Nutrient Storage Cover

Nick Jamison  
_Iowa State University_, njamison@iastate.edu

Cole Reighard  
_Iowa State University_, colereig@iastate.edu

Andy Russ  
_Iowa State University_, andyruss@iastate.edu

Shweta Chopra  
_Iowa State University_, schopra@iastate.edu

Jacek A. Koziel  
_Iowa State University_, koziel@iastate.edu

Follow this and additional works at: [https://lib.dr.iastate.edu/tsm416](https://lib.dr.iastate.edu/tsm416)

Part of the _Bioresource and Agricultural Engineering Commons_, and the _Industrial Technology Commons_.

**Recommended Citation**  
Jamison, Nick; Reighard, Cole; Russ, Andy; Chopra, Shweta; and Koziel, Jacek A., "Nutrient Storage Cover" (2019). _TSM 416 Technology Capstone Projects_: 50.  
[https://lib.dr.iastate.edu/tsm416/50](https://lib.dr.iastate.edu/tsm416/50)

This Report is brought to you for free and open access by the Undergraduate Theses and Capstone Projects at Iowa State University Digital Repository. It has been accepted for inclusion in TSM 416 Technology Capstone Projects by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
Nutrient Storage Cover

**Problem Statement**
Smithfield Hog Production has several processing facilities across the state of Iowa along with numerous contract finishing farms where producers grow their pigs. The hog manure on these sites is pumped into a slurry store for storage. A slurry store is a 1.2-million-gallon round tank that is 18-feet-tall and 120-foot diameter. Since the slurry store is open to the weather, it accumulates rain, snow, and other types of precipitation.

While evaporation generally equals precipitation, there are some years where precipitation is greater than evaporation. The result is a reduction in manure holding capacity and additional cost to hog production. Also, excess precipitation lowers the per gallon value of the nutrients as a crop fertilizer due to dilution. A cover of some type that would withstand wind and weather would reduce the accumulation of precipitation.

Smithfield has investigated cover designs, but the alternatives cost too much for their producers to implement. Many cover solutions have been implemented in other industries, such as human waste, and universities have researched this topic.

Our team developed a cover for a slurry store structure that will effectively reduce the accumulated rainfall inside the structure and increase the per gallon value of the manure.

**Disciplines**
Bioresource and Agricultural Engineering | Industrial Technology
Nutrient Storage Cover

Nick Jamison a, Cole Reighard b, Andy Russ c, Shweta Chopra d and Jacek A. Koziel e

a Agricultural Systems Technology, ABE, ISU, njamison@iastate.edu
b Agricultural Systems Technology, ABE, ISU, colereig@iastate.edu
c Agricultural Systems Technology, ABE, ISU, andyruss@iastate.edu
d Dept. of Agricultural and Biosystems Engineering, ISU, 4344 Elings Hall, Ames, IA 50011, schopra@iastate.edu, 515-294-4898
e Dept. of Agricultural and Biosystems Engineering, ISU, 4350 Elings Hall, Ames, IA 50011, koziel@iastate.edu, 515-294-4206

*course instructors and corresponding authors.

Client: Smithfield Hog Production, 2124 90th Avenue Algona, IA 50511

Contact(s): Ray Foerster, Regional Production Manager, rfoerster@smithfield.com
Bob Coffelt, Director of Business Development, bcoffelt@smithfield.com

1 PROBLEM STATEMENT

Problem Statement

Smithfield Hog Production has several processing facilities across the state of Iowa along with numerous contract finishing farms where producers grow their pigs. The hog manure on these sites is pumped into a slurry store for storage. A slurry store is a 1.2-million-gallon round tank that is 18-feet-tall and 120-foot diameter. Since the slurry store is open to the weather, it accumulates rain, snow, and other types of precipitation.

While evaporation generally equals precipitation, there are some years where precipitation is greater than evaporation. The result is a reduction in manure holding capacity and additional cost to hog production. Also, excess precipitation lowers the per gallon value of the nutrients as a crop fertilizer due to dilution. A cover of some type that would withstand wind and weather would reduce the accumulation of precipitation.

Smithfield has investigated cover designs, but the alternatives cost too much for their producers to implement. Many cover solutions have been implemented in other industries, such as human waste, and universities have researched this topic.

Department of Agricultural and Biosystems Engineering (abe@iastate.edu) aims to be a premier team serving society through engineering and technology for agriculture, industry and living systems. ABE welcomes opportunities to discover and improve new technologies for all stakeholders.
Our team developed a cover for a slurry store structure that will effectively reduce the accumulated rainfall inside the structure and increase the per gallon value of the manure.

**Business Case Statement:**

- The biggest issue we have encountered is a cover solution has been implemented before, so many of our possible solutions have been attempted.

- Most of our problems occurred when we were in the design stage because there was always another problem or minute detail to iron out. We consulted faculty and the team at Smithfield to get feedback as we resolved the problems.

- Putting a cover over a 120-foot tank presents some issues. Many external factors had to be accounted for during the project; these include wind, water weight in the center of the tarp, how to get the water out of the tarp, how to attach the tarp to the outside of the tank, and making sure it is easily removed and installed.

- It makes strategic sense to solve this problem based on actual and opportunity costs faced by a producer. This project adds value to a production site through increased freeboard levels, reduced manure hauling costs, and the ability to transport manure farther.

- Smithfield cares about the problem; however, producers will want to care about a cover solution once they understand the quantitative and qualitative benefits. Producers will need to feel comfortable around a cover because they will be the ones benefiting from reduced rainfall accumulation in the slurry store.

2 **Goal Statement**

Our goal with this project was to create a feasible cover option for manure holding structures that would help to eliminate accumulated rainfall in the manure. Finding a way to reduce the amount of water entering the tank during rain events was the fundamental problem we were trying to address. By reducing the amount of rainfall in the tank, we provide more space for manure slurry as well as increase the per gallon value of the raw slurry in the tank. A cover over the structure would also help with following regulations regarding the maintenance of freeboard space at the top of the tank.

The value of covering the structure to prevent rainfall accumulation could be measured in a few specific ways:

1. Pumping manure could go from two times per year to one time per year due to less volume of raw slurry. This would result in time and money savings for the grower.
2. The manure slurry would be more concentrated because the rainfall is diverted outside the tank. This could result in lighter application rates, allowing the product to cover more acres.
3. Transportation benefits would also be seen by hauling fewer gallons of water. The slurry could also be hauled longer distances economically.

Department of Agricultural and Biosystems Engineering ([abe@iastate.edu](mailto:abe@iastate.edu)) aims to be a premier team serving society through engineering and technology for agriculture, industry and living systems. ABE welcomes opportunities to discover and improve new technologies for all stakeholders. 2
Our cover concept provides a cost-effective option for growers that will benefit the operation in numerous ways throughout the process of managing their manure. We believe that by reducing the amount of water in the structure with the manure, the qualitative and quantitative savings would support the idea of a temporary cover.

- **Main Objective**
  Our main objective for this project is to develop a cover solution that is cost effective and meets the criteria of reducing the accumulated rainfall within a manure holding structure.

- **Rationale**
  After this project, our client will be able to analyze and review our cover ideas and determine the benefit to the company. Our client will also be able to use the data provided to further the research on new ideas and the overall benefits a cover would provide for managing manure slurry.

- **Project Scope**
  The scope of our project focused on developing a cost-effective nutrient cover solution to provide growers with an option for reducing the amount of rainfall in their manure holding structures. Throughout the project, we narrowed our scope to above ground slurry store structures, to focus our designs and data collection. We also chose to focus on rainfall because it accounts for the largest amount of precipitation accumulated in the tank.

3 PROJECT PLAN/OUTLINE

**A. Methods/Approach**

Our method of solving this problem required research on current products and data collection on prospective solutions. Our main resources were faculty that helped us at various roadblocks; they are listed in the resource section. We used their expertise during data collection, which was conducted through product searches, experiments, and calculations. The results can all be viewed in the appendix of this report.

We utilized all the TSM classes that we had to take for the last four years in the development of a cover solution. Several of the specific competencies used were project management, statics, and plastics. Our final solution was developed in conjunction with a team from Smithfield that approved milestones in the project. The final solution was considered a success by addressing the following:

1. Cost less than current covers on the market ($65,000 or less)
2. Provide a fresh perspective on an old problem by developing new concept designs
3. Client feedback from periodic in-person meetings was used to evolve the cover design

**B. Organization:**

Department of Agricultural and Biosystems Engineering (abe@iastate.edu) aims to be a premier team serving society through engineering and technology for agriculture, industry and living systems. ABE welcomes opportunities to discover and improve new technologies for all stakeholders.
1. Work was managed using a work breakdown spreadsheet that assigned responsibility.
2. The major milestones of the project were TSM 415 poster presentation, Smithfield’s producer banquet in March, and TSM 416 final presentations.
3. The most important factor that kept our project going through challenges was communication internally with team members and externally with our client and department staff.

C. **Timeline**

- **Milestone Timeline**

  ![Milestone Timeline](image)

4 **RESULTS**

Our project deliverables include attending Smithfield’s producer banquet, the TSM 416 final report, and the TSM 416 final presentation. Our key recommendations are as follows:

1. Have a structural engineer evaluate any designs before implementation.
2. Further testing of the stress the tarp can handle is needed.
3. Investigate worst case scenario failures and catastrophic weather events
4. Build a full-scale cover to test how weather impacts the design.

We developed a concept; however, steps can be taken after the project by Smithfield or another capstone team:

1. Testing of the components to verify longevity and feasibility.
2. Create a procedure for installation and removal.
3. Develop more efficient fastening methods.
4. Design fail safes in case of system malfunction.

5 **BROADER OPPORTUNITY STATEMENT**

Having a cover design that works on slurry store structures will provide a base design that can be adapted for many uses. Within Smithfield, covers could be created for concrete storage tanks and earthen basins. Any industry that deals with waste, such as municipal waste at a city, would benefit from a reduced-cost cover.
6 GRAPHICAL ABSTRACT

Department of Agricultural and Biosystems Engineering (abe@iastate.edu) aims to be a premier team serving society through engineering and technology for agriculture, industry and living systems. ABE welcomes opportunities to discover and improve new technologies for all stakeholders.
7 REFERENCES

Smithfield Team:
The team from Smithfield was very helpful providing necessary information related to the project. Our capstone team enjoyed working with them and learning from their expertise.

1. Bob Coffelt
2. Ray Foerster
3. Scott McLaughlin
4. Kellie Welter

Faculty:
These people from Iowa State were instrumental in completing our project and we thank them for their time.

1. Mark Huss
   • Showed us current designs on the market.
   • Discussed cover concepts Iowa State already tried.
2. Russ Hoffman
   • Helped with brainstorming cover solutions.
   • Identified tarp material that we used.
   • Helped set up our material tests.
3. Tim Shepard, P.E.
   • Provided resources about manure and covers.
   • Shared past personal experiences.
   • Gave honest feedback at critical roadblocks.
4. Jake Behrens
   • Provided lab space to conduct experiments and store materials.
   • Shared expertise in plastic materials.
   • Brainstormed cover solutions.

Documents:
https://iowasudas.org/manuals/design-manual/#introduction

https://pentairaes.com/pump-calculator

https://water.usgs.gov/edu/earthrain.html

Department of Agricultural and Biosystems Engineering (abe@iastate.edu) aims to be a premier team serving society through engineering and technology for agriculture, industry and living systems. ABE welcomes opportunities to discover and improve new technologies for all stakeholders. 6
## APPENDIXES

### A. Tarp Testing

1. **Testing Methods**

   We tested the tarp material with a quick, effective method that would allow us to prove our concept. In the photo on the right, you can see the experiment. A strip of material with a seam of the one-inch square was suspended from the table edge. Twelve pounds of weight was hung from the sample and no noticeable failure occurred.

2. **Weight Holding Calculations**

   With this information, we could calculate the information in Table 1. The test concluded that twelve pounds per square inch would not break our seam. Knowing that the seam is the weakest section of the tarp, we calculated that each one-inch seam could hold 17,280 pounds of weight. To hold one inch of rain, four seams would be needed or one four-inch seam. Having calculated the amount of rainfall weight, we are designing the tarp for the max weight we believe the tarp could hold. By dividing rain weight by the amount of weight a seam can hold, we can find the necessary number of seams. This is shown in the green highlighted box of Table 1. The ideal design would have no seams in the tarp for the most weight holding capacity; however, at some point, a joint will need to be made for fastening the tarp to the structure.

<table>
<thead>
<tr>
<th>Knowns</th>
<th>Conversions</th>
<th>Data From Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 ft</td>
<td>12 in/ft</td>
<td>1 in²/2</td>
</tr>
<tr>
<td>60 ft</td>
<td>2,000.00 lb/ton</td>
<td></td>
</tr>
<tr>
<td>7050.15 gal</td>
<td>8.34 lb/gal water</td>
<td></td>
</tr>
<tr>
<td>11309.73 ft²</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Max Weight</th>
<th>Tarp Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>58,798.25 lbs</td>
<td>12 PSI</td>
</tr>
<tr>
<td>1,650.00 lbs</td>
<td>17,280.00 lbs</td>
</tr>
<tr>
<td>60,448 lbs</td>
<td>4.00 1 inch seams</td>
</tr>
</tbody>
</table>

Table 1. Weight Holding Calculations
3. Tarp Submersion Testing

To identify if the tarp material we selected would withstand manure and the gases produced by a slurry store we submerged a sample in manure. This sample was left in the manure for the entirety of the semester with no noticeable depredation to the material. The manure solids were easily cleaned off to reveal a slight yellowing of the material, but no noticeable effects to the structural integrity.

4. Tarp Material Weight Calculations

There are different weights of tarp on the market that could be used for a cover application. Each is measured on ounces per square foot. As Table 2 shows, an 11,000 square foot tarp is very heavy. This data would be very important to the selection process and the overall longevity of the cover.

<table>
<thead>
<tr>
<th>Tarp Material Weight Comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 ft diameter = About 11,000 sq ft</td>
</tr>
<tr>
<td>Tarp weights that could be used for this application (Tarp Weight Only)</td>
</tr>
<tr>
<td>22 oz*</td>
</tr>
<tr>
<td>3 oz per 9 sq ft</td>
</tr>
<tr>
<td>2.4 oz per sq ft</td>
</tr>
<tr>
<td>.3 oz per sq ft</td>
</tr>
<tr>
<td>Total Weight (Pounds)</td>
</tr>
<tr>
<td>1650</td>
</tr>
</tbody>
</table>

Table 2. Tarp Material Comparisons
B. Water Weight

1. Identifying Water Volume

While trying to figure out the total weight the tarp needed to hold, a question of how much water will fall and how often it occurs. This information was obtained from the Iowa Storm Water Management Manual. In this document, we found that in Central Iowa, a 1.89-inch rainfall was a five-year event and a 2.23-inch rain in one hour was a ten-year event. Based on the life span we hoped to achieve with this tarp, our team designed based on a ten-year rain event.

2. Calculating Water Weight

Our calculations for weight in the tarp are listed below. Due to the frequency of large rains, our tarp system is designed to remove one inch of rain falling in one hour. To do this, we calculated the area of the tarp and multiplied that by a rain conversion factor. This result was just slightly over seven thousand gallons of water in the tarp. To calculate the removal rate, the amount of water in the tarp was divided by 60 min for a removal rate of 118 gallons per minute. The max weight is if the pump was not running and the entire rain remained on the tarp. If the pump was running and we accounted for the rain in the tarp, theoretically it can handle a ten-year rain event.
C. Pump Calculations

1. Head loss

The first step in identifying the size pump we needed was calculating the required gallons per minute of water removal. After that, the next important factor in a pump is a head loss. Head loss is the friction in the pipes that water will encounter, causing the capacity of the pump to decrease. We used an online calculator to find the head loss in our pump. Then we researched one of many pump options that would work for this situation. The calculations we conducted are in the figure below. Several assumptions had to be made, therefore, recalculating may be necessary if the depth of the tarp changes or extra fittings are needed.

Figure 1. Pump Head Loss
D. Cost Analysis

The cost analysis that we conducted is based on several assumptions that had to be made on the type and quantity of each material used. Our sources are included for ease of reference. Two of the most prevalent costs are D-Rings and the tarp material. These costs are subject to change based on the weight of the material, and the size of D-Rings used. To lower the D-Ring cost, wider rings should be used to increase the amount of surface area in each glued joint. This will increase the weight each fastener can withstand thus reducing the number of fasteners needed.

### D-Ring Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Qty.</th>
<th>Unit</th>
<th>Total</th>
<th>Cost/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabric</td>
<td>10</td>
<td>ft²</td>
<td>3.30</td>
<td>0.33</td>
</tr>
<tr>
<td>Structure D-Rings</td>
<td>6</td>
<td>rings</td>
<td>8.10</td>
<td>1.35</td>
</tr>
<tr>
<td>Tarp D-Rings</td>
<td>8</td>
<td>rings</td>
<td>10.80</td>
<td>1.35</td>
</tr>
<tr>
<td>Hog Slat 3/16 Braided Poly Cord</td>
<td>30</td>
<td>ft</td>
<td>1.38</td>
<td>0.05</td>
</tr>
<tr>
<td>HH-66 Vinyl Cement</td>
<td>1</td>
<td>can</td>
<td>45.32</td>
<td>45.32</td>
</tr>
</tbody>
</table>

### Pump System Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Qty.</th>
<th>Unit</th>
<th>Total</th>
<th>Cost/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump</td>
<td>1</td>
<td></td>
<td>719.00</td>
<td>719.00</td>
</tr>
<tr>
<td>Hose</td>
<td>1</td>
<td></td>
<td>73.02</td>
<td>73.02</td>
</tr>
</tbody>
</table>

### Sources

- Billboard Tarps
- Grainger
  - Tarp D-Ring
  - Structure D-Ring
  - Vinyl Cement
- Hog Slat
  - Rope

To figure out the D-Ring cost, information from the water weight calculations was used to show needed weight holding capacity. Then using tarp test information, the individual holding capacity of each D-Ring was calculated. Using the circumference and amount of weight each fastener would hold, a spacing of 6.3 inches was achieved. More research can be done to find the optimum width and strength of a D-Ring to support the load while using the least number of rings.

### Amount of D-Rings Needed

<table>
<thead>
<tr>
<th>Description</th>
<th>D-Ring Chosen</th>
<th>Circumference</th>
<th>Fasteners Required</th>
<th>Spacing of D-Rings</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5 in²</td>
<td>84 lbs/fastener</td>
<td>4523.89 in</td>
<td>720</td>
<td>6.28 in</td>
</tr>
</tbody>
</table>
E. Prototype

A prototype was developed to help demonstrate the concept and identify the number of materials needed for construction. This prototype allowed us to see how the tarp will lay when fastened to the tank. The prototype could be used for further testing and analysis of the design. Tests for weight holding capacity and water flow would be good areas for future testing. This design would allow for the tank to still be agitated while still reducing the majority of the rain accumulation. This design would also be removed in the winter to reduce the stress of snowpack weight on the cover system and tank. Suspension wires are also utilized to disperse the weight under the tarp as well. We believe this design will be effective in reducing the accumulated rainfall inside the tank.