TECHNICAL NOTE

DESIGN TECHNICAL NOTE NO. SD2011-1 **OCTOBER 3, 2011**

BEEF AND DAIRY BEDDED PACK BARN PLANNING AND DESIGN

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Introduction

In South Dakota (SD), traditionally open feedlots have been used for backgrounding and finishing cattle. Recently, feeding cattle under roof with a bedded pack has become more common. These facilities are typically called bedded pack, deep-bedded pack, or compost barns. This document introduces bedded pack barns and focuses on describing our design methodology to determine the amount of required solid manure storage for these types of facilities.

This technical note is limited in nature, and intended to give a brief description of bedded pack barns, and to describe the design process to determine the amount of required manure storage. For a more in depth review of different bedded pack facilities, it is recommended to review the items in the *Additional Information* and *References* sections of this document.

The research, assistance, guidance, and expertise of the authors of documents within the references section were greatly appreciated to aid us in the development of this technical note. We would also like to thank the producers who allowed us to view their facilities and let us take manure samples within their barns. In addition, we would like to thank Michael Russelle, with United States Department of Agriculture Agricultural Research Service, for the use of their bedded pack manure sampler.

Section 1: Planning Bedded Pack Barns in South Dakota

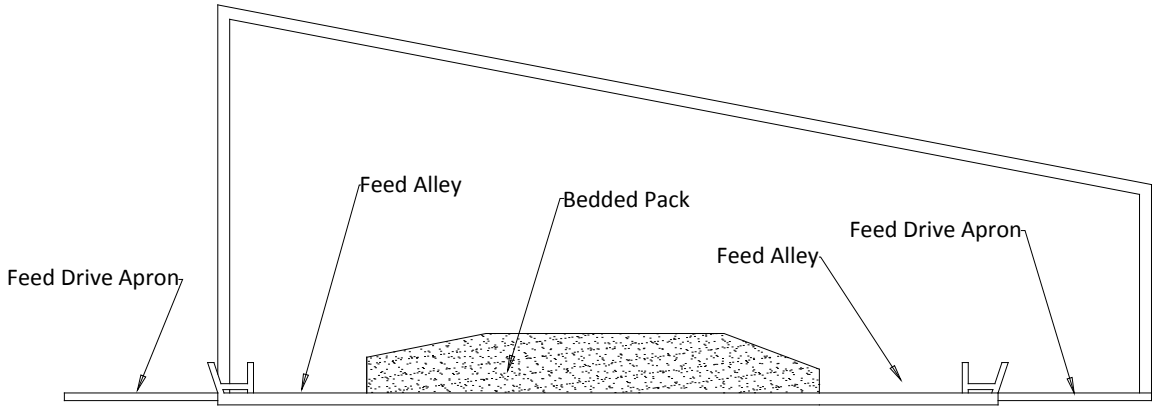
What is a Bedded Pack Barn?

A bedded pack barn is an alternative for livestock producers in SD. Producers are increasingly utilizing this type of animal housing for beef cattle feeding and dairy operations in this region. There are different variations of bedded pack barns, which include different types of building, different types of bedding and different types of bed pack management.

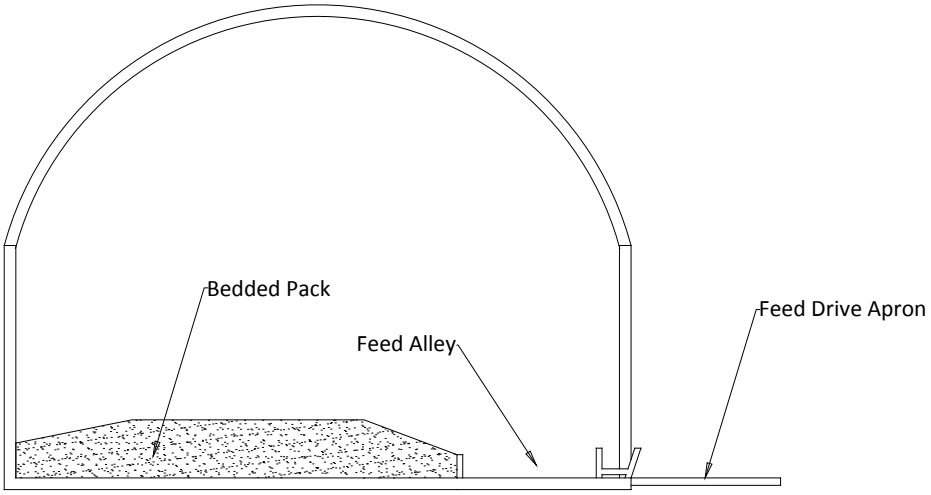
Typical Mono-Slope Barn

Typical Hoop Barn

The two most common types of bedded pack buildings are hoop structures and mono-slope structures. See pictures above and side views below. Hoop structures are generally constructed with wood or concrete sidewalls, tubular steel truss system, and a woven polyethylene fabric cover. Mono-slope structures have been typically constructed with concrete walls, steel frame, and steel roof.



Typical Mono-Slope Barn



Typical Hoop Barn

Both hoop and mono-slope barns are generally orientated in an east-west direction. They are normally naturally ventilated, so the east-west orientation takes advantage of the prevailing wind direction. The mono-slope designed barns facilitate solar radiation and natural ventilation. Sufficient ventilation is needed to remove animal heat and moisture, so it is recommended that these barns be located in an open area to allow for adequate ventilation.

Many different types of bedding are used in these barns. In this region, the typical bedding types are corn stalks, straw, soybean stubble, and wood chips. Bedding is usually added to the barn at regular intervals, usually ranging from every other day to once a week. The amount of bedding added varies depending on the size of animals, density of animals, air temperature and humidity. More bedding is needed during the winter, in wet periods, and for poorly ventilated barns. More bedding is necessary to keep the bedded pack drier during these periods when more moisture is available to be absorbed. When not enough bedding is added to the barn, the producer will generally tell by noticing that the animals are dirtier. A specific amount of bedding usage is variable between different facilities, but average use has been recorded in various research projects.

Published animal performance from bedded pack barns has shown to be similar to open feedlots. A study by Honeyman et al., (2009) showed no differences for animal weight gain, average daily gain, average daily feed intake, or feed/gain ratio between cattle in an open lot with a covered feed alley to animals in a hoop barn. There were also no differences in fat cover, ribeye area, marbling, quality grades or yield grades by housing type in this study. Results at the SD State University (SDSU) Opportunities Farm of comparative feeding between an open lot, open lot with the feeding area covered, and a monoslope barn showed small differences in cattle performance between the different facility types. See specific results from this study in Appendix B and Appendix C.

Producers vary in their management of removal of the bedded pack and manure from the barns. Most producers scrape the manure from the feed alleys at regular intervals ranging from every day to every couple weeks. Producer management within the bedded pack portion of the barn varies more than feed alley management. While most facilities do not actively manage the bedded pack other than add more bedding, some dairy operations

stir, till, or aerate the bed pack to enhance aerobic biological degradation of the manure and urine. These barns are typically referred to as “compost barns,” although bedding temperatures and chemical characteristics indicate that the bedding material is not composting (Barberg et al., 2007). Observations do suggest that the bedded pack in “compost barns” is aerobic and biologically active.

Timing of removal of the bedded pack portion of the barn also varies. Some facilities remove the bedded pack following the removal of each turn of cattle from each pen, while some facilities remove the bedded pack annually, and others allow the bedded pack to accumulate for years. The facilities that allow the bedded pack to accumulate rely on the animals to track and push bedding and manure into the feed alleys, which is scraped on a regular basis. Scraped feed alley and bedded pack manure is sometimes stored in a manure bay or a designated stacking area at the end or middle of the barn. See photo below.

Solid manure storage bay

From a manure management standpoint, bedded pack barns provide two distinct differences from traditional open lots. The first is that the bedding in the barns absorbs the water in the manure and the second is that the roof keeps precipitation out of the cattle feeding area. This eliminates runoff from the feeding operation and the need for runoff collection, storage, and treatment measures. For facilities with geotechnical conditions not conducive to constructing runoff storage ponds, this can make a barn the preferred option to feed cattle at the location.

Advantages of a bedded pack barn versus a traditional open lot

- The animal density (animals per square foot of space) is higher, so the overall space required for the cattle feeding area is smaller.
- Collection, storage, and application of open lot runoff are eliminated.
- Manure storage and application is more predictable and consistent than open lot runoff. Open lot runoff is dependent on variable precipitation, not on manure and bedding accumulation.

- Lower chance of a catastrophic manure spill since manure is stored and handled as a solid.
- There is a somewhat controlled environment inside of the barn for the animals and the producer.
- In locations with high ground water where a holding pond is not feasible, a barn may provide an option to feed cattle.
- There is generally less dust leaving a bedded pack barn versus an open feedlot.

Disadvantages of a bedded pack barn versus a traditional open lot

- Higher initial investment.
- Adequate bedding and an area to store the bedding are necessary.
- Ventilation of the facility must be managed.
- More regular maintenance to add bedding and remove manure and bedded pack from the barn.

Structural requirements for mono-slope barns and hoop barns are included in the SD Conservation Practice Standards (CPS) for Waste Storage Facility (313) and Roofs and Covers (367). As noted in these standards, "The design and construction of the roof structure shall be approved and sealed by a professional engineer licensed to practice engineering the State of SD." Typically, a non-NRCS engineer is providing this sealed design and construction of the roof structure. To facilitate getting the required documentation from the non-NRCS engineer, the SD-ENG-59 form should be used for both the design and the certification of the roof structure. If more than one non-NRCS engineer are providing the design and/or certification of the construction, multiple SD-ENG-59 forms should be used. It is the responsibility of the NRCS engineer exercising job approval authority to ensure that certifications are obtained for the design and construction of all of the roof structure. The definition and extents of a roof structure are also described in the SD-ENG-59 form.

For the floor of the bedded pack building, there are five different types of floors that are allowed in the SD CPS for Waste Storage Facility (313). Standard drawings for these five floor types are available on the standard drawing section of the SD NRCS Web site.

Section 2: Site Visits and Bedded Pack Measurements

In an effort to gather information about bedded pack barns, we completed several site visits in 2010 and 2011. During these visits, we took measurements of the bedded pack moisture contents to compare them to the published results and aid in our design methodology. The following is a summary of these site visits.

Site 1

We completed this site visit in May 2010. The site consists of 2 hoop barns that are approximately 500' long and 50' wide. Approximate widths of the barns included a 23' wide bed pack, 12' wide scrape alley, and 15' wide indoor feed drive alley. The scrape alley was concrete, the bedded pack area was clay lined and the indoor feed drive alley was gravel and soil. The long dimension of the barns is oriented in the NE to SW direction. There were approximately 375 head in the barns but varied depending on the size of the heifers or cows in the barn. There were holstein and some holstein/jersey cross dairy cows in the barns.

During our site visit, the ground straw bedded pack probably averaged 10" to 12" deep in the barn. The producer indicated that they get the bedded pack about another 2-3' higher in the barn than the current depth. They have adjustable gates that can be raised as the bedded pack gets higher. The bedded pack is tilled approximately every 3 days. They use approximately 1,200 bales per year for bedding. The bales weigh approximately 1,000 pounds each.

We took two manure samples from the northern part of the south barn. The first manure sample was from a depth of 13" (at the bottom of the bed pack) and had a moisture content of 63.0 percent. The second sample was taken at a 9" depth and had a moisture content of 72.4 percent. They were removing the bedded pack from the barns and putting it outside in rows for further composting. We took manure samples from the rows, which had moisture contents of 68.9 percent, 72.0 percent, and 75.4 percent.

Site 2

We completed this site visit in September 2010. The facility consists of 1 hoop barn that houses 500 steers. The barn has six total pens and has an indoor feed drive alley with a gravel surface. The producer indicated that they generally house the steers at an animal density of 40 ft^2/head. They bed the barn with about 1.5 bales of straw per head each year and the bedded pack is not tilled or aerated.

The center of the bedded area within each pen is not cleaned out, but the perimeter of each pen is scraped out on a weekly or semi-weekly basis. The bedded pack in the center of the pens has accumulated to about two feet high.

We took three manure samples from middle areas of the bed pack. One sample was in the easternmost pen and two were from the westernmost pen. The sample from the east pen had a moisture content of 65.7 percent while the samples from the west pen had moisture contents of 67.7 percent and 63.8 percent.

Site 3

We visited this beef feeder cattle site in January 2011. The facility consists of 2 hoop barns that are approximately 70' wide and 200' long. The feed drive alleys on both barns

are outside of the barns. The barns are bedded with over 5 pounds per head per day of corn stalks and the deepest part of the bed pack was roughly 15" deep. They scrape the feed alley about every week or two to a manure bay at the end of the barn. This manure bay is roughly 12'-15' long.

It was somewhat humid in the barns at the time of our visit, with a light fog within the barns. We took three manure samples from the barn. The sample from the south barn, which had lighter cattle than the north barn, had a moisture content of 72.0 percent, while the sample from the north barn had 73.0 percent moisture content. We also took a sample from the area of the barn that is scraped on a weekly or semi-weekly basis and it had a moisture content of 82.4 percent.

Site 4

We took manure samples from this site in May 2010. The facility consists of one hoop barn for approximately 200 head of beef feeder cattle. The 35' wide barn has a 23' wide bedded pack area and a 12' wide feed alley that is scraped approximately once a week. The feed drive alley is outside of the barn but the roof does overhang over the edge of the feed bunk. Thirty feet at the end of the barn is allocated for manure stacking.

Chopped straw bedding is added every other day to the facility at the rate of slightly over one 800 to 900 pound bale per day. The producer does not till or mechanically aerate the bedded pack. The bedded pack ranged from 9" at the edge of the feed ally to 24" deep at the side of the barn opposite of the feed alley. Approximately the top four-to-five inches of bed pack was drier and then it appeared to be relatively consistent in moisture content lower in the bedded pack.

Four manure samples were taken within the main bedded pack section of the barn. Sample number 1 was taken at a depth of 12" and had a 75.8 percent moisture content, sample 2 at a depth of 18" and had a 75.3 percent moisture content, sample 3 at a depth of 20" and had a moisture content of 74.5 percent, and sample 4 at a depth of 8" and had a moisture content of 74.2 percent. One manure sample was taken in the feed lane scrape area and produced a moisture content of 63.7 percent. We also took one manure sample in a manure stacking area that was out in an application field and the moisture content of this manure was measured at 76.1 percent.

Site 5

We visited this steel mono-slope facility in November 2010. This facility consists of one barn with an approximate beef feeder capacity of 2,000 head. There are feed bunks on both sides of the barn with bed packs maintained in the middle of each pen. At the time of the site visit, there were approximately 900 pound cattle in the pens and the bed pack was 6"-8" deep.

We took manure sample from two different pens near the west end of the barn. The manure samples had moisture contents of 68.6 percent and 80.4 percent.

Site 6

We visited this steel mono-slope facility in January 2011. It is a multiple barn facility with a capacity of several thousand beef feeder cattle. At the time of our visit, it was humid enough in the barns to cause a relatively thick fog. Chopped straw is used as the bedding for the bedded pack.

Manure samples were taken from three representative pens at the facility. The moisture content of these samples measured 70.5 percent, 72.3 percent, and 73.4 percent.

Section 3: Bedded Pack Barn Design

Design background and criteria

The following are specific solid manure storage criteria for bedded pack barns (roofed structures) that are listed in the October 2011 versions of the SD CPSs for Waste Storage Facility (313) and Roofs and Covers (367):

1. The minimum required capacity for the portion of the manure handled as a solid is 270 days. Storage capacity for manure, bedding, and other wastes shall be provided within the roofed structure and/or other storage facilities such as stacking pads.

2. For storage facilities exposed to direct precipitation, the liquid runoff must be stored or may be contained within a vegetated treatment area meeting the requirements of NRCS CPS Vegetated Treatment Area (635).

3. The minimum animal space requirements are:
   Dairy heifers (less than 650 pounds): 28 square ft./head
   Dairy heifers (650 - 800 pounds): 32 square ft./head
   Dairy heifers (800 – 1,200 pounds): 40 square ft./head
   Dairy cows (more than 1,200 pounds): 50 square ft./head
   Beef (less than 600 pounds): 25 square ft./head
   Beef (more than 600 pounds): 35 square ft./head

Historically, to determine the volume of a manure and bedding combination, the NRCS in SD, has used the methodology described on page 2.2 of Midwest Plan Service 18 – Livestock Waste Facilities Handbook, Second Edition (1985) and by equation 6 on page 17 of Midwest Plan Service 18, Section 1 – Manure Characteristics, Revised Second Edition (2004). This methodology is described in the following equation:

Total volume = manure volume + half of the bedding volume

In addition to the calculated volume from the above equation, we have also considered additional volume reduction if the producer is actively tilling or aerating the manure pack.

By interviewing producers and gathering information regarding typical bedding addition, pack density, pack moisture, and manure/bedding removal from these barns, we don't feel that the answers we are getting from the equation above are reasonable. We feel that the equation above overestimates that amount of manure/bedding combination that develops within the barn and other manure/bedding storage areas.

We plan to use a volume calculation methodology that uses the solid inputs to the bedded pack, along with the final moisture content and density of the bedded pack. This avoids having to estimate the evaporation of water and absorption of manure liquids into the bedding, which the above equation is essentially estimating. Available research and the manure samples from the site visits we completed show that the final bedded pack moisture content is somewhat consistent. We will now use the following equation to determine the volume of manure and bedding combination:

Total volume = (weight of the solid portion of the manure + weight of the solid portion of the bedding) / (1 – bedded pack moisture content) / (bedded pack density)

Where:

- Solid portion of the manure is in pounds
- Bedding is in pounds
- Bedded pack moisture content is as a decimal, for example 70 percent = 0.70
- Bedded pack density is in pounds per cubic foot

This equation can be described further with the following two equations:

Solid inputs weight = (weight of the solid portion of the manure + weight of the solid portion of the bedding)

Bedded pack solids content = (1-bedded pack moisture content)

The first equation can then be reduced to:

Total volume = (Solid inputs weight) / (bedded pack solids content) / (bedded pack density)

Since the:

Total bedded pack weight = (Solid inputs weight) / (bedded pack solids content)

Then the:

Total volume = (Total bedded pack weight) / (bedded pack density)

We will use the MidWest Plan Service (MWPS) values for the solid portion of the manure and university research for the bedding amounts, moisture content of the bedded pack and density of the bedded pack. As noted above, we took some manure measurements from the site visits we completed to compare barns in our area to the university research values we are using.

To compare these two different equations, we will use the following scenario:

- 100 finishing beef cattle weighing 1,100 pounds for a 270-day storage period
- 5.18 pounds of bedding per animal per day (Honeyman, et al. 2009), Note that the bedding is assumed all dry matter, which makes the answer slightly conservative, i.e., the calculated required storage is more than if the bedding was assumed as having some moisture.
- 7 pounds/cubic feet density of chopped straw bedding (MWPS-18, 2004)
- 68.1 percent moisture content of the bedded pack (Spiehs, et al. 2011)
- 58.2 pounds/cubic feet density of the bedded pack (Russelle, et al. 2009)
- Daily manure production of 0.86 cubic feet per animal (54 pounds per animal) (MWPS-18, 2004)

- 92 percent water content of the excreted manure (MWPS-18, 2004)

In order to make an equal comparison, scrape alley manure is not considered in this scenario. Using the MWPS equation of:

Total volume = manure volume + half of the bedding volume

Total volume = (0.86 cubic feet)*(100 head)*(270 days) + (0.5)*((5.18 pounds) / (7 pounds per cubic foot))*(100 head)*(270 days)

Total volume = (0.86 * 100 * 270) + (0.5 * (5.18/7) * 100 * 270)

Total volume = 23,220 cubic feet + 9,990 cubic feet

Total volume = 33,210 cubic feet

In comparison, using the equation from the *SD NRCS Bedded Pack Design Worksheet* of:

Total volume = (weight of the solid portion of the manure + weight of the solid portion of the bedding) / (1 – bedded pack moisture content) / (bedded pack density)

Total volume = (((54 pounds * (1 – 0.92) percent solids) + 5.18 pounds) / ((1 – 0.681) percent moisture) / (58.2 pounds per cubic feet)) * (100 head) * (270 days)

Total volume = (((54 * 0.08 + 5.18)) / (1 – 0.681) / (58.2)) * (100 head) * (270 days)

Total volume = 13,815.7 cubic feet

For this specific scenario, the required bedded pack volume of the *SD NRCS Bedded Pack Design Worksheet* would be 13,815.7 divided by 33,210, or 41.6 percent, of the required bedded pack volume using the MWPS – 18 equation.

Section 4: Bedded Pack Barn Design Spreadsheet

The *SD NRCS Bedded Pack Design Worksheet* can be used to determine the adequacy of the storage capacity of a bedded pack barn. If necessary, the spreadsheet will also determine the amount of required volume to be stored in an outside stacking facility. This spreadsheet is located on the SD NRCS Web site at http://www.sd.nrcs.usda.gov/technical/Engineering_Tools.html.

Facility Info sheet

Within this spreadsheet, use the **Facility Info sheet** to enter the basic information about the animals, type of barn, and bedded pack management at the facility. The following items are entered by the user on the **Facility Info sheet**:

- Landowner
- Conservation District
- Field Office
- County
- Designed by and date
- Checked by
- Number of animals for each designated animal type and size: Manure volumes and manure characteristics are taken from the MWPS table depending on the animals indicated. The required animal space requirements are also calculated from the requirements within the SD CPS Waste Storage Facility (313).
- Length and Width of Available Animal Space: These values are used to calculate the available area for animals within the building. An error message is produced if the available area for the animals is below the required animal area.
- Days of Design Storage Used for the facility: This value is used to calculate the total bedded pack and scraped manure requirements for the facility. The required minimum amount of days according to the SD CPS Waste Storage Facility (313) is 270.
- Type of Barn: Choose either Mono-Slope Barn or Hoop Barn from the drop-down list. This selection affects the amount of bedding used in the calculations. For hoop barns, the bedding used is 5.18 lbs/day/animal, and for mono-slope barns the value is 6.1 lbs/day/animal.
- Regular tilling or aeration of the bedded pack: Choose either yes or no from the drop-down list. For the calculations in the spreadsheet, the moisture content of the bedded pack is 63.4 percent for a regularly aerated bedded pack. The moisture content of the bedded pack is 68.1 percent when not regularly aerated.
- Bedded pack removed to a stacking area inside the barn: Choose either yes or no from the drop-down list. The answer to this question determines which scenario you should use for your calculations.
- Feed Alley scraped to a stacking area: Choose either yes or no from the drop-down list. The answer to this question determines which scenario you should use for your calculations.

- Stacking area for scraped feed alley inside or outside the barn: Choose either "Stacking Area within the Barn" or "Outside Stacking Area" from the drop-down list. The answer to this question determines which scenario you should use for your design.

After entering the required information and answering the questions on the **Facility Info sheet**, the user is directed to a scenario to use for their design. When using the different **Scenario Sheets**, utilize the comments in the cells for additional information.

Scenario 1 sheet

Scenario 1 is for a barn where the manure and bedding is stored within the bedded pack in the barn. There is no separate scraping of the feed alley. Any excess bedded pack that does not fit in the building will be stored in a separate structure. The following items are entered by the user on the **Scenario 1 sheet**:

- Length of building (for bedded pack): This length is used for the bedded pack volume calculations, so should only include the length of the building that has the bedded pack.
- Various bedded pack dimensions: These dimensions should correspond to the diagram. The dimensions are for the maximum bedded pack size to calculate the maximum available volume in the bedded pack.
- Feed alley width and height: These dimensions should correspond to the diagram. The dimensions are for the maximum anticipated dimensions of the feed alley manure to calculate the maximum available volume.
- Length of building (for feed alley): This length is used for the feed alley manure volume calculations, so should only include the length of the building that has manure stored in the feed alley.

The following items are calculated on the **Scenario 1 sheet**:

- Available Total Bedded Pack and Feed Alley Storage: This is the calculated available volume within the bedded pack and feed alley. This is calculated from the dimensions entered for the bedded pack and feed alley manure.
- Required Bedded Pack and Feed Alley Volume for Storage Period: This is the calculated required volume of bedded pack and feed alley manure. This answer is calculated from the data in this section. For additional information about this calculation, see the description of the previous calculations in this technical note and in the comments within the spreadsheet cells.
- Required Extra Bedded Pack and Feed Alley Volume for Storage Period: This volume is the bedded pack and feed alley manure that will need to be stored in a separate structure.

Scenario 2 sheet

Scenario 2 is for a barn where the feed alley is scraped on a regular basis to a separate manure storage outside of the barn. Manure and bedding is stored within the bedded pack in the barn, and any excess bedded pack that does not fit in the building will be stored in a separate structure. The following items are entered by the user on the **Scenario 2 sheet**:

- Length of building (for bedded pack): This length is used for the bedded pack volume calculations, so should only include the length of the building that has the bedded pack.
- Various bedded pack dimensions: These dimensions should correspond to the diagram. The dimensions are for the maximum bedded pack size to calculate the maximum available volume in the bedded pack.
- Feed alley width: This dimension should correspond to the diagram. This dimension is used to calculate the total width of the barn.

The following items are calculated on the **Scenario 2 sheet**:

- Available Total Bedded Pack Storage: This is the calculated available volume within the bedded pack. This is calculated from the dimensions entered for the bedded pack.
- Required Bedded Pack Volume for Storage Period: This is the required volume of bedded pack for the design. This answer is calculated from the data in this section. For additional information about this calculation, see the description of the calculations previously in this technical note and in the comments within the spreadsheet cells.
- Required Extra Bedded Pack Volume for Storage Period: This volume is the bedded pack and that will need to be stored in a separate structure.
- Required Scraped Feed Alley Manure Volume for Storage Period: This is the required volume for scraped feed alley manure that will need to be stored in a separate structure. This answer is calculated from the data in this section. For additional information about this calculation, see the description of the previous calculations in this technical note and in the comments within the spreadsheet cells.
- Summary: A narrative of the calculations is provided at the bottom of the sheet.

Scenario 3 sheet

Scenario 3 is for a facility where the feed alley is scraped on a regular basis to a separate manure storage outside of the barn. Manure and bedding is stored within the bedded pack in the barn, and any excess bedded pack that does not fit in the bedded pack area will be stored in a designated solid manure stacking area within the barn. The following items are entered by the user on the **Scenario 3 sheet**:

- Length of building (for bedded pack): This length is used for the bedded pack volume calculations, so should only include the length of the building that has the bedded pack.
- Various bedded pack dimensions: These dimensions should correspond to the diagram. The dimensions are for the maximum bedded pack size to calculate the maximum available volume in the bedded pack.

- Feed alley width: This dimension should correspond to the diagram. This dimension is used to calculate the total width of the barn.
- Various within building stacking area dimensions: These dimensions should correspond to the bedded pack diagram, which can also be used for the stacking area dimensions. The dimensions should be the maximum size of the stacked manure to calculate the maximum available volume of the stacking area.

The following items are calculated on the **Scenario 3 sheet**:

- Available Total Bedded Pack Storage: This is the calculated available volume within the bedded pack. This is calculated from the dimensions entered for the bedded pack.
- Required Bedded Pack Volume for Storage Period: This is the required volume of bedded pack for the design. This answer is calculated from the data in this section. For additional information about this calculation, see the description of the calculations previously in this technical note and in the comments within the spreadsheet cells.
- Extra Bedded Pack Volume Required for Stacking Area: This volume is the excess bedded pack that will need to be stored in the stacking area that is in the barn.
- Required Length of Building for Stacking area: This is the required length of the designated stacking area. This is calculated by using the stacking area dimensions and the extra bed pack volume that needs to go to this stacking area.
- Required Scraped Feed Alley Manure Volume for Storage Period: This is the required volume for scraped feed alley manure that will need to be stored in a separate structure. This answer is calculated from the data in this section. For additional information about this calculation, see the description of the previous calculations in this technical note and in the comments within the spreadsheet cells.
- Summary: A narrative of the calculations is provided at the bottom of the sheet.

Scenario 4 sheet

Scenario 4 is for an operation where the feed alley is scraped on a regular basis to a designated solid manure stacking area within the barn. Manure and bedding is stored within the bedded pack in the barn, and any excess bedded pack that does not fit in the bedded pack area will also be stored in the designated solid manure stacking area within the barn. The following items are entered by the user on the **Scenario 4 sheet**:

- Length of building (for bedded pack): This length is used for the bedded pack volume calculations so should only include the length of the building that has the bedded pack.
- Various bedded pack dimensions: These dimensions should correspond to the diagram. The dimensions are for the maximum bedded pack size to calculate the maximum available volume in the bedded pack.
- Feed alley width: This dimension should correspond to the diagram. This dimension is used to calculate the total width of the barn.
- Various within building stacking area dimensions: These dimensions should correspond to the bedded pack diagram, which can also be used for the stacking area dimensions. The dimensions should be the maximum size of the stacked manure to calculate the maximum available volume of the stacking area.

The following items are calculated on the **Scenario 4 sheet**:

- Available Total Bedded Pack Storage: This is the calculated available volume within the bedded pack. This is calculated from the dimensions entered for the bedded pack.
- Required Bedded Pack Volume for Storage Period: This is the required volume of bedded pack for the design. This answer is calculated from the data in this section. For additional information about this calculation, see the description of the calculations previously in this technical note and in the comments within the spreadsheet cells.
- Required Scraped Feed Alley Manure Volume for Storage Period: This is the required volume for scraped feed alley manure that will need to be stored in the stacking facility within the barn. This answer is calculated from the data in this section. For additional information about this calculation, see the description of the previous calculations in this technical note and in the comments within the spreadsheet cells.
- Required Extra Bedded Pack Volume for Storage Period: This volume is the excess bedded pack that will need to be stored in the stacking area that is in the barn.
- Required Total Stacking Area Volume for Storage Period: This is the combined volume of the excess bedded pack and the scraped feed alley manure that will need to be stored in the stacking area that is in the barn.
- Required Length of Building for Stacking area: This is the required length of the designated stacking area. This is calculated by using the stacking area dimensions and the required total stacking area volume.
- Summary: A narrative of the calculations is provided at the bottom of the sheet.

Reference Documents sheet

This sheet contains the documents that were used to obtain spreadsheet values, such as moisture content and bedding. The documents can be opened up by double clicking on the adobe icon next to the document name.

Data sheet

The designer does not need to use this sheet.

Section 5: Additional Information

Several publications, Web sites and Web casts give more in depth information regarding hoop barns and mono-slope facilities than this document. Some suggested publications for further information are:

- *Bedded Hoop Barns for beef cattle* – This is a fact sheet type publication developed by Iowa State University Extension. It can be found at: http://www.iowabeefcenter.org/Docs_feedlot/hoopbarnfactsheet.pdf.

- *Hoop Barns for Beef Cattle, MidWest Plan Service AED 50* – This MWPS document goes through planning, design, operation and other considerations for beef cattle hoop barns. It is a general reference in nature that touches on most items that need to be considered for beef hoop barns. It can be purchased at: https://www.extension.iastate.edu/store/ItemDetail.aspx?ProductID=12099.

- *The University of Minnesota Dairy Extension Compost Barn Web site* – A summary of research and links to additional information regarding dairy compost barns. The site is at: http://www1.extension.umn.edu/dairy/facilities/compost-barns/.

- *Dry Manure Housing Webcast, Bedded Barns for Beef Cattle and Compost Barns for Dairy Cattle* – A Web cast that was presented by the Livestock and Poultry Environmental Learning Center on January 18, 2008. The presenters were Shawn Shouse, Iowa State University, and Kevin Janni, University of Minnesota. The Web cast is archived at: http://www.extension.org/pages/55670/dry-manure-housing-webcast-bedded-barns-for-beef-cattle-and-compost-barns-for-dairy-cattle.

- *Environmental Conditions in Beef Deep-Bedded Mono-Slope Facilities* – This leaflet published by Iowa State University Extension, provides a summary of research completed on two deep-bedded mono-slope facilities in Iowa. Odor, environment characteristics, and bedded pack characteristics are included within the information presented. It is located at: http://www.ans.iastate.edu/report/air/2011pdf/R2582.pdf.

- *Compost Bedded Pack Barns for Dairy Cows* - This is a Web site that describes planning, layout, and bedded pack management for compost dairy barns. It is located at: http://www.extension.org/pages/9471/compost-bedded-pack-barns-for-dairy-cows.

- *Beef Feedlot Systems Manual* – This publication developed by Iowa State University Extension, provides an economic comparison between different types of beef cattle feeding systems. It is at: http://www.extension.iastate.edu/Publications/PM1867.pdf.

- *Beef Cattle Feeding in a Bedded Hoop Barn: Three Year Summary* – This is a leaflet developed by Iowa State University Extension, which provides a cattle performance comparison between types of beef cattle feeding systems. It can be found at: http://www.ans.iastate.edu/report/air/2009pdf/R2403.pdf.

- *A Survey of Manure Characteristics from Bedded Confinement Buildings for Feedlot Beef Production - Progress Report* – This Iowa State University Extension leaflet provides a summary of the bedded pack nutrient characteristics that were observed within several bedded hoop barn. It is located at: http://www.ans.iastate.edu/report/air/2009pdf/R2408.pdf.

- *Environmental Conditions in a Bedded Hoop Barn with Market Beef Cattle* – This leaflet developed by Iowa State University Extension, provides a summary of environmental conditions that were observed within a bedded hoop barn. It is located at: http://www.ans.iastate.edu/report/air/2008pdf/R2326.pdf.

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Appendix A
Bedded Pack Barns Fact Sheet (SD-FS-76)

A fact sheet summarizing the information about beef and dairy bedded pack barns is available for distribution by the SD NRCS. The fact sheet is posted on the SD NRCS Web site and can be found at:

ftp://ftp-fc.sc.egov.usda.gov/SD/www/News/FactSheets/SD-FS-76_Bedded_Pack_Barn.doc

Appendix B
Animal Performance at the SDSU Opportunities Farm

South Dakota Cooperative Extension Service

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Animal Performance in Feedlot Facilities at the Opportunities Farm

The Opportunities Farm (Lennox, SD) has three feedlot facility designs for finishing cattle. Each facility contains 4, 80-head pens. Each pen contains an individual automatic water trough and 80 ft of bunk space (12 in./head). A description of the facilities is below:

- **Open (OPN)** – Open, mounded, soil-surfaced feedlot pens (80 x 275 ft). Mounds are approximately 7 feet tall with 30 ft^2/head space on the mound. Total pen space is 275 ft^2/head. A concrete bunk pad extends 15 ft from the feedbunk into the pen.
- **Partial (PTL)** – Mounded, soil-surfaced feedlot pens (80 x 215 ft) partially covered within a monoslope barn. The barn covers the feed alley, feedbunk, and 20 ft of pen. Concrete extends from the feedbunk and an additional 12 feet beyond the end of the roof. Mounds are 3 ft high.
- **Confinement (CON)** – Concrete surfaced feedlot pens (80 x 40 ft) completely enclosed in a monoslope barn. Deep pack bedding is used in the back half of the pen. Bedding is applied once weekly, and the areas near the feedbunk and water trough are cleaned weekly.

Cattle are sourced on lots of at least 200 head and randomly allotted to one pen in each of the three facilities. Cattle are managed similarly (feed, implant and health protocols, days on feed) across facilities within lot. Beginning in 2004, 28 lots of backgrounded and yearling cattle were sourced (BW = 805 ± 93 lb; range = 628 to 1,004 lb) and managed similarly as to diet, implant and health protocols, and days on feed across facilities within lot. Closeout data were analyzed using mixed models. Fixed affects included facility design, quarter closed (JAN-MAR = quarter 1; APR-JUN = quarter 2; JULY-SEP = quarter 3; and OCT-DEC = quarter 4), and the interaction of facility and quarter closed. Lot was considered a random effect. Results are below:

Feedlot performance of cattle in three facility designs.

	Facility Design				
Item	OPN	PTL	CON	SEM	Probability[1]
Initial BW, lb	808	808	808	17.7	NS
Final BW, lb	1,371[b]	1,387[a]	1,380[a]	15.89	F, F x Q
ADG, lb/d	3.55[b]	3.66[a]	3.62[a]	0.06	F, Q, F x Q
DMI, lb/d	24.5	24.5	24.3	0.38	NS
Feed:Gain	6.96[a]	6.74[b]	6.73[b]	0.09	F, Q, F x Q
Feed:Gain by Quarter Closed					
JAN-MAR	8.03[a]	7.50[b]	7.27[c]	0.19	F
APR-JUN	6.60[a]	6.32[b]	6.36[b]	0.19	F
JUL-SEP	6.54	6.34	6.48	0.19	NS
OCT-DEC	6.66	6.78	6.78	0.19	NS

[1]Probability of the overall F-test. NS = not significant ($P > 0.10$); F = significant facility effect; Q = significant quarter closed effect; F x Q = significant facility x quarter closed interaction ($P < 0.05$).
[a,b,c]Means in a row without a common superscript differ ($P < 0.05$).

When averaged over the year, cattle with fed some protection by a building (PTL and CON) gained faster and were more efficient than cattle fed in open lots (OPN), but facility design interacted with quarter closed for Final BW, ADG, and Feed:Gain. Cattle in PTL and CON were gained faster and were more efficient than OPN when they were on feed mostly during the winter (lots closed in JAN-MAR and APR-JUN. However, performance was similar across facility when cattle were fed mostly in summer and fall (lots closed in JUL-SEP and OCT-DEC. Previous research showed a slight shift in quality grade, with 59.7% of OPN cattle grading Choice or better vs. 64.7 PTL and 65.6% CON cattle (Machado, 2009, Ph.D. Dissertaion, SDSU). When open feedlots have adequate wind protection, mounds, and drainage, animal performance is only slightly improved for cattle are fed a confinement building. If considering building or expanding cattle feedlots in the Northern Plains, improvements in cattle performance in confinement barns must be balanced with feedlot construction expense, manure quality and quantity, and labor and bedding requirements of different facility designs.

Appendix C
Cattle Feeding at the SDSU Opportunities Farm

South Dakota Cooperative Extension Service

Opportunities Farm

What we've learned about cattle feeding facilities at the Opportunities Farm

Facilities:

Each facility contains 4, 80-head pens. Each pen contains an individual automatic water trough and 80 ft of bunk space (12 in./head). A description of the facilities is below:

- **Open (OPN)** – Open, mounded, soil-surfaced feedlot pens (80 x 275 ft). Mounds are approximately 7 feet tall with 30 ft^2/head space on the mound. Total pen space is 275 ft^2/head. A concrete bunk pad extends 15 ft from the feedbunk into the pen.
- **Open with Shelter (OS)** – Mounded, soil-surfaced feedlot pens (80 x 215 ft) partially covered within a monoslope barn. The barn covers the feed alley, feedbunk, and 20 ft of pen. Concrete extends an additional 12 feet beyond the end of the roof. Mounds are 3 ft high.
- **Monoslope (MON)** – Concrete surfaced feedlot pens (80 x 40 ft) completely enclosed in a monoslope barn. Deep pack bedding is used in the back half of the pen. Bedding is applied once weekly, and the areas near the feedbunk and water trough are cleaned weekly.

Performance:

From 2004 to 2009, 28 comparisons between facilities have been made with the same cattle, diets, management, and environment.

- Performance was similar for cattle fed in **OS** and **MON** facilities.
- Compared to **OPN**, **OS** and **MON** had 0.9% advantage in final weight, 2.5% advantage in ADG, and 3.1% advantage in feed efficiency.
- These differences are due to cattle that finished in the 1st and 2nd quarters, when the feed efficiency advantage of buildings was improved 3.5 to 9.5% compared to **OPN**. No differences between facilities occurred when cattle finished in the 3rd and 4th quarters.

Economics:

	OPN	OS	MON
		$ per head space	
Construction costs	$550.76	$767.96	$687.06
Non-Feed Operating Costs		*$ per head per day*	
Equipment	$0.089	$0.111	$0.186
Bedding	$0.023	$0.023	$0.115
Labor	$0.012	$0.015	$0.025
Total Operating Costs	$0.125	$0.149	$0.326

Considering building costs, operating costs, and animal performance, feed costs must be greater than $121.74/ton of dry matter for **OS** to be a more cost effective system than **OPN**, and $488.80/ton of dry matter for **MON** to be a more cost effective system than **OPN.**

Summary:

- When open feedlots have adequate wind protection, mounds, and drainage, animal performance is only slightly improved for cattle are fed a confinement building.
- If considering building or expanding cattle feedlots in the Northern Plains, improvements in cattle performance in confinement barns must be balanced with feedlot construction expense, manure quality and quantity, and labor and bedding requirements of different facility designs.

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