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South Dakota Odor Footprint Tool (SDOFT), Part II: Examples

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Introduction

Part 1 of this fact sheet introduces the scientific principles behind the SDOFT and the formulation of the tool. As a follow-up, Part 2 focuses on the use of the SDOFT to establish appropriate setback distances and it may be used independently as a quick guide. Three example questions are given for streamlining the learning process. The first example shows how to manually calculate the total odor emission rate and then how to establish setback distances using the data charts and tables in Part 1. The second and third examples show how to use the SDOFT to accomplish similar tasks in a simple and intuitive fashion.

Example 1. Manual Calculation of Setback Distances for a Sow Farm

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 1) located in Brookings County, SD. The county suggests setbacks equal to the 97% annoyance-free curve from 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?

The calculation involves a two-step procedure. Step 1 estimates the total odor emission rate from a farm site and Step 2 determines the required setback distances by simulating the atmospheric dispersion of the odor emission from the site.

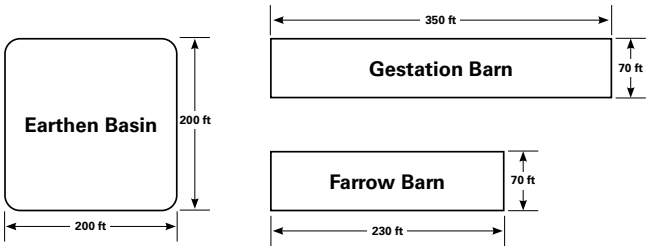


Figure 1. Sketch of the example sow farm.

Step 1. Determining the total odor emission rate from a farm site

A worksheet is used to assist the calculation (Table 1). 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 rate for each odor source
- **Column C.** List the area of each source (in the unit of square foot, ft^2)

Table 1. Worksheet for calculating the total odor emission fate for a farm site.

Column A Odor source	Column B Odor emission factor (OU/ft^2-sec)	Column C Area (ft^2)	Column D Odor control factor	Column E Odor emission rate (× 10^4 OU/sec)
1.				
2.				
3.				
4.				
			Total odor emission rate; the sum of Column E =	

- **Column D.** Enter any odor control factors
- **Column E.** Fill in Column E 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 rate for the site.

For this example question:

1. There are three odor sources at the site: two buildings and one basin. The three sources' names are listed in Column A (Table 2), along with the odor emission factors for each source acquired from Tables 1 and 2 of Part 1.

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

3. There is no odor control technology for this farm site. So 1 (i.e., no odor reduction) is entered in Column D for each source.

4. The odor emission factor (E) for each source is found by multiplying the numbers in Columns B, C, and D and dividing the product by 10,000.

5. The three odor emission factors in Column E are summed to determine the total odor emission rate for the site. In this case, the number is 719 × 10^4 OU/sec.

Step 2. Determining the setback distance through odor dispersion modeling

Brookings County is located in Area 1. Therefore, we should use annoyance-free curves from Figures S1-S4 of Part 1. Since the residence in question is south of the site, Figure S3 of Part 1 should be used. On the chart, we first locate 719 on the x-axis (Figure 2) and move up vertically to the 97% odor annoyance-free curve. Then, from the crossing point, we move horizontally to the vertical axis. 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 guidelines because the community will experience annoying odors greater than the allowable 3% per month (22 hours per month).

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; according to Table 3 of Part 1) and a geotextile cover on the manure storage (odor control factor of 0.5). Table 3 indicates the changes in odor emissions with these two modifications. Note that Columns A, B, and C did not change between Tables 2 and 3.

With the reduced total odor emission rate, we use Figure S3 of Part 1 to redo the setback calculation. We locate 173 on the x-axis and draw a vertical line until it reaches the 97% odor annoyance-free curve (Figure 3). Then, from the crossing point, we draw a horizontal line until it reaches the vertical axis. The minimum setback distance to achieve 97% annoyance-

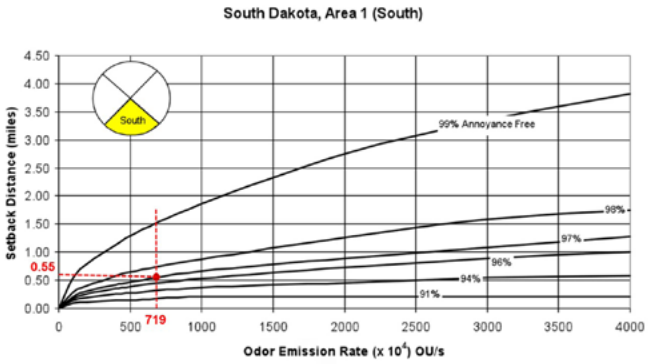


Figure 2. Determining the setback distance south to the farm site at the 97% annoyance-free level.

Table 2. Worksheet for calculating the total odor emission fate for the example sow farm.

Column A Odor source	Column B Odor emission factor (OU/ft^2-sec)	Column C Area (ft^2)	Column D Odor control factor	Column E Odor emission rate (× 10^4 OU/sec)
1. Gestation barn	146	24,500	1	358
2. Farrowing barn	68	16,100	1	109
3. Earthen basin	63	40,000	1	252
			Total odor emission rate; the sum of Column E =	719

Table 2. Worksheet for calculating the total odor emission fate for the example sow farm with odor control technology implemented.

Column A Odor source	Column B Odor emission factor (OU/ft²-sec)	Column C Area (ft²)	Column D Odor control factor	Column E Odor emission rate (× 10⁴ OU/sec)
1. Gestation barn	146	24,500	0.1	36
2. Farrowing barn	68	16,100	0.1	11
3. Earthen basin	63	40,000	0.5	126
Total odor emission rate; the sum of Column E =				173

free is approximately 0.25 miles or 1320 ft. The control technologies implemented should enable compliance with the county guidelines.

Example 2. Use the SDOFT to Establish Setback Distances for the Same Sow Farm

The SDOFT is available as an MS Excel file with a single spreadsheet (https://www.sdstate.edu/agricultural-and-biosystems-engineering/south-dakota-odor-footprint-tool). The spreadsheet consists of two parts. The upper part is for data input and the bottom part displays the calculation results. A brief description of the procedure is also given on the top of the spreadsheet. The data input includes five steps:

1. Select South Dakota County from a drop-down list where the site is located (Figure 4). For this example question, we select Brookings. This allows the SDOFT to load the odor annoyance-free frequency curve charts (Figures S1-S4 of Part 1) for Area 1, Northeast South Dakota where Brookings is located.

2. Select Odor Source Type from a drop-down list for each odor source at the site. There are four source types currently included in the SDOFT: cattle yard, dairy barn, swine barn, and manure storage. This farm site has three odor sources: two swine barns and one manure storage.

3. Select housing or manure storage type from a drop-down list for each odor source at the site. For the two swine barns at the site, one is a gestation barn with pull plug gutters (shallow pits) and the other is a farrowing barn with pull pug gutters. The manure storage here is an earthen storage basin. Steps 2 and 3 together allow the SDOFT to load the odor emission factors for each odor source (Tables 2 and 3 of Part 1). These factors are displayed under the row of "Housing Type or Manure Storage" as "Emitting Factor". If your particular barn does not match any of the available options, please contact Dr. Xufei Yang to help determine which option is most appropriate to use in your situation.

4. Enter the size (width and length; in ft.) of the emitting surface for each odor source at the site. Once the width and length numbers are entered,

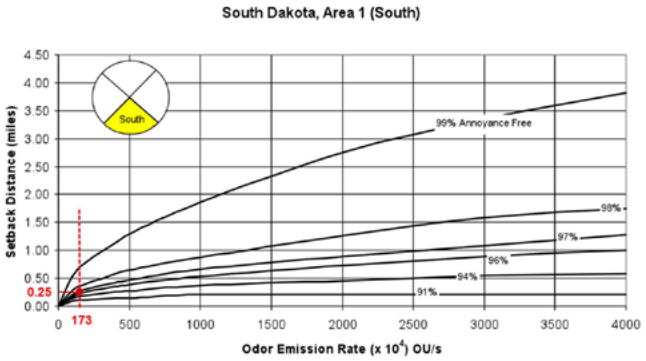


Figure 3. Determining the setback distance south to the farm site at the 97% annoyance-free level, with biofilters and geotextile covers implemented.

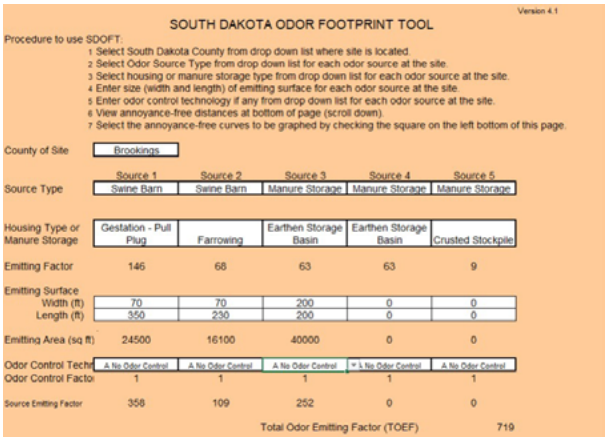


Figure 4. Inputting data for the swine farm in the SDOFT.

the spreadsheet automatically calculates the emitting area of each odor source in the unit of ft^2.

5. Select Odor Control Technology from a drop-down list for each odor source at the site. Without any odor control technology implemented at the site, we should select "A No Odor Control". Once this is done, the SDOFT automatically calculates the total odor emission rate (shown as "Total Odor Emitting Factor (TOEF)"). We can see that the TOEF number here is the same as that calculated with the manual method.

The setback calculation results are displayed in a graph and a table at the bottom of the spreadsheet (Figure 5). The graph maps the frequency of the occurrence of odor annoyance surrounding the farm site, with the site located at the origin (0, 0), i.e., the center of the graph. The x-axis is west to east and the y-axis is south to north, in the unit of mile. A user can select which annoyance-free curves to display by checking or unchecking the options left to the graph. For this example, since Brookings County suggests the use of 97% odor annoyance-free as the management goal, we select the 97% annoyance-free curve only. Any residence beyond the curve would expect to experience odor annoyance in less than 3% of the time from April through October. For a community directly south from the farm site, the curve shows that the minimum setback distance is ~0.55 miles, slightly greater than the actual distance (0.5 miles). Therefore, this farm does not comply with the county guidelines. The setback distances can also be read from the Table. For communities south from the farm site, the setback distance required to be at the 97%

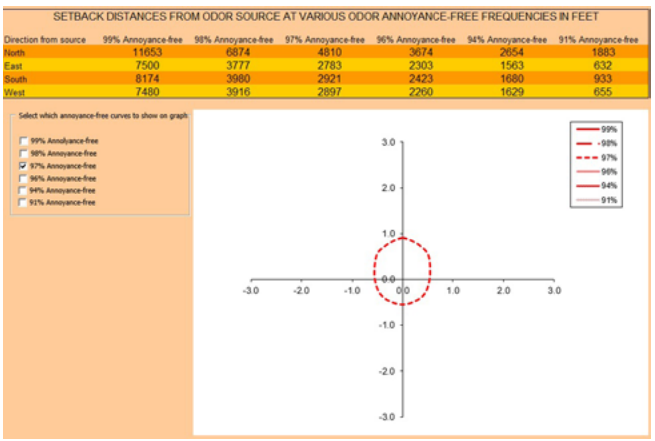


Figure 5. Setback calculation results for the swine farm using the SDOFT.

annoyance-free level is 2921 ft, which is greater than the actual distance (2641 ft), suggesting a necessity to implement odor control technologies at the site.

The SDOFT is useful for the evaluating appropriate odor control technologies. A user can compare different odor control options regarding their effectiveness in reducing the total odor emission rate from a farm site and in reducing the setback distance required to be compliant with the local guidelines. For example, applying oil sprinkling in the gestation barn alone would reduce the total emission rate to 540 $\times 10^4$ OU/sec and lower down the required setback distance from 0.55 miles to 0.41 miles.

Example 3. Use the SDOFT to Establish Setback Distances for a Dairy Farm

A family dairy farm in Lake County, SD consists of a free-stall barn, a dirt lot, and an earthen storage basin (Figure 6). The county suggests setbacks equal to the 94% annoyance-free curve at the nearest community. No odor control is implemented in any facility. Use the SDOFT to establish the setback distance from the farm to a community north from the farm.

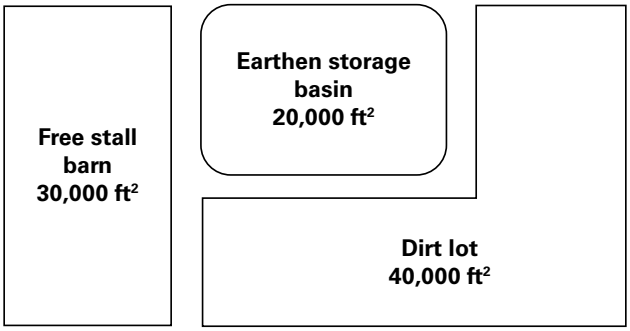


Figure 6. Sketch of the example dairy farm.

The same procedure as that for Example 2 is followed (Figure 7).

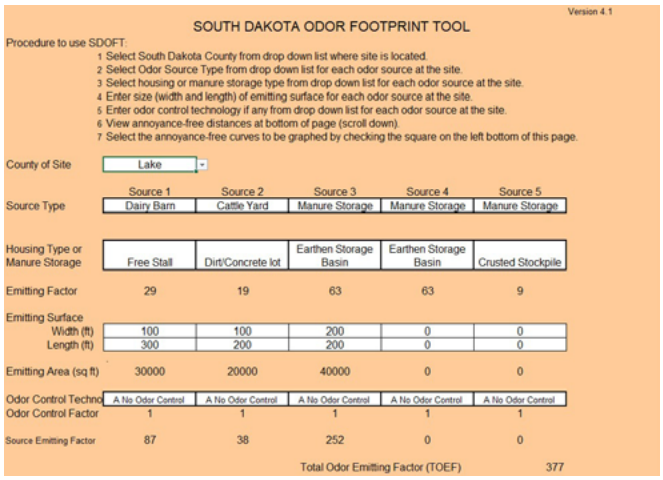
1. County of site. Select Lake.

2. Source type. There are three odor sources: a dairy barn, a manure storage, and a dirt lot. For the dirt lot, no dirt lot option is listed under the source type of dairy barn so cattle yard is selected to approximate.

3. Housing type or manure storage. Under dairy barn, select free stall. Under cattle yard, select dirt/concrete lot. Under manure storage, select earthen storage basin.

4. Emitting surface (width and length). Width and length are unknown for each facility. To make it even worse, the dirt lot is not rectangular. How should a user handle this situation? Recall that the entire farm site would be considered as a point source, i.e. a single point during odor dispersion modeling. Thus, the specific shape of each odor source does not matter. The key thing is to ensure each source's emitting area is correct so that the total odor emission rate from the entire site is correct. Therefore, for each odor source, we can assume any width and length numbers that lead to the correct emitting area. For example, we may assume a size of 100 × 300 ft for the free-stall dairy barn, 100 × 200 ft for the earthen basin, and 200 × 200 ft for the dirt lot.

5. Odor Control Technology. Select "A No Odor Control". The total odor emission rate (shown as "Total Odor Emitting Factor (TOEF)") is 377 × 10^4 OU/sec.



SOUTH DAKOTA ODOR FOOTPRINT TOOL

Version 4.1

Procedure to use SDOFT:

1 Select South Dakota County from drop down list where site is located.
2 Select Odor Source Type from drop down list for each odor source at the site.
3 Select housing or manure storage type from drop down list for each odor source at the site.
4 Enter size (width and length) of emitting surface for each odor source at the site.
5 Enter odor control technology if any from drop down list for each odor source at the site.
6 View annoyance-free distances at bottom of page (scroll down).
7 Select the annoyance-free curves to be graphed by checking the square on the left bottom of this page.

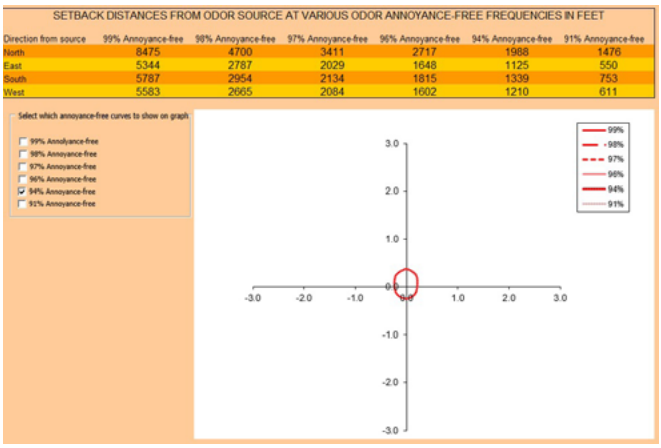
County of Site: Lake

	Source 1	Source 2	Source 3	Source 4	Source 5
Source Type	Dairy Barn	Cattle Yard	Manure Storage	Manure Storage	Manure Storage
Housing Type or Manure Storage	Free Stall	Dirt/Concrete lot	Earthen Storage Basin	Earthen Storage Basin	Crusted Stockpile
Emitting Factor	29	19	63	63	9
Emitting Surface Width (ft)	100	100	200	0	0
Emitting Surface Length (ft)	300	200	200	0	0
Emitting Area (sq ft)	30000	20000	40000	0	0
Odor Control Techno	A No Odor Control	A No Odor Control	A No Odor Control	A No Odor Control	A No Odor Control
Odor Control Factor	1	1	1	1	1
Source Emitting Factor	87	38	252	0	0

Total Odor Emitting Factor (TOEF) 377

Figure 7. Inputting data for the dairy farm in the SDOFT.

Figure 8 shows the setback calculation results. We can see from the graph that for a community directly north from the farm site, a minimal setback distance of ~0.3 miles is required to meet the county's management goal (94% annoyance-free). The setback distance (1988 ft.) can also be read from the table above the graph.



SETBACK DISTANCES FROM ODOR SOURCE AT VARIOUS ODOR ANNOYANCE-FREE FREQUENCIES IN FEET

Direction from source	99% Annoyance-free	98% Annoyance-free	97% Annoyance-free	96% Annoyance-free	94% Annoyance-free	91% Annoyance-free
North	8475	4700	3411	2717	1988	1476
East	5344	2787	2029	1648	1125	550
South	5787	2954	2134	1815	1339	753
West	5583	2665	2084	1602	1210	611

Select which annoyance-free curves to show on graph

- [ ] 99% Annoyance-free
- [ ] 98% Annoyance-free
- [ ] 97% Annoyance-free
- [ ] 96% Annoyance-free
- [x] 94% Annoyance-free
- [ ] 91% Annoyance-free

Figure 8. Setback calculation results for the dairy farm using the SDOFT.

Data Interpretation

Perimeter or center?

A common question is whether the setback distance should be figured from the outermost perimeter or the center of a "farm site". The answer is the outmost perimeter. However, the "farm site" here includes odor sources only and does not include any non-odor sources. With that being said, the outermost perimeter should not be confused with the perimeter of a single housing or manure storage area, or the property line of a farm. A major reason for this is that the entire site is treated as a point source, i.e. a single point during odor dispersion modeling. The size and shape of the farm site are not considered in the calculated setback distances.

Effect of complex topography

The SDOFT simulates odor dispersion from a farm to its neighbor(s) by assuming flat terrain. However, rolling hills are common in South Dakota. As discussed in Part 1 of this fact sheet, topography (e.g. hills and valleys) has a significant impact on odor dispersion, and accordingly, the establishment of an appropriate setback distance. A question then is: How should we apply the SDOFT in a hilly area where the topographic effect is significant? The following are the comments made by Guo et al. (2005) on such a scenario:

- Add a margin factor of 10% or 20% to the setback distance determined by the SDOFT (i.e. 1.1 or 1.2 × SDOFT setback distance)
- A margin factor of 10% may be used for a livestock farm located on a hill
- A margin factor of 20% may be used for a livestock farm located in a valley

However, it is noteworthy that no clear definition about hills or valleys was provided in the same article. Thus, cautions must be taken when you cite those margin factors. Alternatively, you may refer to Table 1 and Figure 9 in "Determining Separation Distances Using the Nebraska Odor Footprint Tools: User's Manual for the Spreadsheet Tool" (https://water.unl.edu/documents/Users%20manual%20-%20Spreadsheet%20NOFT.pdf) for terrain adjustment factors. For cases requiring special handling, you may contact SDSU and request for advanced odor modeling.

Acknowledgments

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References

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