needed science air quality research groups at South Dakota State University, University of Nebraska, and University of Minnesota developed the South Dakota Odor Footprint Tool (SDOFT) for estimating odor impacts from livestock and poultry facilities to the surrounding community. These estimations are useful for local government land use planners, livestock producers, and citizens concerned about the odor impact of existing, expanding, or new animal production sites.

The SDOFT involves a two step procedure. Step 1 estimates the average emissions from a variety of animal facilities and manure storages. This estimate is based on odor measurements from livestock and poultry farms in the upper Midwest. Step 2 estimates the atmospheric dispersion of the emissions from the site. This dispersion is based on Environmental Protection Agency (EPA) approved modeling using South Dakota climatic conditions.

The SDOFT results provide rural communities and local government officials with the information needed to incorporate science and objectivity into the permitting process. They decide what levels of odors are acceptable, and then determine the consequence of the "acceptance" level. Also the tool provides the livestock producer with odor management and decision-making information.

Using the Tool

Input factors needed to estimate the amount of odor emitted from a particular farm include: animal species, housing types, manure storage and handling methods, the size of the odor sources (square feet of facility), the implementation of odor control technologies, and the location in South Dakota (related to local climate).

Since the odor effect on the surrounding neighborhood or community is a function of local weather conditions, the location of the production site in South Dakota is important. Odor impact includes the strength of the odors and the frequency and duration of the odor events. SDOFT combines odor emission measurements and the average local weather conditions to estimate the strength and frequency of odor events at various distances from a given farm.

Step 1 – Determining the Total Odor Emissions Factor (TOEF)

The TOEF is the sum of all scaled odor emission rate from all main odor sources on the site. A scaled odor emission rate needs to be calculated for each odor source. If there are multiple facilities that are of similar type (e.g. two swine finishing barns) on the site, the combined areas can be used to simplify the calculations.

Use the Worksheet 1 on page 10.3 to assist you in calculating the TOEF. Column headings indicate what values to insert and where/how to obtain the desired value. Individual scaled odor emission rates (OER) are found using the following formula:

$$\text{OER} = [\text{Odor emission number} \times \text{Plan area} \times \text{Odor control factor}] \div 10{,}000$$

Odor Emission numbers

SDOFT bases the odor emission numbers on measured odor emission rates obtained from measurements made on farms located in the Upper Midwest. Average values for a series of measurements from each odor source type are in Tables 1 and 2. Average values must be used since wide variation between sites with similar sources existed. Variation is related to such factors as farm management, animal diet, or such things as ambient temperature, humidity, and wind speed. Therefore, the actual odor from a given site may vary as compared to the results from this tool because of the same factors.

Odor Control Factors

Several technologies are currently available to control odor, although little testing and research has been done to document their effectiveness.

Figure 2 Odor control is a critical part of reducing the frequency of annoying odor events.

The only technologies where sufficient information is available to determine likely reductions in odor emissions for field conditions are listed in Table 3. The factors vary from 0.1 to 1; where 1 indicates no odor control and 0.1 indicates 90 % odor reduction. Changes and additions to the odor control factors (Table 3) will be made as more research is conducted and more technologies are developed. Currently, there is no standard procedure for getting odor control technologies listed on Table 3, nor is it required by SDOFT to allow only odor control technologies listed in Table 3. However, estimated reductions in odor emissions should be based on sound scientific research.

Figure 3. Two odor sources; the barn and manure storage.

Instructions for completing the worksheet are:

Column A. List all the odor sources on the farm site (e.g. buildings, manure storage areas, etc.)

Column B. Use Tables 1 and 2 to determine the odor emission number for each odor source.

Column C. List the surface area of each odor source in (in square feet).

Column D. Enter any odor control factors from Table 3.

Column E. Fill in Column E of Worksheet 1 by multiplying the values in Columns B, C, and D and dividing by 10,000. Sum all the numbers in Column E to determine the Total Odor Emission Factor (TOEF) for the farm site.

Worksheet 1 for calculating the Total Odor Emission Factor.

Column A Odor source	Column B Odor Emission Number/ft.^{2}	Column C Area (sq. ft.)	Column D Odor Control Factor	Column E Odor Emission Factor (B x C x D/10,000)
1.				
2.				
3.				
4.				

Total Odor Emission Factor (TOEF) sum of Column E =	

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

Species	Type/Stage of Production	Type of Facility	Odor Emission Number
Cattle	Beef	Dirt/concrete lot; Free stall, scrape	19
	Dairy	Free stall, deep pit; Loose housing, scrape	29
		Tie stall	10
Swine	Gestation	Deep pit, natural or mechanical	243
		Pull plug, natural or mechanical	146
	Farrowing	Pull plug, natural or mechanical	68
	Nursery	Deep pit or pull plug, natural or mechanical	204
	Finishing	Deep pit, natural or mechanical	165
		Pull plug, natural or mechanical	97
		Hoop barn, deep bedded, scrape	19
		Cargil / open front, scrape Loose housing, scrape Open concrete lot, scrape	53
Poultry	Broiler	Litter	5
	Turkey	Litter	10

Table 2. Odor emission numbers for manure handling facilities.

Type of Facility*			Odor Emission Number
Manure storage facility	Earthen basin		63
	Steel or concrete tank, above or below ground		136
	Crusted stockpile		9
Treatment facility	Anaerobic lagoon	Purple (phototrohic)	2
		Non-photrophic (non-purple)	3

**Earthen basins are designed for manure storage without any treatment. Lagoons are anaerobic treatment systems,*

Table 3. Odor control factors.

Odor Control Technology		Odor Control Factor
No supplemental odor control implemented on the facility		1.0
Biofilters receiving 100% of air from all exhaust fans		0.1
Oil sprinkling used to control dust within building		0.5
Geotextile cover (at least 2.4 mm thick)		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

The relative impacts of various odorous sources can be assessed by comparing the size of individual scaled odor emission rates. For example, if a manure storage facility has a scaled odor emission rate of 150 compared to 100 for the housing facility, then the manure storage facility can be projected to have 50% greater influence than the housing facility on the minimum desired setback distance and the resulting overall odor impact on neighbors. The relative size of the scaled odor emission rates also is a good indicator of where odor control would be most beneficial. Generally, you want to spend resources where they will have the greatest benefit overall – on the facilities with the largest odor emission rate.

Step 2 – Determining distance and frequency of odor event

Once the TOEF is calculated, the frequency of odor occurrences at various distances from the farm site can be estimated using Figures 8-19. The horizontal axis is the TOEF as calculated in the worksheet. The vertical axis is the distance from the farm site. There are three sets of graphs with each set containing 4 graphs. Each set is devoted to a region in South Dakota (Figure 4). The four graphs in a set provide set-back annoyance-free distances for each direction from the odor emitting site.

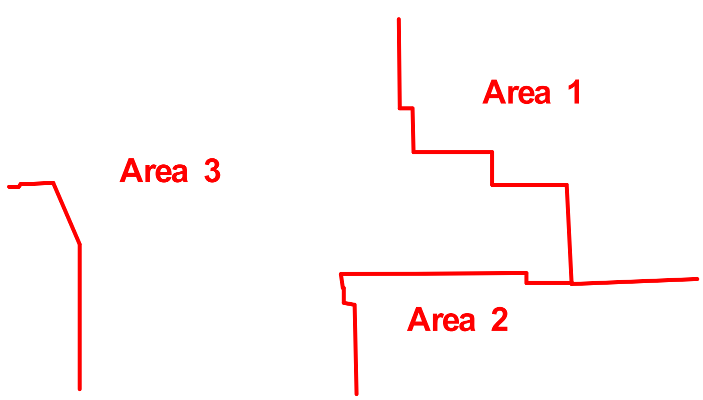

Figure 4. South Dakota Footprint Tool Areas

Annoyance-free Frequency
The annoyance-free frequency curves represent different frequencies of time when odors will not be at levels considered "annoying." Options include 91%, 94%, 96%, 98% and 99%. **These odor annoyance-free frequency curves represent the percent of time during the spring-through-fall period where odors are possibly detected, but at a level that is NOT typically considered annoying.** A odor less than 2 on an intensity scale of 0 to 5 is defined as not annoying (SDSU Extension Fact Sheet 925-A). Odors with an intensity of less than 2 are weak or mild odors that are not likely to be annoying. A small percentage of the population is highly sensitive to odors. These individuals may detect odors at very low levels and be annoyed at intensities less than 2.

The curve selected represents the minimum proportion of hours during which a residence situated at or beyond the setback distance should not be exposed to annoying levels of odor coming from the particular livestock site. Odor annoyance-free frequencies of 99%, 98%, 97%, 96%, 94%, and 91% correspond to 7, 15, 22, 29, 44, and 66 hours/month of annoying odors during the months of April through October. During the winter months less frequent odor events can be expected due to the reduced odor emissions during cold weather. Since these predicted frequencies are based on "average" weather conditions, actual frequencies of odor events may be significantly different.

To find the separation distance for a specific frequency curve and TOEF, simply find the TOEF on the horizontal axis, then move vertically to the desired annoyance-free frequency curve, and then move horizontally to the vertical axis. The number on the vertical axis is the separation distance (in feet) needed to achieve the desired frequency of odors. For example, if the 96% curve is chosen, odors at a location within the setback distance would be expected to be at annoying levels more than 4% (100% - 96%) of the time, while odors at a location beyond the setback distance would be expected to be at annoying levels less than 4% of the time.

Different odor annoyance-free frequencies result in different setback distances for the same TOEF. For example, to achieve an odor annoyance-free frequency of 99% for a facility with a TOEF of 150 requires a separation distance of 1.5 miles. (This separation distance is measured from the edge of the nearest odor source.) During the rest of the time (1% or 7 hours per month), annoying odors will be detected at this distance. Reducing the frequency of annoyance-free odors to 96% would require a separation distance of less than 0.5 miles. At this distance, annoying odors would be experienced 4% of the time or 29 hours per month.

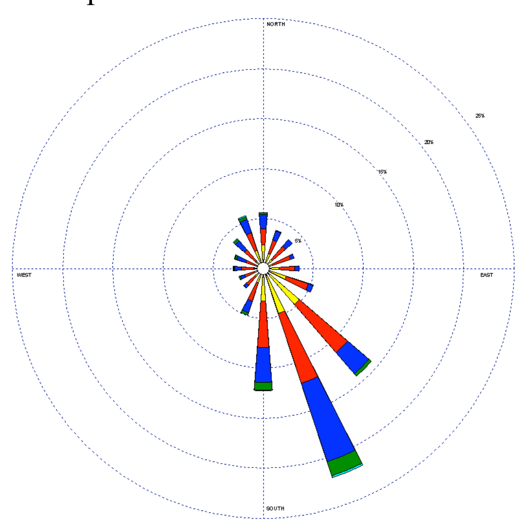

Figure 5. Watertown, SD wind rose for July.

Meteorological Data
Weather is one of the most important factors that affect the movement and dispersion of odors. The frequency curves used in SDOFT combine the average wind speeds and atmospheric stability conditions in South Dakota from various weather stations over a ten-year period. The data was used in the air

distribution model *Aermod* to develop the annoyance-free curves. Since there is considerable variability in weather conditions for any location, SDOFT could over or under estimate an odor events in any given month.

Prevailing Wind Direction
SDOFT accounts for prevailing wind direction by incorporating information from South Dakota wind roses (Figure 5). A wind rose shows the information about the distributions of wind speeds, and the frequency of the varying wind directions. Wind roses vary from one location to the next but neighboring areas are often fairly similar. For more information on South Dakota wind roses visit the web at: http://climate.sdstate.edu/climate_site/climate.htm

Topography
Topography (hills, valleys, trees, buildings, etc.) also affects odor dispersion. During very stable meteorological conditions with cooling temperatures, odorous air may travel long distances along low lying areas. Wind breaks may increase the dilution of odorous air thus reducing the travel distance of annoying odors. The "odor annoyance-free" curves given in Figure 4-15 were obtained assuming flat terrain with no obstructions. Significantly more effort is required to conduct a site specific odor evaluation which would include topographic features.

Cumulative Impact
SDOFT may have the ability to consider the cumulative odor impact of multiple farm sites. However, to do this accurately would require site specific information. A general idea of cumulative impact on a specific location could be demonstrated by adding the annoyance-free frequencies from the surrounding farm sites.

Example

A farmer has a 1200-head sow gestation and farrowing operation with mechanical ventilation and pull plug gutters and a single stage earthen basin (Figure 6) located in Brookings County. The county suggests setbacks equal to the 97% annoyance-free curve at the nearest community. Currently, the nearest community is 0.5 miles (2640 feet) directly south from the swine site. Does this farm meet the county guidelines?

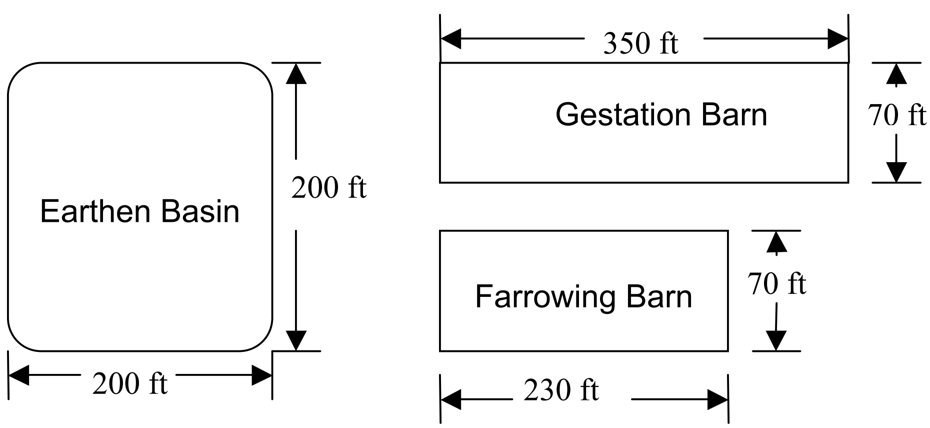

Figure 6. Example farm sketch.

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 Worksheet 2 along with the odor emission numbers for each source from Table 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). These areas are entered in Column C of Table 5.

Step 3 There is no odor control technology for this site, so 1 is entered in Column D 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 TOEF for the site. In this case the TOEF is 719.

Step 6 Brookings County is located in Area 1, therefore use annoyance-free curves from Figures 8 – 19. Since the residence in question is south of the site use Figure 10 and locate 719 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 0.55 miles or 2900 ft. Therefore, this farm does not comply with the county guidlines because the community will experience annoying odors greater than the allowable 3% per month (22 hours per month).

Worksheet 2 for calculating the Total Odor Emission Factor.

Column A Odor source	**Column B Odor Emission Number/ft.^{2}**	**Column C Area (sq. ft.)**	**Column D Odor Control Factor**	**Column E Odor Emission Factor (B x C x D/10,000)**
1. Gestation Barn	146	24,500	1	358
2. Farrowing Barn	68	16,100	1	109
3. Basin	63	40,000	1	252
Total Odor Emission Factor (TOEF) sum of Column E =				719

To comply with county regulations, the farmer must reduce odor emissions from his animal production site. 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) and a geotextile cover on the manure storage (odor control factor of 0.5). Worksheet 3 indicates the changes in odor emissions with these two modifications. Note that Columns A, B, and C did not change between Table 5 and Table 6.

With a new TOEF, go to Figure 9 and find 173 on the horizontal scale. For this TOEF only the 99% annoyance-free curve is not reached by a 0.5 mile setback. The odor control technologies used in this example are presently available and have been evaluated.

Worksheet 3 for calculating the Total Odor Emission Factor.

Column A Odor source	**Column B Odor Emission Number/ft.^{2}**	**Column C Area (sq. ft.)**	**Column D Odor Control Factor**	**Column E Odor Emission Factor (B x C x D/10,000)**
1. Gestation Barn	146	24,500	0.1	36
2. Farrowing Barn	68	16,100	0.1	11
3. Basin	63	40,000	0.5	126
Total Odor Emission Factor (TOEF) sum of Column E =				173

Find more information on manure and odor at http://abe.sdstate.edu/wastemgmt/

This web site contains a spreadsheet which calculates the distances for each of the annoyance – free curves. Figure 7 shows the contours for the example. The figure is a typical method or visually presenting the results from the model and can overlaid a map of the community.

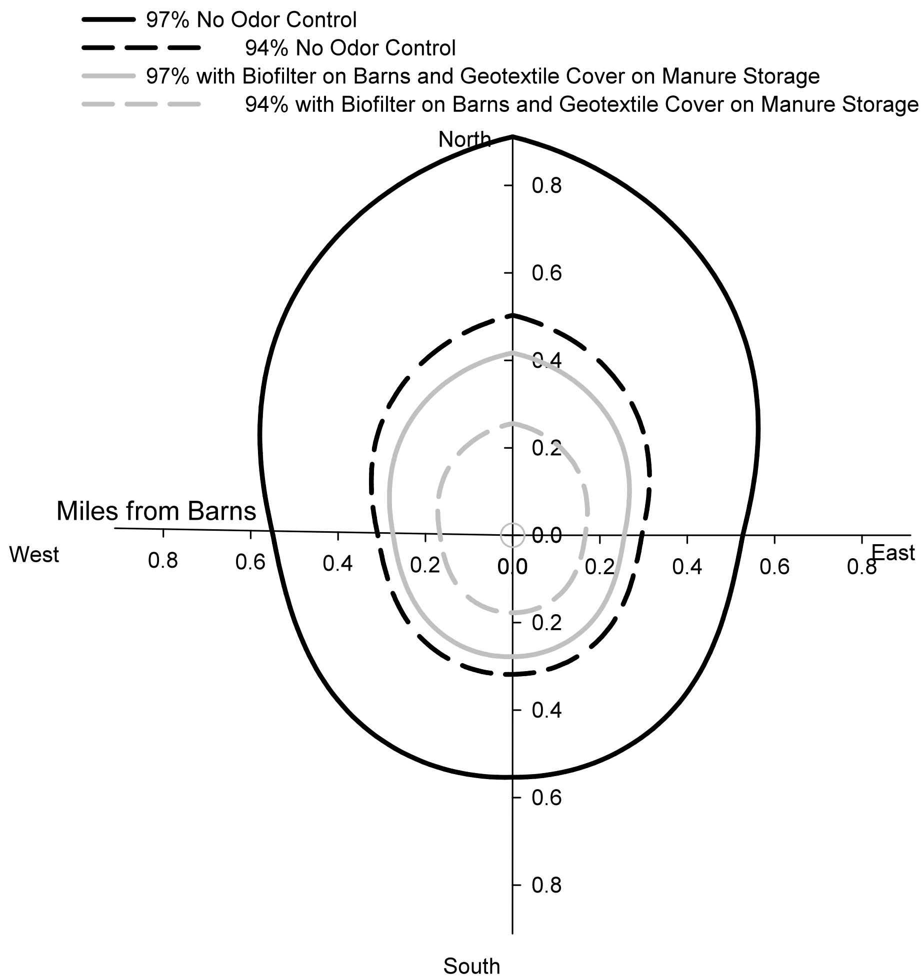

Figure 7 Contours of 97% and 94% annoyance-free distances for example

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Area 1

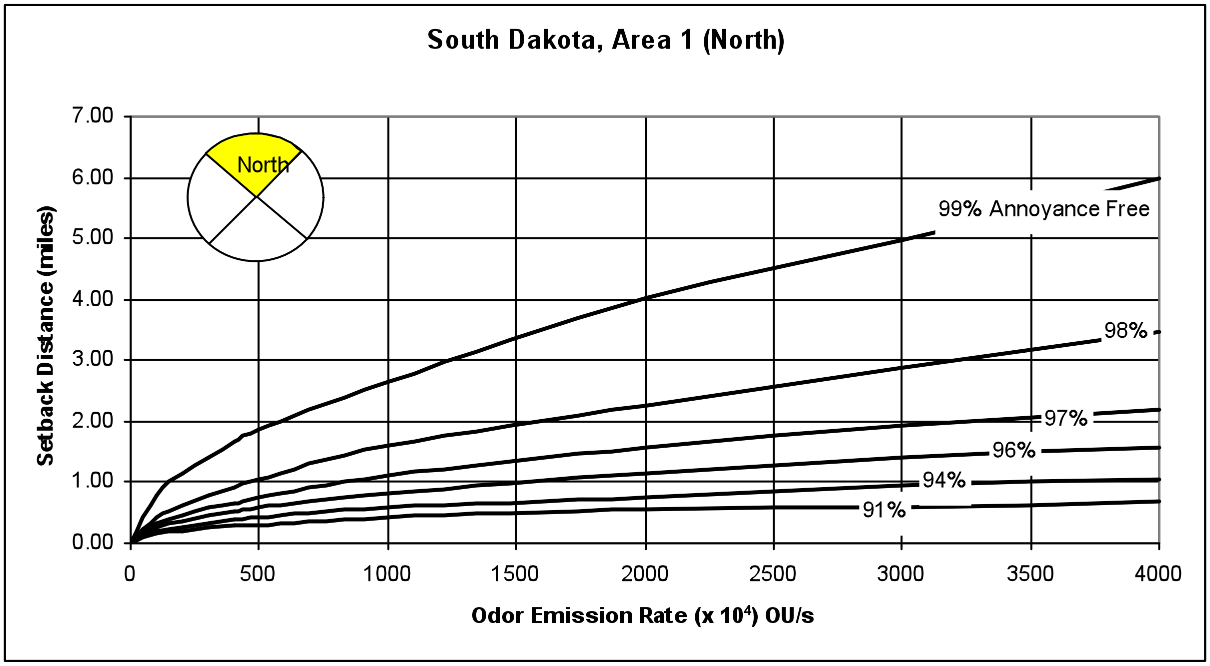

Figure 8. Estimated setback distances (miles) in Northeast South Dakota to the north of a farm at different odor annoyance-free frequency requirements.

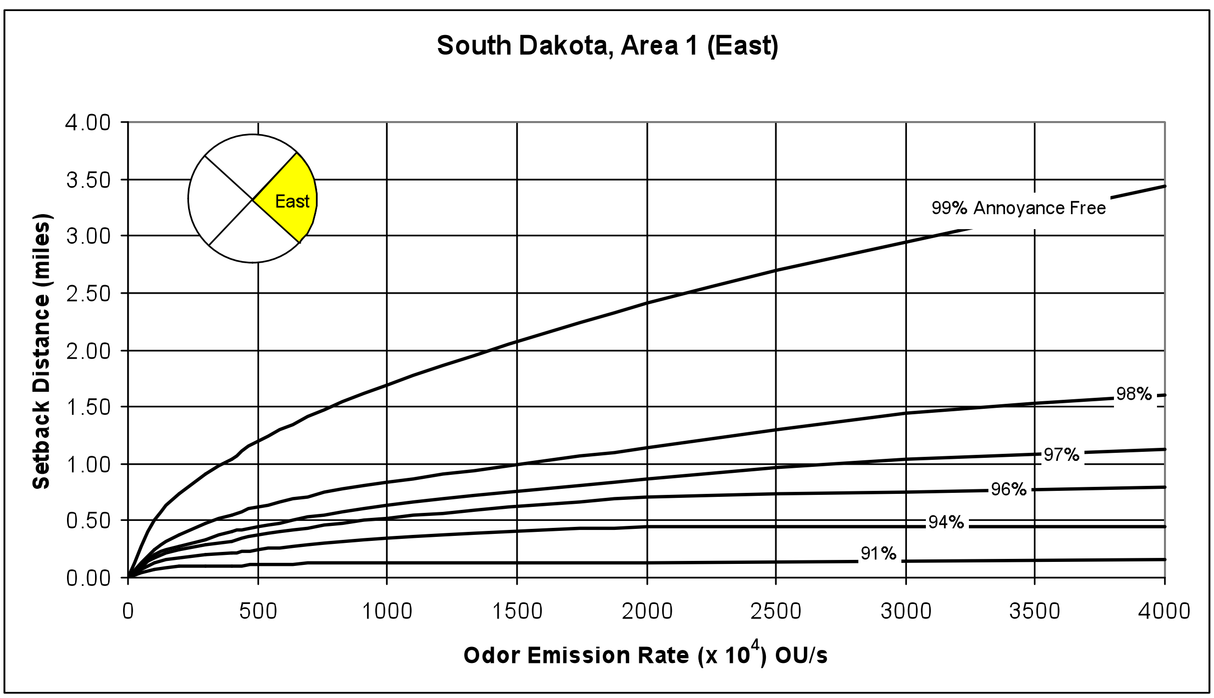

Figure 9. Estimated setback distances (miles) in Northeast South Dakota to the east of a farm at different odor annoyance-free frequency requirements.

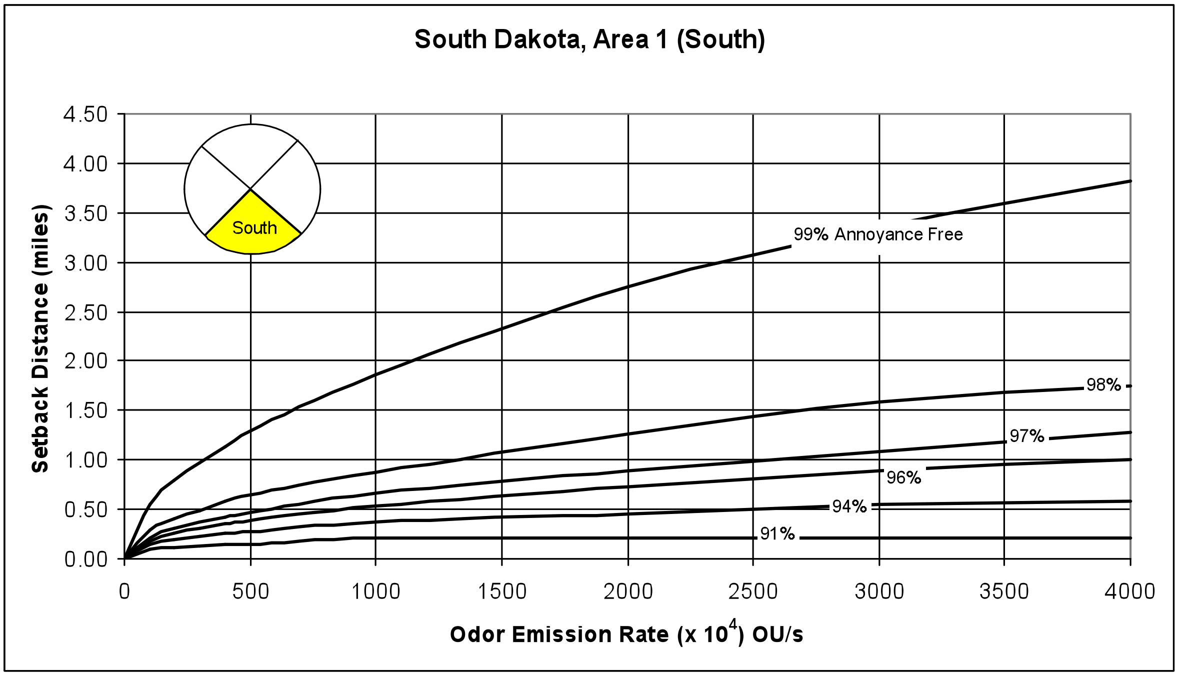

Figure 10. Estimated setback distances (miles) in Northeast South Dakota to the south of a farm at different odor annoyance-free frequency requirements.

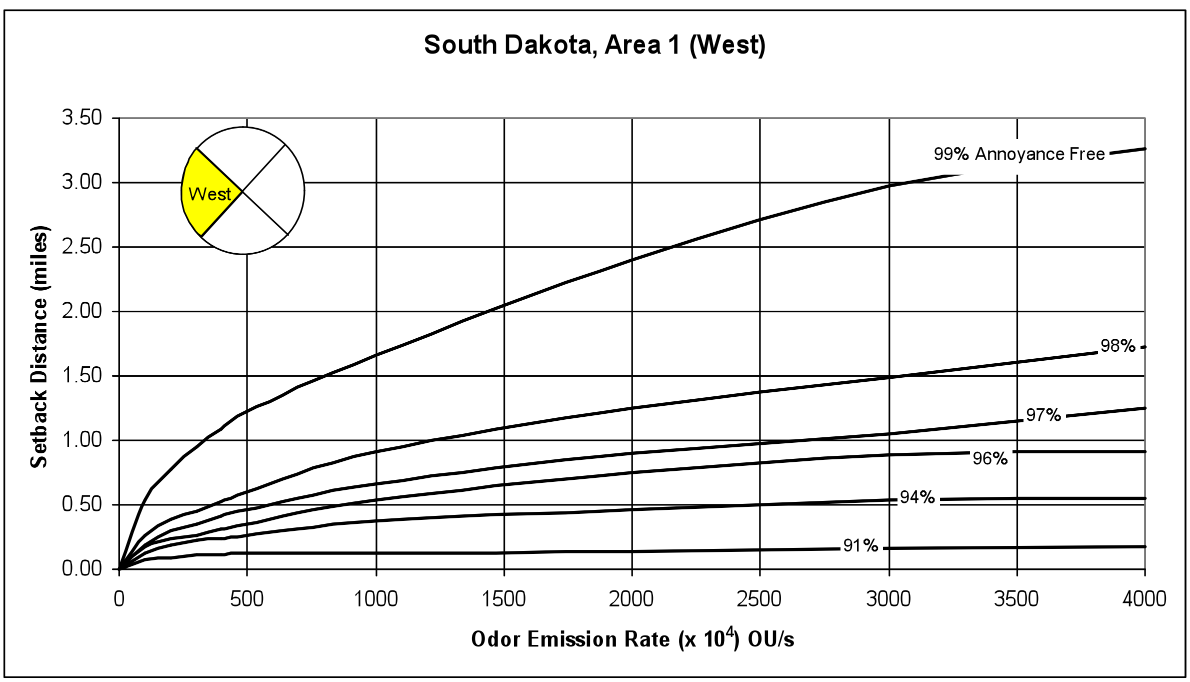

Figure 11. Estimated setback distances (miles) in Northeast South Dakota to the west of a farm at different odor annoyance-free frequency requirements.

Area 2

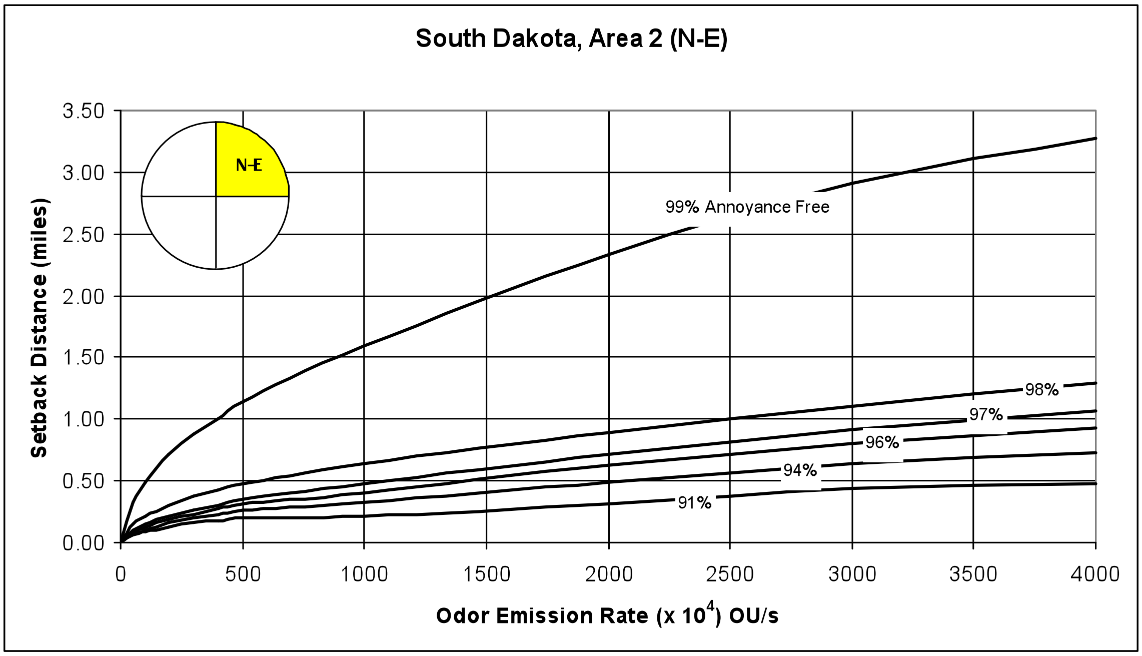

Figure 12. Estimated setback distances (miles) in Southeast South Dakota to the northeast of a farm at different odor annoyance-free frequency requirements.

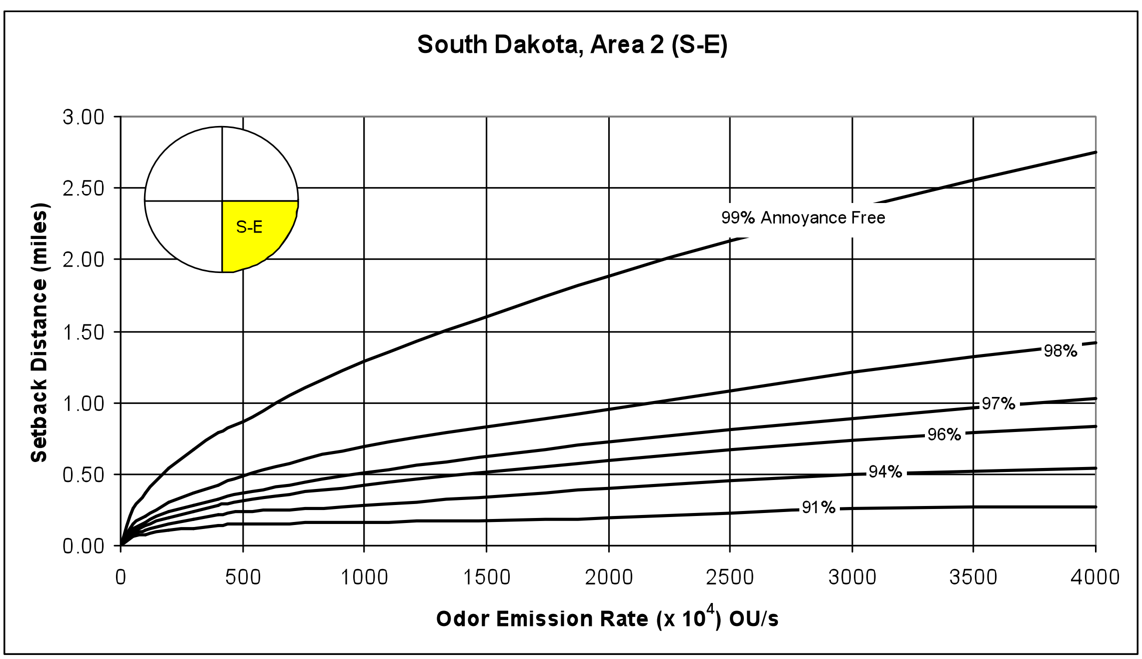

Figure 13. Estimated setback distances (miles) in Southeast South Dakota to the southeast of a farm at different odor annoyance-free frequency requirements.

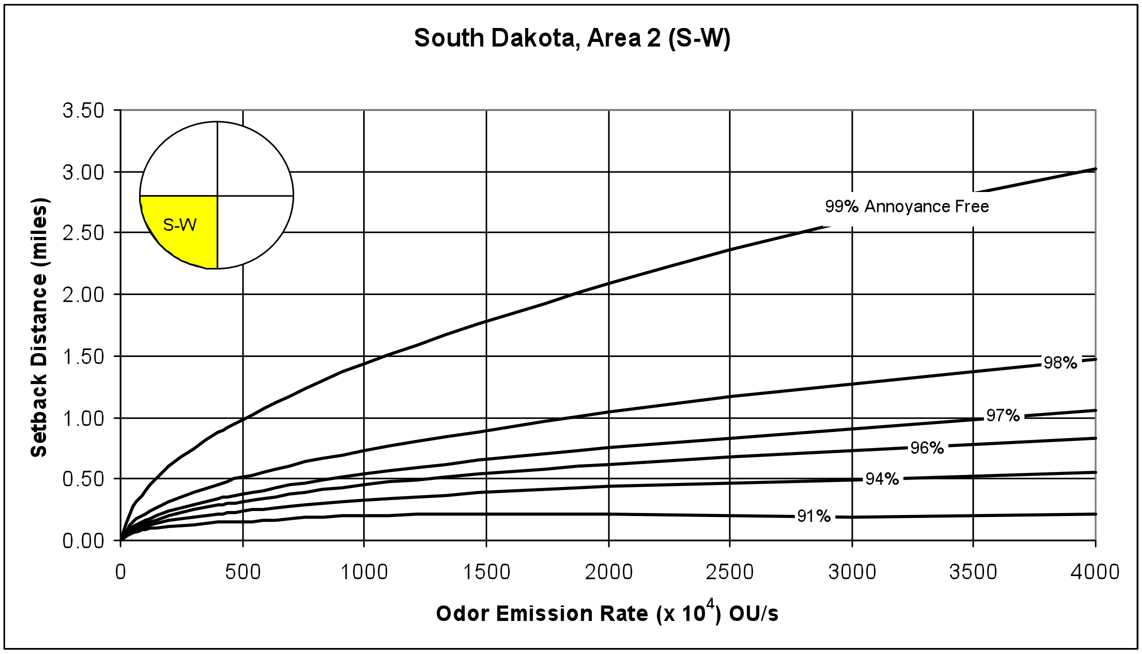

Figure 14. Estimated setback distances (miles) in Southeast South Dakota to the southwest of a farm at different odor annoyance-free frequency requirements.

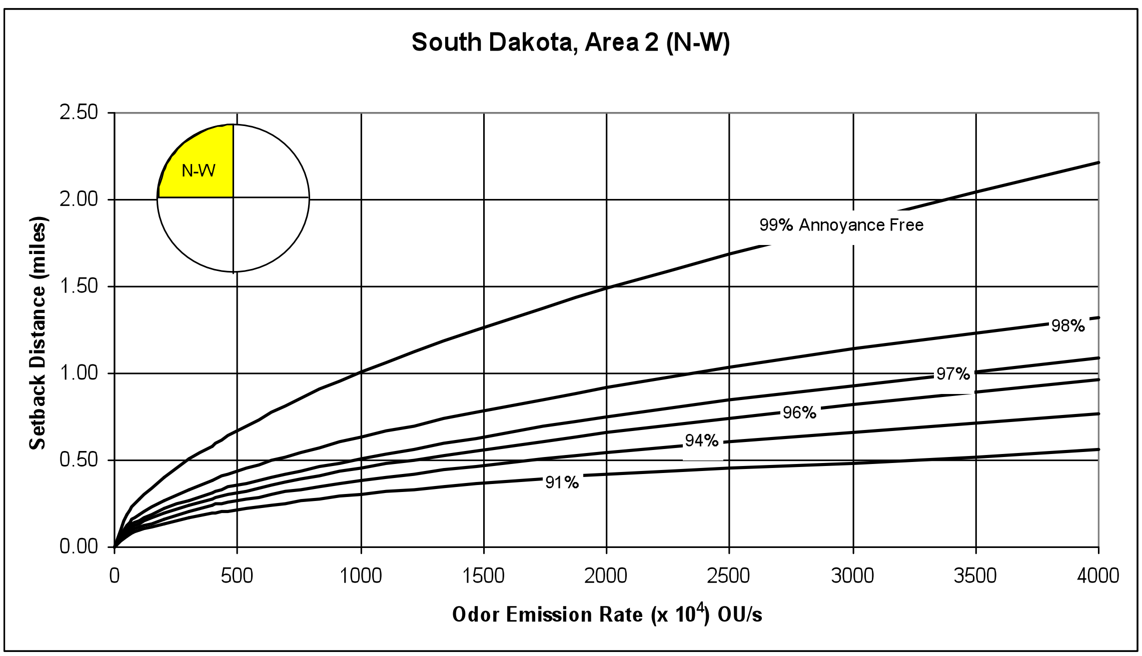

Figure 15. Estimated setback distances (miles) in Southeast South Dakota to the northwest of a farm at different odor annoyance-free frequency requirements.

Area 3

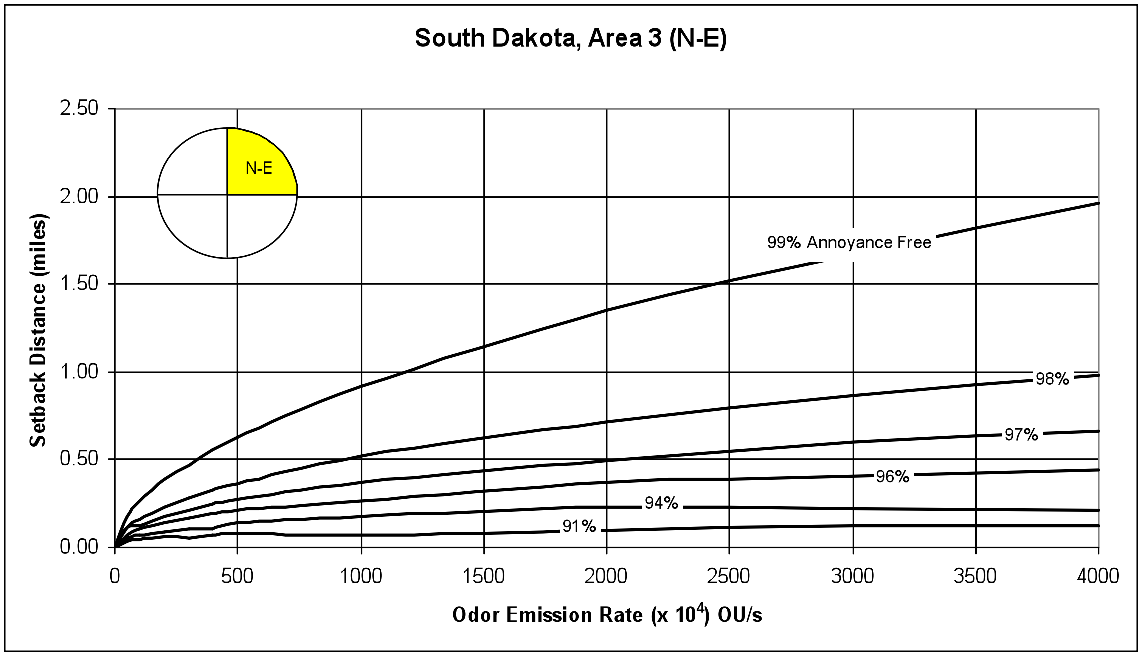

Figure 16. Estimated setback distances (miles) in Western South Dakota to the northeast of a farm at different odor annoyance-free frequency requirements.

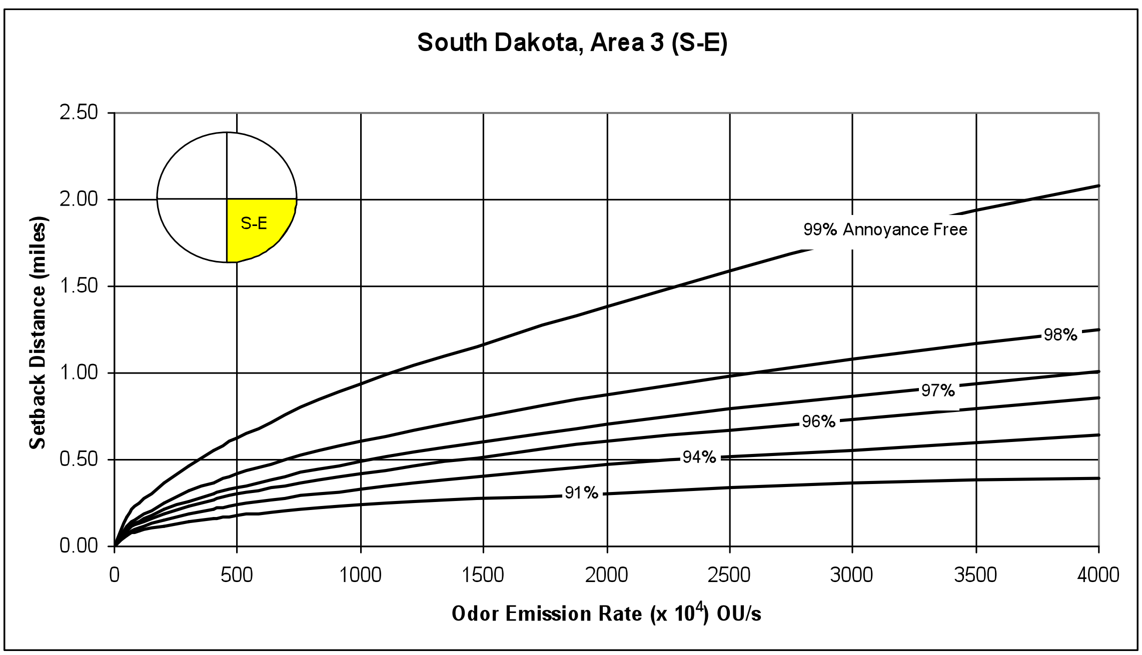

Figure 17. Estimated setback distances (miles) in Western South Dakota to the southeast of a farm at different odor annoyance-free frequency requirements.

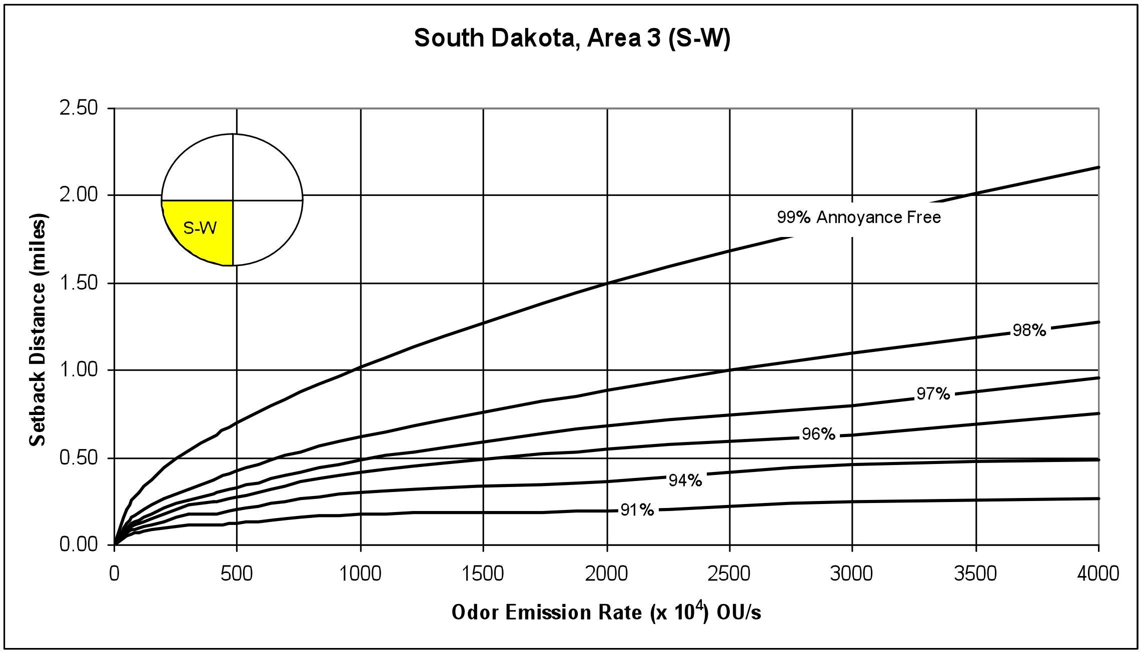

Figure 18. Estimated setback distances (miles) in Western South Dakota to the southwest of a farm at different odor annoyance-free frequency requirements.

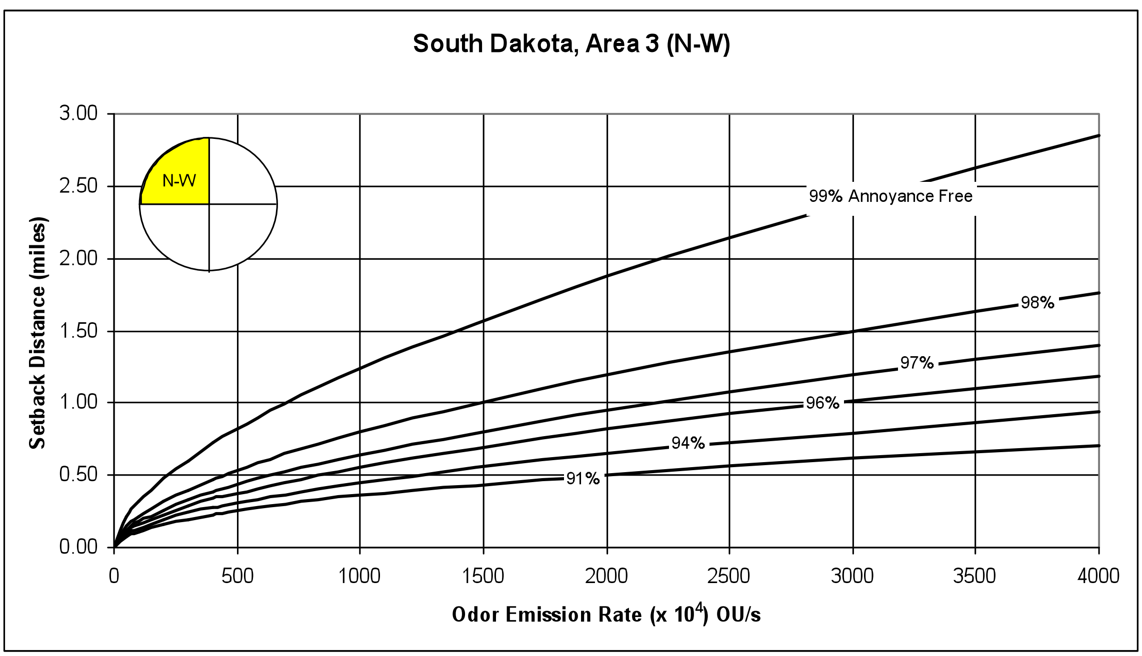

Figure 19. Estimated setback distances (miles) in Western South Dakota to the northwest of a farm at different odor annoyance-free frequency requirements.